FARMERS' ADAPTATIONS TO RAINFALL RELATED CLIMATE VARIABILITY RISKS AND THEIR IMPLICATIONS ON FOOD SECURITY IN THE SEMI-ARID SIKONGE DISTRICT, TANZANIA

HASHIMU MILAMBO KAZOKA

A DISSERTATION SUBMITTED IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN AGRICULTURAL ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2013

ABSTRACT

The study aimed at assessing farmers' adaptations to rainfall related climate variability risks and their implications on food security in the semi-arid Sikonge District, Tanzania. Specifically the study aimed at characterizing the climate related rainfall and maize production risks; assessing the efficacy of adaptation strategies used by farmers; and assessing the adequacy of off-farm strategies used by farming households to sustain their food security in a changing climate. The study used both secondary and primary data. The secondary data were annual rainfall, rain days, area under maize production and maize yields data; and the primary data were on adaptation and coping strategies adopted by farm families to remain food secure in a changing climate and other off-farm income generating activities done by farmers in the study area. The secondary data were collected from Tanzania Meteorological Agency (TMA) for rainfall data and the Ministry of Agriculture, Food security and Cooperatives for maize production data. The primary data were collected from 120 households using a structured questionnaire. Auto-Regressive Integrated Moving Average (ARIMA) approach was used to analyse the relationship between maize production, annual rainfall and number of rain days for the past 30 years. Analysis of efficacy of farmers' adaptation strategies on household food security was done by using descriptive statistics. The findings show a significant ($P<0.001$) positive relationship between maize yields and the climatic factors entailing rain days and rainfall amount. This suggests the likely impact of rainfall related climate change and variability on maize production. The findings show that farmers responded to the climate change and variability by adopting different adaptation and coping strategies, popular ones being sale of livestock and growing drought tolerant, high yielding and early maturing crop varieties. Most of the adaptation strategies adopted by farmers were those related to decreasing household vulnerability both in short-run and long-run. Off-farm activities were

significant contributors of household food security. Income generated from off-farm activities enabled most households to supplement their food needs hence graduated from food insecurity.

DECLARATION

I, Hashimu Milambo Kazoka, do declare to neither the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Hashimu Milambo Kazoka Date

(MSc. Candidate)

The above declaration is confirmed by

Dr. Khamaldin Daudi Mutabazi Date

(Supervisor)

COPYRIGHT

ACKNOWLEDGEMENTS

I am greatly indebted to all individuals whose support, encouragement and assistance made it possible for me to complete this study. I wish to express my reflective appreciation to my supervisor Dr. Khamaldin D. Mutabazi for his guidance, constructive criticism, helpful suggestions and experience without which this work would have been difficult to accomplish.

Thanks should go to staff and colleagues of the Department of Agricultural Economics and Agribusiness, particularly, Professor N. Mdoe, Professor A. Temu, Professor E. M. Senkondo, Dr P. Damas, Dr. F. Kilima, Dr. E. Msuya, Dr. R. Kadigi, Dr. D. Gabagambi and Dr. E. Lazaro. Also, Dr. Msuya Bengesi from Department of Agricultural Education and Extension and Dr. J. Mbwambo from Institute of Development studies for their guidance during the course work part of my studies.

Special appreciation should go to Mr. Sylvester Chisamba from Tanzania Meteorological Agency and Mr. Benard Kalekezi from Planning Department of the Ministry of Agriculture, Cooperatives and Food security for their assistance during data collection.

Also, I would like to thank Mr. Maulid Rashidi, Mr. Bryson Kigahe, Mrs. Anna Masele, Mr. Goodhope Rumenyela, Mr. Juvenile Assey, Mr. George Mlimanazi and Mr. Joseph Shisha who did a great job during data collection as enumerators for this study.

Moreover, I wish to express my appreciation to the District and Village Authorities in Sikonge District for their assistance during the course of my fieldwork. Special thanks should go to farmers who sacrificed their precious time to participate in this study.

Also, I would like to thank Mr. Luitifrid Nnally for his kindness, support and cooperation during my studies here at SUA. Thank you very much for the cooperation.

I am also greatly indebted to my brothers, Katikaza, Mwarabu, Stephano and Kateri; my sisters, Nanzia, Nanguji, Makiuzi, Mangereza and Navuri for without their effort probably I would not have been where I am today. Lastly, special thanks are to my wife, Jackline Donatus for her unlimited patience and support during my long absence. To all, I say GOD bless you.

DEDICATION

This dissertation is dedicated:

To Almighty God, the creator and giver of knowledge

To my parents Mr. Milambo Mwamadi Kazoka who is living in memory and Ingianaeli Mwarabu Kazoka who laid the foundation of my education

To my daughter Anjela and my son Allen

To the victims of climate change and variability all over the world

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APENDICES

LIST OF ABBREVIATIONS AND SYMBOLS

AIACC	Assessments of Impacts and Adaptations to Climate Change
ARIMA	Auto Regressive Integrated Moving Average
CAADP	Comprehensive Africa Agriculture Development Programme
CGIAR	Consultative Group on International Agricultural Research
DADP	District Agriculture Development Plan
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IK	Indigenous Knowledge
IPCC	Intergovernmental Panel on Climate Change
Max.	Maximum
Min.	Minimum
N	Number of Observation
OLS	Ordinary Least Square
^{o}C	Degree Centigrade
Sig.	Significance
SNAL	Sokoine National Agricultural Library
SPSS	Statistical Package for Social Science
SSA	Sub Saharan Africa
Std. Dev	Standard Deviation
SE	Standard Error
SUA	Sokoine University of Agriculture
SWMRP	Soil and Water Management Research Programme

t/ha	Tonnes per Hectare
Tshs	Tanzanian Shillings
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
URT	United Republic of Tanzania
WHO	World Health Organization
WMUU	Wizara ya Mipango, Uchumi na Uwezeshaji

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Agriculture production remains the major source of livelihoods for most rural families in developing countries, including Tanzania. In Sub – Saharan Africa (SSA), agriculture provides employment to more than 70% of the population, contributing to about 26.5% of Gross Domestic Product (GDP) and export earnings of about 60% (Kandinkar and Risbey, 2000; URT, 2008b). Agriculture in this part of the World is rain-fed. Unfortunately, the region has experienced unstable rainfall patterns as a result of climate change which ultimately result in uneven and declining yields with significant effects on household food insecurity (Juliana, 2007; URT, 2008a).

In most cases, severe drought due to climate change and variability leads to severe food shortages, food insecurity and hunger. Since Tanzania's economy is largely dependent on agriculture, it is deemed that sustainable development can only be achieved when strategic actions, both short term and long term are put in place to address climate change impacts on agriculture for ensuring food security in all pillars. In the near future with an optimistic forecast the agriculture share of GDP could shrink to as little as 4% by 2100 due to climate change and variability (Mendelson *et al.,* 2000). It is also believed that agriculture output may decrease by 20% in developing countries by 2020 and an average loss of 15% in cereal production as a result of climate change (Parry *et al.,* 2007; IFAD, 2008; Von Broun, 2007). Mostly at risk are people living in dry lands, along the coasts, in flood plains, mountains and the arctic region (FAO, 2007b; Heltberg, 2007).

Climate change and variability directly affect food and nutrition security of millions of people, undermining current efforts to address undernutrition, one of the world's most serious but least addressed socioeconomic and health problems (FAO, 2010). In developing countries like Tanzania nearly one-third of children are underweight or stunted (Black *et al.,* 2008). Undernutrition, which in turn stems from food insecurity fall hardest on poor households especially those which are headed by females. Undernutrition interacts with infectious disease, causing an estimated 3.5 million preventable maternal and child deaths annually (Black *et al.,* 2008). Despite its vulnerability to the effects of climate change and variability, the agriculture sector continues to be the pillar of the economy of Tanzania and for poverty reduction of the rural community (DADP, 2010; URT, 2008a).

1.2 Problem Statement

Food insecurity is still a global problem and is more critical in Sub-Saharan Africa (URT, 2005). It is estimated that at least one third of Africa's population is food insecure and undernourished (Rutatora *et al.,* 2004; Massawe, 2007). Globally, the number of people suffering from hunger stood at 852 million from 2000 to 2002; out of these 815 million in the countries in transition and 9 million in the industrialized countries. In 2008 the number increased to 925 million whereas in 2010 to 2012 the number decreased a bit to 870 million and maternal and child under nutrition remain pervasive (FAO, 2005; FAO, 2010; FAO, 2012; Horton *et al.,* 2009). About 95% of the food produced in SSA depends on rain-fed agriculture mainly undertaken in the dry-lands (Reilly *et al.,* 2001). Farmers in semi-arid dry lands are exposed to several types of risks caused by climate change and variability which severely affect agriculture and eventually food security (Maddison, 2006).

According to Kurukulasuriya (2006) and Seo (2006), the events of climate change and variability lead to substantial losses of both crop and livestock causing agricultural activities to be at high risk, unattractive and unbeneficial to the majority of small-holder farmers. According to FAO (2008c), most farm families in Tanzania are dependent on rain-fed agriculture for food production and therefore are extremely vulnerable to climate change and variability. Moreover, Gregory *et al.* (2005) observed that climate change and variability can affect food systems in different ways ranging from direct effects on crop production to exchange in markets, as well as food prices and disruption of supply chain infrastructures.

An analysis of recent climatic trends reveals that climate change and variability pose significant risks for Tanzania. While projected changes in precipitation are uncertain, there is a high likelihood of temperature increase as well as sea level rise. Climate change and variability scenarios across multiple general circulation models show increase in country's average mean temperature (Swai *et al*., 2004; Munishi *et al*., 2006). The predictions show that the mean daily temperature will rise by 3^oC – 5^oC throughout the country and the mean annual temperature will rise by 2^oC– 4^oC by 2075 as a direct consequence of climate change. Predictions further show that areas with a bimodal rainfall pattern will experience decreased rainfall of 5% - 45% and those with mono-modal rainfall pattern, in which Sikonge District falls, will experience decreased rainfall of 5%-15% by 2075, (URT, 2003a; Munishi *et al.*, 2006).

Regardless of the pressure exerted by the climate change and variability in different areas of the world including Tanzania, farmers have sustained their lives over the millennia particularly for food security using different adaptation and coping strategies (Mbilinyi *et al.*, 2005). Literally, there is a variety of documentation about adaptation measures to climate change and variability in the dry-land areas (Pender *et al.*, 2004; Chibber and Laajaj, 2007). Most of the researches for example (Enfors, 2008; Prabhakar and Shaw, 2008) concentrated on studying water deficit and farmland management practices without empirical evaluation of their risk reduction efficiency and associated economic benefits. Few studies have been conducted in the country to assess the adequacy of off-farm activities for food security among the farming families for example Shauri (2010) which was conducted in Same District.

However, information on adaptation and coping strategies and adequacy of off-farm income generating activities for food security at household level is lacking in many parts of Tanzania. Similarly no research has been done in Sikonge District to assess farmers' adaptations to rainfall related climate variability risks and their implications on food security. It is for this reason that this study intends to assess farmers' adaptations to rainfall related climate variability risks and their implications on food security in the semi-arid areas of Sikonge District, Tanzania.

1.3 Justification

There is a need to assess the maize crop production dependency on climate related variables of rainfall and rain days; farmers' adaptation strategies for household food security and off-farm activities that farmers depend on when they face shortage of harvest in a given year and their adequacy in maintaining food security.

Findings from this study provide empirical information on how the rainfall related to climate change and variability risks affect maize food production, adaptation strategies adopted by farmers for food security and adequacy of off-farm activities in ensuring household food security. This information can be used to enrich the existing and forthcoming policies on climate change and variability that imply on food security. Since the impacts of climate change and variability on agriculture and food supply includes shortage in grain production resulting in reduced availability of food items, especially to the economically poor people, knowledge of the adaptation and coping strategies adopted by farmers on mitigation of the effects of climate change and variability would help in providing an insight on how to deal with impacts effectively and efficiently.

1.4 Objectives

1.4.1 General objective

The overall aim of this study was to assess farmers' adaptations to rainfall related climate variability risks and their implications on food security in the semi-arid areas of Sikonge District, Tanzania

1.4.2 Specific objectives

(i) To characterize climate related rainfall and maize production risks

(ii) To assess the usefulness of adaptation strategies used by farmers for household food security

(iii) To assess the adequacy of off-farm strategies used by farming households to sustain their food security in a changing climate

1.5 Hypotheses

(i) The trend in rainfall variability has no effects on crop production.

(ii) Farmer's adaptation strategies are not useful for ensuring household food security.

(iii) Off-farm strategies used by farming household to sustain their food security in a changing climate were inadequate.

1.6 Conceptual Framework

Climate change and variability which is highly notable through changes in normal rainfall trends and temperature variations among other indicators is hypothesised to be accelerated by anthropogenic and natural conditions like heavy industrial emissions of CO_2 and other human activities like deforestation, earth drilling and movement of heat waves within the inner earth that generally lead to land degradation (Olmos, 2001). The outcomes of these activities include depletion of ozone layer hence exposing the earth's surface to solar emissions. This leads to the global warming, increased evaporation of water bodies leading to higher rainfall in some parts of the earth while causing severe drought in other areas. If the situation occurs several times some parts of the earth will suffer from floods while others will be suffering from desertification situations.

The prolonged increasing drought if not well balanced with rainfall instantly causes immediately drying up of vegetation and failure of crops which are grown by humans for cash or food purposes. The result of crop failure often leads not only to loss of income but also food insecurity and rising prices of food. The nature of mankind is to fight for survival so if crops fail to give them enough to eat, they always find other means as alternatives to secure food. These alternatives are called adaptation and coping strategies for food security. The strategies may be either opting for some other crop varieties which will cope with the existing situations of drought or finding income generating activities to raise money and purchase food from other areas with higher production especially those places whose drought situations are less severe. If that holds true human beings become safe in all aspects of food security namely food availability, stability, accessibility and utilization as summarized in Fig. 1 below.

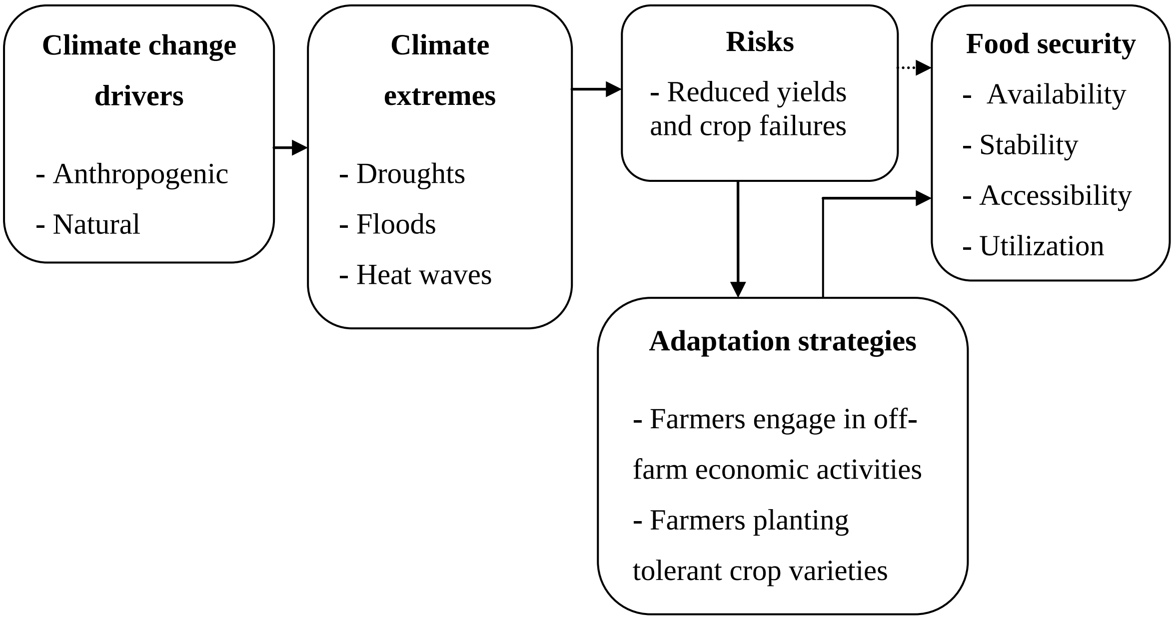

Figure 1: Dependency of food security on the climate variables

1.7 Organization of the Report

This dissertation consists of five chapters: Chapter One provides an introductory part of the research by giving background information of the research, problem statement for the research and justification of the study and research objectives. Chapter Two presents a review of literatures relevant to the study while Chapter Three describes the methodology employed in this study. Chapter Four presents the findings and discussion of the study and Chapter Five presents general summary of the major findings, conclusions and recommendations from the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Climate Change and Variability

Climate change was defined by Ngaira (2007) as the changes in long-term trends in the average weather, such as changes in average rainfalls and temperatures. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "any change in climate over time, whether due to natural variability or as a result of human activity". In the United Nations Framework Convention on Climate Change (UNFCCC) climate change refers to a change in climate that is attributable directly or indirectly to human activity that alters atmospheric composition which in addition to natural climate variability is observed over comparable time periods (IPCC, 2001 and Olmos, 2001). It is, however, important to note that according to FAO (2008b) there is no internationally agreed definition of the term "climate change". Therefore, FAO prefers to use a comprehensive definition of climate change that encompasses changes in long-term (about 30 years) average of all the essential climate variables including rainfall, temperature, wind and pressure (FAO, 2008b).

Climate variability refers to changes in climatic patterns, such as rainfall, weather and climatic patterns (Ngaira, 2007). It is the variation around the average climate, including seasonal variations in atmospheric and ocean circulation such as the El Nino. According to Orindi and Murray (2005), climate variability is the shift from the normal experienced rainfall pattern of seasons to abnormal rainfall pattern.

The climate therefore can be thought of as a long-term summing up of weather conditions, taking account of the average conditions as well as the variability of these conditions, thus the fluctuations that occur from year to year, and the statistics of extreme conditions such as rigorous storms or unusually hot seasons, are refers to climatic variability (UN, 2008).

According to IFPRI (2007) climate change and variability may affect food systems in several ways ranging from direct effects on crop production (for example change in cropping practices), to exchange in markets, food prices and supply chain infrastructure.

2.2 Regions Most Affected by Climate Change

Morton (2007) contends that the threats of climate change are more severe in developing countries, partially due to geographical location. Many low income countries are located in tropical and subtropical regions, which are particularly vulnerable to rising temperatures, and in semi desert zones, which are threatened by decreasing water availability (Tubiello and Fischer, 2007; Heltberg *et al.*, 2008).

In its recent report on vulnerability to climate change, the IPCC states that those with the least resources have the least capacity to cope and are the most vulnerable (Parry *et al.*, 2007). African vulnerability to climate change is generally recognized and that it largely depends on its current low coping and adaptive capacities. The vulnerability of Africa to climate change is not only caused by climate change but through a combination of social, economic and other environmental factors that interact with climate change (Ericksen, 2008).

The vulnerability includes the region’s high prevalence of malnutrition, low literacy rates, a high burden of disease and prevalence of environmental disasters such as floods and droughts. The region is also characterized by poor governance, corruption, conflicts and weak institutions (Nkomo *et al.*, 2006; Parry *et al.*, 2007). Table 1 presents levels of regional nourishment incorporating climate change. Taking into account the effects of climate change, the number of undernourished people in SSA may triple between 1990 and 2080 (Table 1).

Table 1: Number of undernourished, incorporating climate change effect (in millions)

Region / Countries	**1990**	**2020**	**2050**	**2080**	**2080/1990 (proportion)**
Developing countries	885	770	579	554	0.6
Asia, Developing	659	390	123	73	0.1
Sub-Saharan Africa	138	273	359	410	3.0
Latin America	54	53	40	23	0.4
Middle and North Africa	33	55	56	48	1.5

Source: Tubiello and Fischer (2007).

2.3 Risk Associated with Climate Change and Variability in Agriculture

Risk refers to the possibility of danger, damage, loss, injury, or other undesirable consequences from risky events (Heltberg *et al.*, 2008). Risk differs from uncertainty, according to Heltberg *et al.* (2008), risk is where probability distribution of a risk event to occur is known or can reasonably be assumed, and unlikely uncertainty is where no probability distribution can reasonably be assumed. Risk is the result of physically defined hazards interacting with exposed systems, taking into consideration the properties of the systems, such as their sensitivity or social vulnerability.

When climate change and variability occur, there is high possibility of causing damages, danger or disaster to mankind. Events such as droughts, floods, storms and hurricanes, and spells of extremely high or low temperatures are recognised as major risks associated with climate change and variability. Heltberg *et al.* (2008) asserted that risks associated with climate change can adversely affect humans through a variety of direct and indirect pathways. For instance the changes in mean and variance of rainfall and temperature; extreme weather events; food and agriculture production and prices; water availability and access; nutrition and health status could activate potentially remarkable increases in chronic poverty. This in turn can result into increased vulnerability, hunger, diseases, mortality, displacement and violent conflict in many developing countries. These consequences entail that climate change and variability can trigger a series of negative consequences unless the risk management capacity of households, communities, and nations is strengthened.

Thus, events such as droughts, floods, storms and hurricanes, and spells of tremendously high or low temperatures are documented as major risks associated with climate change and variability, however as the time goes it becomes more regular and more rigorous.

2.4 Impacts of Climate Change and Variability on Agriculture

Ongoing climate change and variability is predicted to accelerate during this century and, one can assume, so will the corresponding economic and social impacts. Since agriculture constitutes a larger fraction of GDP in developing than in industrial countries, the projected decrease in productivity will impose larger relative income losses, with important micro and macro-economic implications. This is especially important in Africa where there are many smallholders, many of whom are actually semi-subsistence net consumers of food (FAO, 2008d).

The expected decline in agricultural productivity will negatively impact the poor, as well as producers and consumers via reduced food production and higher food prices. Just as agricultural productivity gains have always been closely linked to poverty reduction, productivity decline in tropical and subtropical agriculture that will result from climate change can be expected to increase the depth and severity of poverty. This potential income loss can trigger increased vulnerability to poverty and hunger for many households, with particularly negative impacts for women, children, elderly and disabled (FAO, 2008a).

Effect of climate change on maize yields through simulations by Crop Environment Resources Synthesis Model (CERES-Maize) showed that maize yield will be lower as a result of higher temperatures and, where applicable, decreased rainfall (Munishi *et al.*, 2006). The average decreases over the entire country will be 33% with decreases as a high as 84% in the central regions of Dodoma and Tabora. Yields in the northeastern highlands will decrease by 22% and in the Lake Victoria region by 17% by year 2100. The southern highland of Mbeya and Songea are estimated to have decreases of 10 – 15%. These results suggest that climate change may significantly influence future maize yields in Tanzania and reduce production in some zones relative to baseline levels. These reductions are due mainly to increases in temperature that shorten the lengths of growing season and decreases in rainfall. Consequently, the continued reliance on maize as a staple food crop over wide areas of the country in the near future could be risky. However, maize production in particular might require special attention for adaptation and mainstreaming responses, given that it is a critical food crop (Munishi *et al.*, 2006).

Crop production forecast and food security assessment reports produced by the Tanzanian Ministry of Agriculture and Food Security annually have established that weather dependent crop production has continued to fail especially in the semi-arid central Tanzania and northern zone comprising Kilimanjaro, Arusha and Tanga regions which used to be the northern grain granary for the country. The bimodal pattern of its rainfall distribution is also gradually switching to unimodal tendency as the short rainy season slowly fades away. Arusha and Kilimanjaro regions are now the hardest hit regions although they used to be heavy rainfall areas (Munishi *et al.,* 2006). Two food assessment reports conducted by the Food Situation Investigation Team (FSIT) for 2003 showed that north eastern and coastal regions received very little or no rains in *vuli* season, a situation which led to food relief distribution to more than 56 districts out of 120.

Both climatic and environmental changes have resulted in declining agricultural productivity, deterioration of water quality and quantity and loss of biodiversity. The increasing populations, livestock and other activities have resulted in changes in land use, land cover, desertification and other environmental degradation (AIACC, 2006; Yanda *et al*., 2006). Climate variability is one of the most significant problems facing human societies especially in developing countries and the most vulnerable to the impacts of climate change are rural areas (IPCC, 2001). Most of the rural people located in the high-risk areas and they lack economic and social resources. These situations lead to failure in adjustment on long-term changes in climate variability (Orindi and Murray, 2005).

In East Africa climate change and variability is likely to alter temperatures and distribution of rainfall, which contributes to sea-level rise and increase the frequency and intensity of extreme weather events (Low, 2005; Orindi and Murray, 2005). The intensity of droughts, floods and changes to growing seasons have significant effects for soil productivity, water supply, food security and in turn human welfare as well as harmful on land resources and, otherwise, can lead to irreversible impacts on biological diversity (AIACC, 2006; Yanda *et al.,* 2006). The ecological gradient that ranges from higher rainfall potential to lower rainfall potential where livelihood systems interact across the different zone have been affected hence influencing land management (Majule *et al.,* 2004). Some of the extreme weather in Tanzania has been the droughts of 1974, 1983, and 1994, which were followed by abnormal climate conditions of El Nino of 1982 - 83 and 1997 - 98 (Majule *et al.*, 2004; Yanda *et al.*, 2006).

2.5 Climate Change and Indigenous Knowledge

Indigenous knowledge (IK) is the unique knowledge to a given culture or society acquired by human beings to regulate stresses brought by climate change, which should be able to bring relief to the stressed community. Indigenous knowledge is the basis for local level decision making in many rural communities. It has value not only for the culture in which it evolves, but also for scientists and planners striving to improve condition in rural localities. According to Gyamphoh (2008), indigenous knowledge or traditional knowledge, has over the time immemorial played significant role in solving problems that are related to climate change and variability.

Indigenous people may not understand the science of climate change but they lightly observe and feel its effects. Some of their responses demonstrate appreciable knowledge of global climate changes. Societies have a long record of coping to climate change and risks. Household asset portfolios and livelihood choices are shaped by the need to manage climate risks, especially in rural areas and for low income households (Heltberg *et al.*, 2008).

IK is capable of observing activities around and first to identify changes, and associated or related coping strategies or practices. For example, the appearance of certain birds, mating of certain animals, flowering of certain plants and sprouting of some plants are all signals, informing individuals and community on how to cope accordingly. Examples of indigenous knowledge commonly used in the developing countries include cultivation of more than one type of grain staple, mixed land use, intercropping; conservation tillage and mixed cropping; cropping pattern decision based on local predictions of climate change; varying planting dates based on complex cultural models of weather; using local germ plasma highly acclimated to withstand harsh climate; and micro-climate manipulation such as afforestation; the practices which are not uncommon in Tanzania.

Srinivasan (2005) observes that the importance of indigenous knowledge is to enhance coping and adaptations to climate change. In spite of the significant role played by indigenous knowledge in different areas of climate change still traditional knowledge is usually neglected in academic, policy and public dialogue (Gyampoh *et al.*, 2008; Srinivasan, 2005). In general, incorporating indigenous knowledge into climate change policies can lead to development of effective coping strategies that are cost effective, participatory and sustainable (Nyong *et al.*, 2007). This happens in almost every country.

2.6 Adaptation and Coping Strategies to Climate Change and Variability

Adaptive capacity is the ability of the system to adjust to climatic change and variability; to moderate potential changes; to take advantage of opportunities; or to cope with the consequences (Parry *et al.*, 2007). Adaptation can also be referred to as an integral part of managing the risks caused by climate change, while risk reduction activities should be embedded in an integrated approach to ensure sustainability (IFPRI, 2007).

Some adaptation measures to climate change and variability as outlined by Low (2005) and Orindi and Murray (2005) include the increase in irrigation to boost crop production, introduction of low water use crops and adoption of sustainable water resource management policies such as harvesting of rainfall water. Other adaptation mechanisms include institution policy mechanism to control unsustainable forest clearing and forest consumption; promotion of techniques for tackling emergency food shortages; adjusting farming areas and control of overgrazing. In addition promotion of the use of alternative source of energy such as solar cookers instead of inefficient woodstoves and charcoal stoves can as well serve this purpose (AIACC, 2006; Yanda *et al.*, 2006).

Major adaptation options in the agriculture sector include crop diversification, mixed crop-livestock farming systems, using different crop varieties, change in planting and harvesting dates, and mixing less productive, drought-tolerant varieties and high yield water-sensitive crops (Bradshaw *et al*., 2004). Widely implemented adaptive strategies in Tanzania include change of crop variety (drought resistance/water logging), irrigation, shifting to higher ground to avoid floods, abandoning most hit areas, rainwater harvesting, water conservation and reservoir construction. Other strategies are planting trees, improving weather forecasts, reducing number of livestock, setting aside grazing areas, and introducing zero grazing reversed by aforestation on the damaged watershed (Adosi, 2007).

According to Kurukulasuriya (2003), the typology of adaptation options is divided into four categories. First is *micro-level* adaptation; these include farm production adjustments such as diversification and intensification of crop and livestock production; changing land use and irrigation; and altering the timing of operations.

Second; there are numerous *market responses* that have emerged as potentially effective adaptation measures to climate change. They include development of crop and flood insurance schemes, innovative investment opportunities in crop shares and futures, credit schemes, and income diversification opportunities.

A third subset of adaptation options encompasses *institutional changes*; many that fall within this category require government responses. The latter comprise pricing policy adjustments such as the removal of perverse subsidies, development of income stabilization options, agricultural policy including agricultural support and insurance programs; improvement in agricultural markets, and broader goals, such as the promotion of inter-regional trade in agriculture.

A fourth set of adaptation is *technological developments;* these consist of the development and promotion of new crop varieties and hybrids and advances in water management techniques (for example, irrigation, conservation tillage). However these categories are considered to produce benefits in short term or long term time dimension.

Furthermore, some authors go further to differentiate between private and public adaptations. According to Mendelsohn (1999) private adaptations are those undertaken only for the exclusive benefit of the individual decision maker aimed at profit and output maximization, while public adaptations are those measures undertaken for the benefit of entire community such as managing water resources for irrigation, maintaining soil quality, forecasting climate, research on adaptation initiatives.

According to Low (2005), many of the coping mechanisms to climate change and variability comprise activities that do not have formal systems recognition by government agencies. Orindi and Murray (2005) suggest that coping strategies for seasonal food shortages include petty business, changes in diet, fewer meals, and loans from traders. However, some people migrate to urban areas in search of paid employment.

2.7 Global Response to Climate Change

Over the past decade climate change has emerged as one of the most important issues facing the international community (Albritton and Meira, 2001). The climate change issue broke onto the international policy making agenda in the mid 1980s between 1985 and 1988. The issue moved from the realm of science to the realm of politics. As such, this period provides fertile ground for exploration of the relationship between science, knowledge and action on international environmental issues (Franz, 1997). Several policy and science entrepreneurs advocated on action to address problems of global climate change. Their conclusions coincided with a number of other developments, including extreme weather in the United States and the successful negotiation of an international agreement to protect the ozone layer, which pressed in the direction of further international attention to environmental problems (Justus and Fletcher, 2006).

2.8 Food Security

Food security has a long history as an "organizing principle" for social and economic development (Maxwell and Frankenberg, 1992). Over time, this concept has been operationally defined in a number of ways. According to Alderman *et al.* (2007) food security exists when all people, at all time, have physical access to enough, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy lifestyle.

However, the misconception of the definition of food security in the 1970's led to the concentration in increasing food production without considering other dimensions of food security. In this case, the concentration was on increasing the amount of food available (grain in particular) to feed the growing population. History shows that there was a huge increase in food output between the 1970's and the 1980's due to cultivation of high yielding varieties, the expansion of land under production and irrigation, greater use of fertilizers and pesticides and greater availability of credit (FAO, 2008a). This period was termed as the Green Revolution.

However, in many countries the grain yield reached their limit, and created social and environmental confusion which was again required to be addressed. In other countries the limit was not reached due to complications brought by climate change but this has again created problems in food availability, distribution and access to food. Thus the new thinking brought in other aspects of food security (Schmidhurber and Tubielo, 2007).

On the other hand, food insecurity exists when people are undernourished due to physical unavailability of food, their lack of physical, social and economic access to food and or inadequate biological utilization of food by the body (URT, 2005). Devereux *et al.* (2004) defines food insecurity as lack of access to an adequate diet which can be either temporary (transitory food insecurity) or continuous (chronic food insecurity) due to unavailability of food, insufficient purchasing power, inappropriate distribution or inadequate utilization at household level. Among other causes of food insecurity low production due to insufficient rainfall led by impacts of climate change and variability is most prominent.

2.9 Food Systems

FAO (2008a) and UNDP (2007) defined food systems as varieties of processes along the food chain that must take place or occur in order to bring about food security. According to (Gregory *et al.,* 2005; Von Braun *et al.*, 2008) food system encompasses activities related to the production, processing, distribution, preparation and consumption of food; and the outcomes of these activities contribute to food security. The outcomes also contribute to environmental and other securities such as income. Interactions between and within natural and human environments influence both the activities and the outcomes.

Food systems, then involve much broader considerations than productivity and production alone. They underpin food security, which is the state achieved when food systems operate such that all people, at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 2008d). Thus, food security is diminished when food systems are stressed. This can be caused by a range of factors in addition to climate and other environmental changes such as conflicts, changes in international trade agreements and policies.

2.10 Pillars of Food Security

2.10.1 Food availability

Food availability is made up of the elements related to production, distribution and exchange. Availability of food refers to the supply of food from production, imports, or stocks at an individual, national and global level. This dimension relates to the availability of sufficient food; that is, the ability of the food systems to meet food demand. It encompasses the agro – climatic fundamentals of crop and pastures production and includes all elements related to production, distribution and exchange of food (Gregory, 2004; Ingram *et al.,* 2005; FAO, 2007b). Food availability is determined by the physical quantities of food that are produced, stored, processed, distributed and exchanged. Adequacy is assessed through comparison of availability with the estimated consumption requirement for each food item. This approach is used in assuring that a country's food supply is sufficient. The same approach can also be used to determine the adequacy of a house hold's food supply. High market prices of food are usually a reflection of inadequate availability (Ingram *et al.,* 2005; FAO, 2008b).

2.10.2 Food stability

The second dimension of food stability is determined by the temporal availability of and access to food (Devereux, 2006; FAO, 2007a). It relates to individuals who are at risk of losing temporarily or permanently their access to the resources needed to consume adequate food, either because they are not capable of withstanding shocks or they lack enough reserves to smooth consumption or both. If projected increase in climate variability materializes, these individuals are likely to succumb to emergency situation for which neither the global food system nor affected local food systems are adequately prepared to help (FAO, 2007a; Schmidhuber and Tubiello, 2007).

2.10.3 Food accessibility

The third dimension is food accessibility which is a measure of the ability to secure food entitlements, defined as the set of resources including legal, political, economic and social that an individual requires so as securing food (FAO, 2003a; Gregory *et al.*, 2005; Ingram *et al.*, 2005). Food access covers access by individuals to adequate resources (entitlements) to acquire appropriate foods for a nutritious diet (Von Braun *et al.*, 2008; WHO, 2009). Moreover, food access includes all elements related to affordability, allocation and food preferences. Thus, a key element is the purchasing power of consumers and the evolution of real incomes and food prices. However, these resources need not be exclusively monetary but may also include traditional rights to food access.

According to Shah *et al.* (2008), food is allocated through markets and non-market distribution mechanisms. The non-market mechanism is the one which is highly affected by climate change. Non-market mechanism include production for own consumption, food preparation and allocation practices within the household and public or charitable food distribution schemes. For rural people who produce a substantial part of their own food, climate change impacts on food production may reduce availability to the point that allocation choices have to be made within the household (Ingram *et al.,* 2005; FAO, 2008a). A family might reduce the daily amount of food consumed equally among all household members or allocate food preferentially to certain members such as children.

The last mechanism of food accessibility is affordability. Most food is not produced by individual households but acquired through buying trading and borrowing (Du Toit and Ziervogel, 2004). Climate impacts on income earning opportunities can affect the ability to buy food and price of certain food products. High prices may make certain foods unaffordable leading to further impact on individuals' nutrition and health status. Changes in the demand for seasonal agricultural labour, caused by changes in production practices in response to climate change, can affect income generating capacity positively or negatively, and consequently affect food affordability (Schipper, 2006).

2.10.4 Food utilization

The fourth dimension is food utilization which encompasses all food safety and quality aspects of nutrition including nutritional values, social values and food safety. Its sub-dimensions are therefore related to health, including the unitary conditions across the entire food chain. According to FAO (2007a), it is not enough that someone is getting adequate quantity of food if his body is unable to make use of the food.

2.11 Household Food Security

Food insecurity is one of the major concerns of developing countries despite the efforts to improve food situation. According to food requirement estimate guidelines to farmers at house hold level issued by the Department of food security in the Ministry of Agriculture, Food Security and Cooperatives, in one year an individual requires 3 bags of cereals (such as maize or sorghum) weighed at 100 kg, or 5 bags of paddy weighed at 75 kg; or 4 bags of sweet potatoes dried chips weighed at 65 kg if only depends on a single crop (MAFS, 2005).

2.12 Determinant of Food Security

Food security in many developing countries is related to poverty in which household that have difficulties in accessing productive resources like land, forests, water, technology and credit are likely to be food insecure (SUA, 2006). Although Tanzania has 39.5 million hectares of arable land, food insecurity and low income among Tanzanians have persisted mainly due to low productivity caused by several limiting factors, which among others include; Dominance of inappropriate technologies, heavy dependency on rain, low soil fertility, poor crop management practices, and field and storage losses (Myaka *et al.,* 2003; Kashuliza *et al.,* 2002).

Keenja (2001) indicated that in Tanzania, 27% of the population is food insecure, about 14% of the harvested crops is lost to pests (SUA, 2006) and at house hold levels, poverty is still pervasive especially in rural areas where about 50% of Tanzanians live in poor conditions. While 36% live in horrible poverty, most households in rural areas are food insecure (Rutatora and Rwenyagira, 2005). Shalli (2003) found that 78.3% of the households with food insecurity due to instability in food production and household income were found to be contributed mostly by unpredictable rainfall, drought being the main.

The per capita income status at the national level was indicated to be Tshs. 242 000 in 2000 (URT, 2000); Tshs. 399 873 in 2006 (WMUU, 2007) and Tshs 869 436 in 2011 (URT, 2012). According to FAO (2008b), lack of reliable market and poor agricultural tools, outdated husbandry practices, lack of crop rotation system and poor environmental protection practices retarded income earning activities at household level, thus poverty alleviation difficulty. Therefore many people are food insecure because of low purchasing power due to limited income especially the farming communities who are rainfall dependent. Also as stated earlier food insecurity is prominent among the poor due to low adaptive capacity to short rainfall.

2.13 Livelihood, Adaptation and Coping Strategies

Livelihood strategies are a range and combination of activities and choices that people normally make or undertake in stable and peaceful times in order to achieve their livelihood goals. They include productive activities (cultivation, livestock-keeping, weaving, collection and gathering); investment strategies; trading; reproductive choices and remittances (FAO, 2003b). Adaptation strategies are medium as well as long term strategies use by farmers to address underlying causes of food insecurity. On the other hand, coping strategies are temporary responses to food insecurity, which in case of extended emergencies they become livelihood strategies. Initially, people choose coping strategies that are not damaging to livelihoods, such as sale of livestock, labour migration and collection of wild foods. As more people adopt the same strategies, the value of these strategies becomes diminished. For instance prices of livestock fall, wages become squeezed and wild food resources became scarce. When this occur, households then have to resort to more damaging strategies that can undermine long-term livelihood viability including selling of key assets such as milking cow, ox, loans at exorbitant rates and land (FAO, 2003b).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the Study Area

Sikonge is one of the six districts forming Tabora Region on the Western part of Tanzania. It is bordered by Chunya District in the South, Uyui District to the North and North-western part, Urambo District to the West, Mpanda District to the Southwest and Manyoni District to the South-eastern part. The District is located between Longitudes 32.00´ E and latitudes 40^0 to 50.50´ S. The District covers an area of approximately 21 000 square kilometres. According to the 2012 Tanzania National Census, the population of the Sikonge District was 179 883 of whom 88 947 were males and 90 936 females (URT, 2013).

The District is characterized by mono-modal type of rainfall, which starts from November to April. The range annual rainfall is usually between 600mm to 900mm. Rainfall distribution is unreliable with usual occurrence of a dry spells between mid-January and February. The temperature ranges from 22^0C to 32^0C (DADPs, 2010). Majority of household in Sikonge are agro-pastoral. Agriculture contributes about 56% of the GDP and 82.7% of the employment of its population. Main crops grown are maize, paddy and cassava while livestock species are cattle, goats, sheep and chickens. Tobacco is a major cash crop in the District (DADPs, 2010).

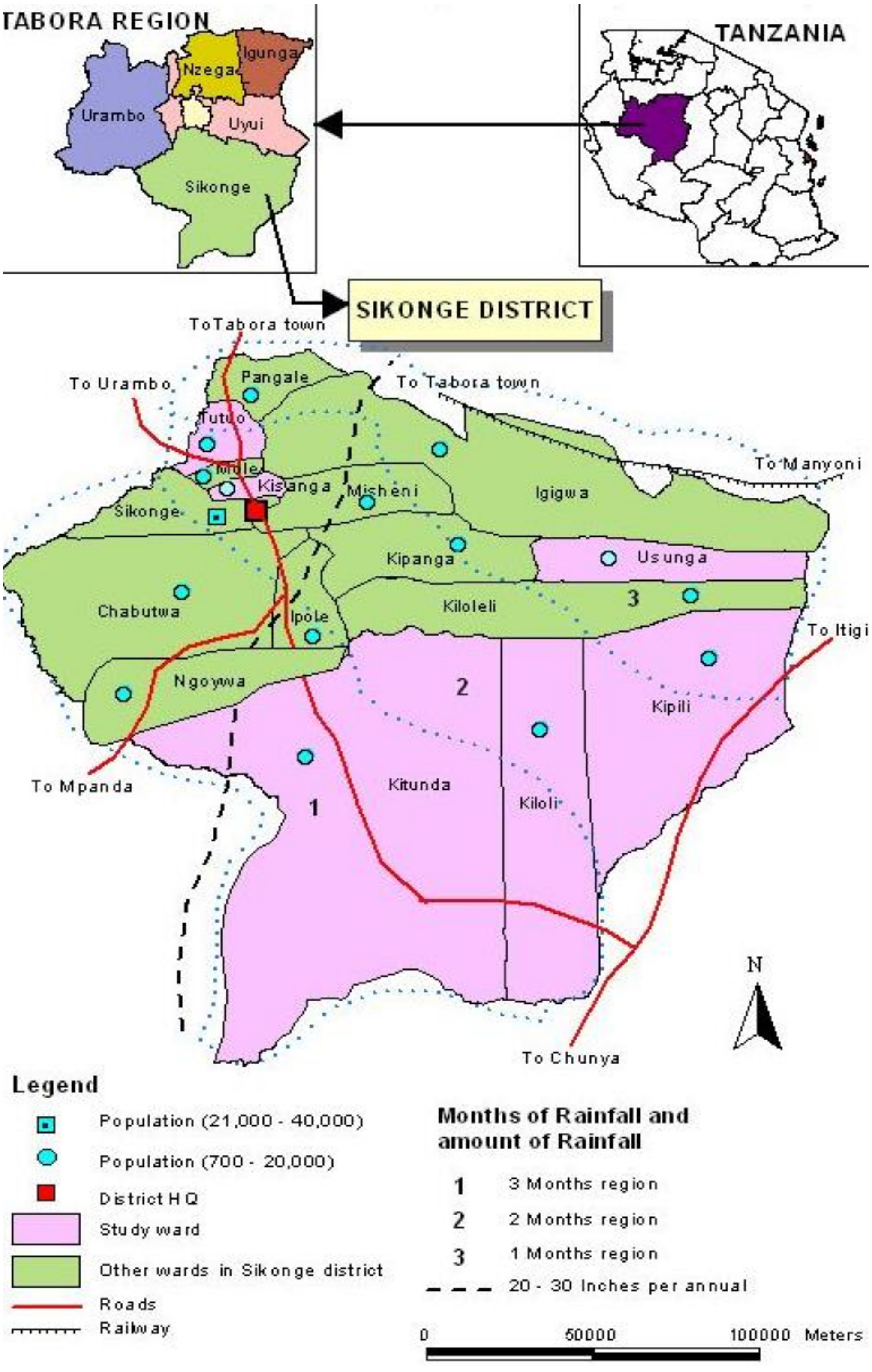

Figure 2: Map of the study area

3.2 Research Design

A cross-sectional research design was used in this study due to its advantage of allowing data to be collected at a single point in time and cost effectiveness. The design is suitable for a descriptive study as well as for determination of relationship between variables (Bailey, 1998).

3.3 Sampling Procedure

The study units for this survey were farming households in Sikonge District. A multi-stage sampling approach was used to select two Divisions of Sikonge District and then three Wards from each division namely Tutuo, Kisanga and Usunga in Sikonge Division and Kitunda, Kiloli and Kipili in Kiwere Division. Three (3) villages each in every selected Ward in the Division were randomly selected to make a total of six villages namely Muungano, Kisanga, Usunga, Mgambo, Majojoro and Kiyombo. A sample of 20 households was randomly selected from each of the 6 villages selected in the district to make a sample size of 120 respondents that was used in the analysis. The sample size was justified for precession by the general formula for sample size shown here under:

$$S = \frac{N}{1 + N(e)^2} \quad \text{...} \quad (1)$$

Whereas;

S Sample size

N Population size

e Level of precision (α)

From the general formula above, the sample size of 120 and population size of 66 000 which is the number of farming households in the District, gave the precision level of as high as α = 0.09 (DADP, 2010). The population was assumed to be homogeneous in most aspects with respect to farming practices as level of technology used, type of crops grown and weather conditions are more less the same.

A multi-stage sampling was used to make sure that spatial heterogeneity is captured. Finally, simple random sampling was employed to give equal chance for any person within the sampling frame of being chosen.

3.4 Data Collection

3.4.1 Primary data

Data related to household characteristics, adaptation and copying strategies used by households to mitigate the negative impacts of climate changes and variability on food security were collected using a structured questionnaire, which was used by the enumerators to interview the respondents.

3.4.2 Secondary data

Relevant secondary data on rainfall and rain days for the past 30 years were obtained from National Meteorological Agency. Area under maize cultivation and maize yields data for the past 30 years were obtained from reports and books in the Ministry of Agriculture food security and cooperatives. Data were complemented by similar information from Sikonge District Council offices, Sokoine National Agricultural Library (SNAL) and the mini library at Soil and Water Management Research Programme (SWMRP) in the Department of Agricultural Engineering and Land Planning at SUA.

3.5 Data Analysis

3.5.1 Descriptive analysis

The descriptive analysis involved the computation of frequency distributions of various socioeconomic characteristics of the respondents as well as some selected measures of central tendency and dispersal such as mean and standard deviation.

3.5.2 Trends of maize yields and rainfall

The analysis of trends of maize yields per hectare, annual rainfall and annual number of rain days was achieved by plotting graphs of variables using sequence charts. Rationale behind this approach was on the nature of trends of rainfall both for annual rainfall and rain days across time and to see how those trends of rainfall are related with maize production per hectare.

3.5.3 Maize yield and its relationship with climatic variables

The functional relationship between maize production and some climatic variables namely annual rainfall and number of rain days in a given year was analysed by using Auto Regressive Integrated Moving Average (ARIMA) approach which is commonly used in Time Series data for prediction and determining the relationship between variables (Box and Jenkins, 1976). The ARIMA models work under the basic assumption that some aspects of the past pattern will continue to remain in the future; that is current data have some effect from the previous data which leads to autocorrelation. Main advantages of ARIMA model is its ability to account for autocorrelation problem which OLS linear regression model does not, ARIMA models discover the patterns in the variation not explained by a regression model and incorporate those patterns into its model, according to Valenzuela *et al.* (2008), ARIMA model is suitable for both short term and long term forecast, besides the said advantages the ARIMA model has some weaknesses; according to Hanke and Wichern (2009) and Khashei *et al.* (2009), ARIMA model needs large amount of historical data and it is not easy to update the parameters of ARIMA model as new data becomes available; since ARIMA models are essentially backward looking they are generally poor at predicting turning points. The ARIMA model that was estimated is given below:

$$Yt = \alpha + \beta_1 (RAINt) + \beta_2 (RAINDAYSt) + \varepsilon i \quad \text{...} (2)$$

Whereby;

Y_t	Maize yields in tonnes per hectare of the i^{th} year.
α	Y intercept
$RAIN_t$	Average annual millimetres of rainfall of the i^{th} year.
$RAINDAYS_t$	Number of rainy days of the i^{th} year.
β's	Regression coefficients for predictors
εi	Error term in the observed value for the i^{th} case

In addition, the Pearson correlation coefficient for the predictors and the dependent variable was computed to give an indication of the directional relationship between them.

3.5.4 Role of farmers' adaptation strategies in household food security

This was achieved by identifying strategies adopted by farmers especially seasons when they experience crop failure. Different adaptation and coping strategies to climate change and variability were asked in the questionnaire which was administered to respondents.

The adaptation and coping strategies were categorized basing on how they are related to causing vulnerability to the household both in the short-run and long-run basis. This helped to see whether the adaptation and coping strategies used by farmers were worthy while using or would push a family in a more risky environment. The adaptation strategies were categorized into four groups namely those which increase vulnerability both in the short-run and long-run, those which decrease vulnerability in the short-run but increase in the long-run and those which increase vulnerability in the short-run but decrease in the long-run. The last category of adaptation strategies is those which decrease vulnerability both in the short-run and long-run.

The categorized strategies were assigned numbers ranging from 1 to 4 basing on their severity in terms of causing vulnerability to food insecurity situation from worst to the best scenario. The first category of adaptation strategies that are related to increasing vulnerability to food security both in the short-run and long-run was assigned number 1. The second category of adaptation strategies that are related to decreasing vulnerability in the short-run but increase in the long-run were assigned number 2, the third category that is related to increasing vulnerability in the short-run but decrease in the long-run was assigned number 3 and the last which is related to decreasing vulnerability both in the short-run and long-run was assigned number 4. The descriptive analysis was then used to show proportion of farmers using adaptation and coping strategies in those four categories and potential strategies used by farmers in the categories.

3.5.5 Assessing the adequacy of off-farm activities on household food security

This was achieved by calculating annual household food requirements by comparing household size and maize crop production on 2010/11 crop year. Household food requirement was estimated by using the assumption that an individual in the household which depends on a single crop requires 3 bags of maize weighted at 100 kg equivalent to 2753.425 kcal per person per day to achieve food security in a year (URT, 2002b and MAFS, 2005). Basing on this benchmark, the household requirement of maize in a year was estimated from its respective total number of individuals in a household under the assumption that all individuals' food consumptions are the same regardless of age, sex, body size and health status also by assuming that maize is the only food crop in the area. Household food security status was determined by subtracting food produced by the household from the household food requirement. The model used is given herein below:

$$HFSS^1i = FPHi - HFRi \quad \text{.. (3)}$$

Whereby;

$HFSS^1i$	Food security status of the i^{th} household depending on own produced food
$FPHi$	Food produced by i^{th} Household in a year
$HFRi$	Food requirement by i^{th} household in a year

In the above equation the value of $HFSS^1i$ can be either positive if the household produces enough food for its members or negative if the food produced by household is not enough to feed its members for the whole year round.

On the 2010/11 crop season, many households in the study area engaged themselves in other off-farming income generating activities. The off-farming activities done include small/petty business, selling of labour, receiving remittances from relatives, receiving loans/credit, selling of household assets (including home facilities, livestock and their products), food aid, salary/wage and selling of cash crops (including other crops except maize was also regarded as non-food crop and their incomes were added to off-farm activities).

The income from off-farm activities was used in purchasing food to supplement maize produced by the household. According to URT (2009) the Poverty and Human

Development report of 2007 shows that in rural areas of Tanzania, households spend 64% of their incomes on food. Therefore, for every household involved in the study 64% of its income from off-farm activities was assumed that it was used to buy food in the reference year. Basing on the assumption that an individual member of household would require 3 bags of maize to suffice his food requirements in the year (MAFS, 2005); the amount of money allocated for food was divided by the price of one bag of maize to get number of bags of maize that household was able to buy and add on its food stock. Price of one bag of maize was Tshs 55 000, this price was extracted from the annual crops price report 2011 at Sikonge District council office. Again the household food security was calculated by adding the number of bags of maize purchased from off-farm incomes to the number of bags of maize in excess or deficit in equation (3) above as per equation below:

$$HFSS^2i = HFSS^1i + FBOIi \qquad (4)$$

Whereby;

$HFSS^2i$ Food security status of the ith household after adding bought food

$HFSS^1i$ Food security status of the ith household depending on own produced food

$FBOIi$ Food bought from off-farm incomes by the ith household

In both steps used to examine household food security status a positive result signifies food surplus whereas zero signifies break even and negative implies food insecurity. The two steps above that are equations 3 and 4 were also used for sensitivity analysis to test the household food adequacy in case the climate change and variability leads to 25% and 50% loss in crop yields, respectively.

Also the household food excess data were regressed in OLS linear model with some household characteristics namely; size of the household, asset level of the household, sex of household head, age and level of education attained to examine how these characteristics can influence household food security. The fitted regression equation takes the form below;

$$logYi = \alpha + \beta j logX1i + \beta j logX2i + \beta j logX3i + \beta j logX4i + \beta j logX5i + \varepsilon i \quad \ldots \ldots\ldots(5)$$

Whereas,

logYi	Logarithm value of household food excess at i^{th} household
α	Value of Y intercept
βj	Value of slope coefficients for the j^{th} predictors, j = 1 to 5
logX1i	Logarithm value of age of i^{th} respondent in years
logX2i	Logarithm value of household size of the i^{th} household
logX3i	Logarithm value of household assets monetary value of the i^{th} household
logX4i	Logarithm value of level of education at least primary education attained by the i^{th} respondent, dummy 1 = attained formal education and 0 = no formal education is attained
logX5i	Logarithm value of sex of household head of the i^{th} household, dummy as 1 = male and 0 = female
εi	Error term in the observed value for the i^{th} case

CHAPTER FOUR

4.0 FINDINGS AND DISCUSSION

4.1 Socio-economic Characteristics of the Respondents

Table 2 shows the socio-economic characteristics of the sampled respondents. According to Hoppe (2002), age affects both experience and decision making all of which affects how one works and hence influences individual productivity. The mean age of all respondents was 40 years. Majority of the respondents 61% are between 26 and 45 years old; this is the most active age group in economic activities and more productive compared to other groups. Saris *et al*. (2006) reported that an active labour can be household members of 15 years and above but less than 65 years old; this is due to physical fitness and ability to take risk. The group aged between 46 to 65 years was 23% of all respondents and less than 6% of respondents were above 65 years.

Majority of respondents (71%) were married while relatively low proportion were either widows or divorced. The study also found out that more married couples were engaged in crop production meaning that they were actually the target population as the study targeted farmers. Many respondents were primary school leavers while a small proportion had secondary school education. Despite the wide range of household size majority of households in the sample population had an average of 6-8 members per household entailing a large manpower to work in farming activities.

Table 2: Socio economic characteristic of the respondents in Sikonge District Tabora, Tanzania

Socio economic characteristic	Frequency	% of response
Age (years)		
15 - 25	12	10.0
26 – 35	45	37.5
36 – 45	28	23.3
46 – 55	19	15.8
56 - 65	9	7.5
66 – 75	6	5.0
76 – 85	1	0.9
Sex		
Male	72	60.0
Female	48	40.0
Marital status		
Single	29	24.2
Married	85	70.8
Divorced	2	1.7
Widow	4	3.3
Level of education		
Primary school	106	88.3
Secondary school	14	11.7
Major economic activity		
Agriculture	66	55.0
Both Agriculture and Livestock keeping	54	45.0
Household size		
1 – 5	46	38.3
6 – 8	49	40.8
9 – 11	15	12.5
12 – 15	8	6.7
16 – 20	2	1.7

Source: Field data 2011

4.2 Characterization of Climate Related Rainfall and Maize Production

4.2.1 Trends of maize yields, annual rainfall and annual rain days

Visual inspection of data show a similar pattern for all graphs whereby, maize yields seems to increase with the increase in amount of rainfall and number of rain days respectively. The amount of maize yields seems to decrease concomitantly with the decrease in amount of rainfall and number of rainy days Fig 3 and 4. Generally the data show decreasing trends over the whole period of 30 years with cycles of ups and downs from year to year. The annual rainfall, annual rain days and maize production per hectare in the area are also characterized by seasonal peaks and troughs which reoccurred after approximately every ten years period Fig 3 and Fig 4.

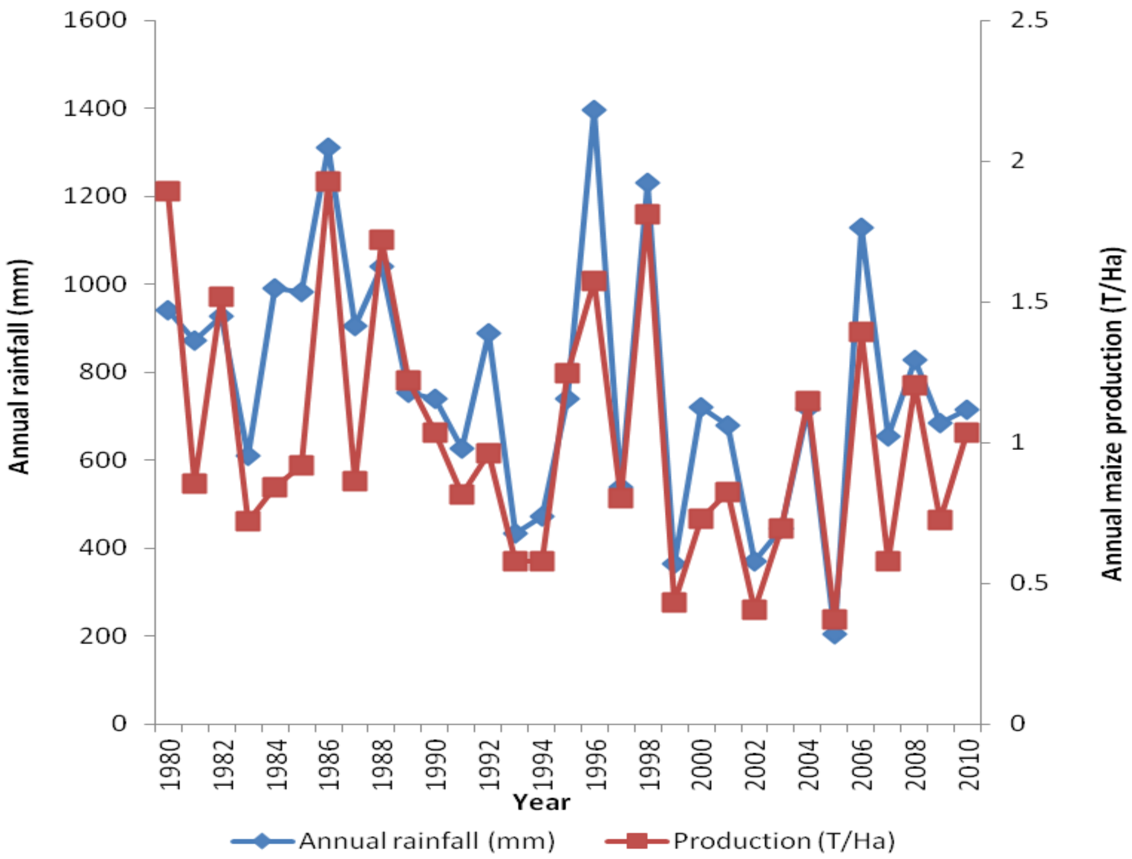

Figure 3: Maize yields and annual rainfall trends in Sikonge District (1980-2010)

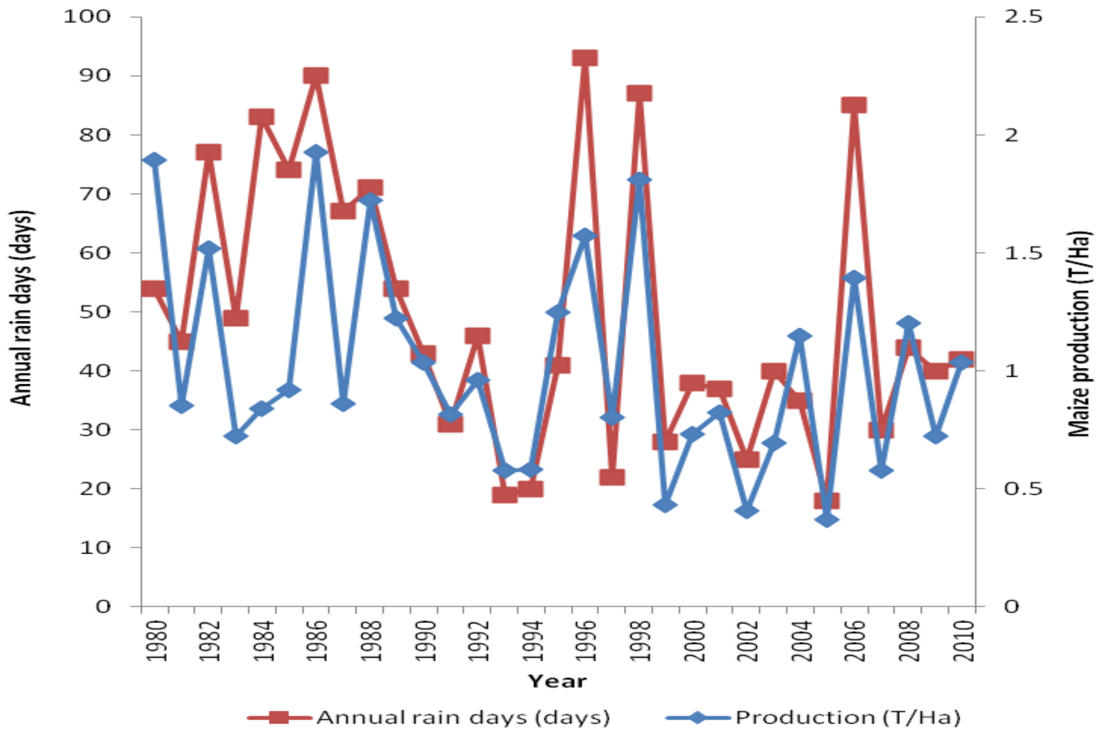

Figure 4: Maize yields and number of annual rain days trends in Sikonge District (1980-2010)

Maize production per hectare in Sikonge District showed a decreasing trend over the thirty years period (1980 - 2010). Production area increased from 7349 ha in 1980 to 15 280 ha in 2010 though the planted area changed according to fluctuations in climate variability. Average annual maize production in the District for the past three decades was 1.014 t/ha. Average annual maize production for the decades 1980 – 1989 and 1990 – 1999 was 1.248 t/ha and 0.984 t/ha respectively while the average annual maize production for the decade 2000 – 2010 was 0.828 t/ha. Overall average maize yields declined by 34% from 1979/1980 to 2009/2010 which shows higher effect of rainfall decrease to maize yield. The effect of climate change on maize yields through simulations by Crop Environment Resources Synthesis Model (CERES-Maize) showed that maize yield will be lower as a result of higher temperatures and, where applicable, decreased rainfall and the average decrease over the entire country will be 33% (Munishi *et al.*, 2006). This shows that the decrease in maize production in the study area has been even higher than the predicted value as depicted by Munishi *et al*. (2006).

4.2.2 Trends in rainfall

Analysis of rainfall data over 30 years revealed that the general trend has been declining over the years (Fig. 3). The onset of the long rains changed slightly. The average rainfall recorded over 60 days period at the onset of the rain season (October) decreased dramatically from 92.35 mm in 1980-1989 to 76.89 mm in the 2000 - 2010. The mean monthly rainfall (30 days records) recorded in October in the decade (51.78 mm) was significantly different from that of the 2000-2010 decade (31.6 mm). The average annual rainfall was 888.38 mm in the 1980-1989 which decreased to 698.05 mm in the 2000-2010.

According to the data, possibly the onset of rainfall had shifted from October to September; this is evident as frequency of rainfall onset on September or as early as August has increased (Table 3). The rain season started on September in 2003, 2008, 2009 and 2010. In 2004 and 2006 it started on August whereas in the earlier decades (1980 - 1989) it started early in only two seasons that is, in 1984 when it started on August and in 1987 when it started on September. This means that the rains start earlier in recent years as compared with how it used to be in the past. Analysis of climate change scenarios across multiple general circulation models shows that areas in Tanzania with a bimodal rainfall pattern will experience decreased rainfall of 5% - 45% and those with unimodal type of rainfall pattern which the study area falls will experience decreased rainfall of 5% - 15%, (Munishi *et al.,* 2006).

Table 3: Starting month of rain season over years

Month	Frequency	Years
August	3	1984, 2004 and 2006
September	5	1987, 2003, 2008, 2009 and 2010
October	9	1980, 1981, 1982, 1983, 1986, 1988, 1992, 1997 and 2005,
November	5	1985, 1989, 1991, 2000 and 2002
December	5	1990,1994, 1995, 1998 and 2001
January	3	1993/1994, 1996/1997 and 2007/2008
February	1	1999/2000

Source: Tanzania Meteorological Agency 2011

Data from Sikonge Meteorological Station show that in 2005 the amount of rainfall recorded was 203.4 mm which was the least amount since 1980 (Fig. 3). The amount of maize yield per area in the same year was the least for all thirty years. According to Rapid Vulnerability Assessment Report, the crop failure due to poor rainfall rendered 1 939 026 people in 320 026 households adversely food insecure in Tanzania. The number of food unsecured population in Sikonge district was 31 275 (21%) of total population (URT, 2003b). Alexandrov and Hoogenboom (2000) observed that decreases in annual precipitation during 20th century in Bulgaria during critical period of maize development limited growth development and final yields of maize.

4.2.3 Trends in rainy days

The numbers of rainy days showed to be decreasing year after year (Fig. 4). The total number of rainy days for the decade 1980 – 1989 was 664 days while in the decade 1990 – 1999 was 430 days. The total number of rainy days for the last decade 2000 – 2010 was 392 days. Generally, the number of rainy days decreased by 41% between 1980 – 1989 and the last decade 2000 – 2010. This is a clear shift in weather patterns that can be attributed to climate variability. The rainfall in semi-arid areas is described as relatively inadequate; highly variable with greater uncertainty and nearly throughout the country potential evaporation exceeds rainfall for more than nine months in a year (Hatibu *et al.*, 2006). The decrease of rain days can lead to the failure of seasonal rainfall to sustain crop growth to reach maturity stage and so does for maize crop.

4.2.4 Relationship between rainfall and maize production

A two predictor ARIMA model was fitted to the data to examine the relationship between them and maize yields. The ARIMA estimation was carried out by following the standard procedure in SPSS © version 18 in the Windows 2007 environment. With first order differencing the model was able to eliminate the non-stationarity entailing that the partial-autocorrelation coefficients were below the critical limit. The regression model estimated was an ARIMA (1, 1, 1) meaning that 1 lag was used for auto-regression, with 1 differencing levels and 1 moving average correction. The result of the fitted data showed that:

MAIZEYIELDt = 2.413+ 1*(MAIZEYIELDt - MAIZEYIELDt-1) + 1.112*(RAINFALt - RAINFALt-1) + 1.636*(RAINDAYSt - RAINDAYSt-1)

Table 4: ARIMA model parameter estimates

Parameter	B	SEβ	T	Sig.
Constant	2.413	4.435	0.544	0.591
Rainfall (mm)	1.112	0.439	2.535	0.018**
Rain days	1.636	5.694	0.287	0.776

Note: *** = Significant at 99% α level; **Significant at 95% α level

The ARIMA model parameter Table 4 above displays values for the parameters in the model. Annual rainfall was a significant predictor of maize yield ($p < 0.05$) as was expected whereas rain days was insignificant ($p > 0.1$), the two predictors showed a standard error of 0.439 and 5.694 respectively. The constant was not significant ($p >$ 0. 1). The standard error (SEβ) is an estimate of the magnitude of error that can be expected in estimating future values of dependent variable (Cohen *et al.,* 1983). It shows that maize production in the study area was highly determined by the amount of rainfall in the particular cropping year whereas rain days were not as much explaining factor for maize crop production as rainfall did. Both predictors had positive beta signs (slope) indicating that they had both contributed positively to maize production. That tells us that as rainfall and rain days increased the maize production increased also and maize production decreased as amount of rainfall and number of rain days in the season decreased.

4.2.5 Correlation between maize yields and climate change factors

Table 5 below shows the correlation matrix for maize yields in Tones per hectare and climatic factors namely annual rainfall and rain days. The Table shows a strong positive correlation between maize yields and the climatic factors. This implies that an increase in amount of rainfall and rain days is met with a simultaneous increase in maize yields. The correlation matrix shows that an addition of 19 hours of rain days enabled the addition of maize production by 1 tone/ha and an addition of 0.84 mm of rainfall led to addition maize production by 1 tone/ha at 0.01 significant level.

Table 5: Inter Item Correlation matrix

Variable	Maize yields (Tones/ha)	Rain days (Days)	Annual rainfall (mm)
Maize yields (Tones/ha)	1.000		
Rain days (Days)	0.807 (p = .000)**	1.000	
Annual rainfall (mm)	0.843 (p = .000)**	0.939 (p = .000)**	1.000

Note: ** = significant at 0.01 level of alpha

4.2.6 Model goodness of fit statistics

The model statistics table provides summary information and goodness of fit statistics for each estimated model. Although the Time Series Model offers a number of different goodness of fit statistics, the statistic in this study was the stationary R squared value. This statistic provides an estimate of the proportion of the total variation in the series that is explained by the model and is preferable to ordinary R squared when there is a trend or seasonal pattern. Larger values of stationary R squared (up to a maximum value of 1) indicate better fit. A value of 0.893 which was obtained in this study means that the model did a good job of explaining the observed variation in the series (Table 6).

Table 6: Model goodness of fit

Model	**Number Predictors**	**Model Fit statistics**		**Ljung-Box Q(18)**			**Number of Outliers**
		Stationary R^2	**R^2**	**Statistics**	***Df***	**Sig.**	
DIFF(MAIZEYIELDS,1)-Model_1	2	0.893	0.616	15.186	16	0.511	0

The Ljung-Box statistic, also known as the modified Box-Pierce statistic, provides an indication of whether the model is correctly specified. A significance value less than 0.05 implies that there is structure in the observed series which is not accounted for by the model. The value of 0.51 shown here is not significant, so the model is correctly specified. Furthermore, the model has not detected any point that was considered to be outlier hence there was no any point that needed to be modelled appropriately from the series. Therefore this model was proper for this analysis.

4.2.7 Partial autocorrelation functions

Two of the Autocorrelation Function (ACF) charts are shown below (Fig. 5). For instance, Partial Autocorrelation Function (PACF) and for lag 3 shows the correlation between the current period and 3 periods back, disregarding the influence of 1 and 2 periods back. In contrast, the ACF for lag 3 shows the combined impact of lags 1, 2 and 3." The PACF therefore, gives a clear indication of the presence of "non-stationary" and the level of differencing required. The ACF (along with the PACF) are often used to determine the Moving Average process.

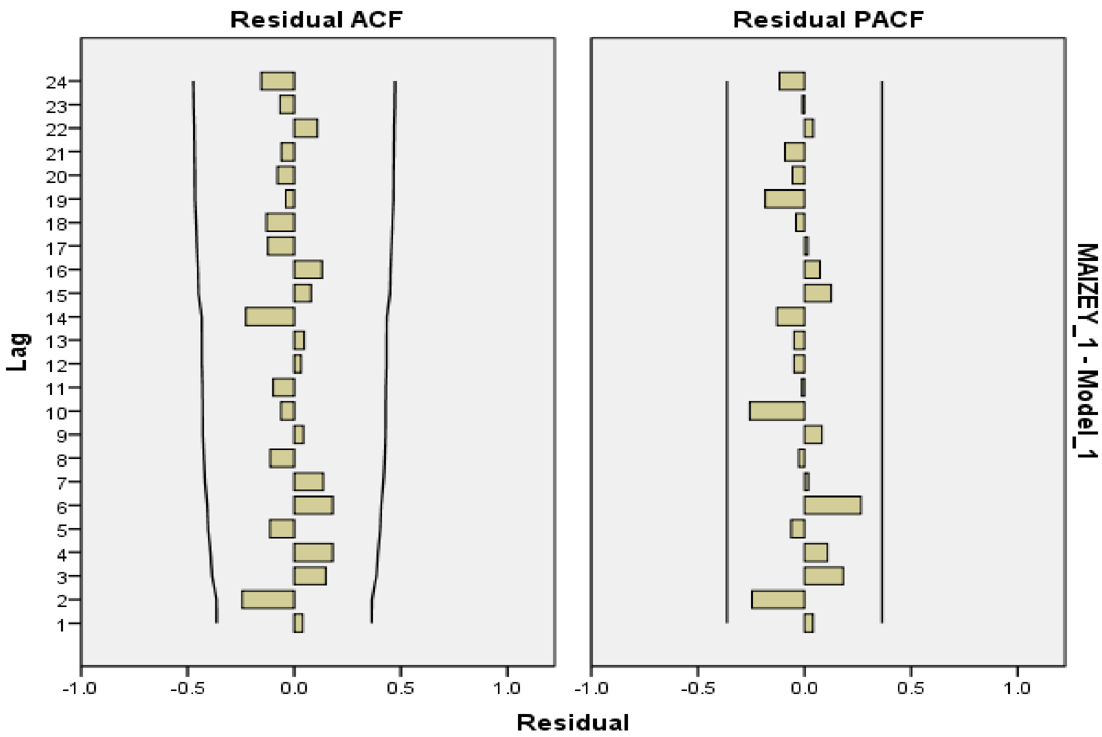

Figure 5: Autocorrelation Functions

In this analysis, both partial auto-correlation charts shown in Fig. 5 (ACF and PACF) have shown that first-differenced transformations do not have the problem of non-stationarity. According to Fig. 5 none of the partial-autocorrelation coefficients are above the critical limit. This indicates the absence of non-stationarity and strongly indicates the use of first-order differenced transformations of this variable ARIMA model regression analysis was correctly specified.

4.2.8 Reliability of the survey results

Reliability analysis was used to evaluate the reliability of the relationship between maize yields and climatic variables of interest namely amount of rainfall and annual rain days. Reliability refers to the property of a measurement instrument that causes it to give similar results for similar inputs. The reliability analysis of annual rainfall, rain days and maize yield data resulted into non standardized Cronbach's alpha of 68.9% and standardized Cronbach's alpha of 95% which shows a high level of internal consistence hence high reliability of the survey results (Table 7). Cronbach's alpha (Cronbach, 1951) is a measure of reliability. More specifically, alpha is a lower bound for the true reliability of the survey. Mathematically, reliability is defined as the proportion of the variability in the responses to the survey that is the result of differences in the respondents.

Table 7: Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
0.689	0.950	3

4.3 Adaptation and Coping Strategies Employed by Farmers for Food Security

Farmers use different techniques to ensure that household members get food following the extreme weather events that decimate food production. As depicted in Table 8 farmers adapt and cope by receiving remittances from migrant household members, collecting wild fruits, switching to non-farming activities or in extreme cases, selling assets. Adaptation and coping mechanisms during drought and other climate extremes also includes casual labour, brick making, handicraft, collecting honey and charcoal burning. Other strategies for adaptation and coping with seasonal food shortages include petty business, changes in diet, fewer meals and loans from traders; migration to urban areas in search of paid employment was also practiced in the study area.

4.3.1 Short term adaptation and coping strategies

The main strategy during severe food shortage in Sikonge District was switching to non-farm activities (Table 8). Few livestock keepers participate in non-farm activities compared to crop producers because they used to sell their animals and buy foods from the food markets. Many people worked as casual labourers for payment of either cash or food. Charcoal making, carpentry, and brick making were performed more in developed centres because they were in higher demand than in far interiors.

Table 8: Coping strategies to climate change and variability in Sikonge District

Coping Strategy	Frequency	% of response
Rely on less preferred and less expensive foods	60	50.0
Borrow food or relying on help from friend or relative	47	39.2
Purchasing food on credit	66	55.0
Gather wild food, hunt or harvest immature crops	37	30.8
Consume seed stock held for next season	33	27.5
Sale of assets to gain income for buying food	67	55.8
Sending children to eat with neighbours	8	6.7
Sending household members to beg	4	3.3
Reducing amount of food taken	35	29.2
Restrict consumption by adults for small children to eat	13	10.8
Buying prepared food	39	32.5
Reduce number of meals eaten in a day	70	58.3
Skip entire day without eating	7	5.8
Total dependence on external food aid	15	12.5

Source: Field data 2011

According to the respondent's dry cassava, dried sweet potatoes locally famously known as *Matoholwa* and dried vegetables known as *Nsanza* were the main source of food during dry seasons and also during severe food shortage. Most dry cassava and potatoes are brought from Sukuma areas in and outside the district. Even though the quality of these dried cassava and sweet potatoes are questionable so there is a need to find a way of improving quality and food safety to mitigate health risks such as mycotoxins and aflatoxins related food poisoning.

4.3.2 Long term adaptation and coping strategies

Farmers in Sikonge District have developed different long-term strategies to adapt and cope with both expected and unexpected variability of rainfall and water resources. The strategies are mainly related to the local production systems and the adaptation of local people to the surrounding environment. The strategies included rainwater harvesting, change of cultivation seasons, cultivation patterns, cultivation techniques and type of crops grown. These strategies were mostly intended to reduce the expected risk of rainfall variability on the production systems and life in general.

All respondents indicated that rainwater harvesting was effective and widely used as one of the adaptation mechanisms to rainfall and water resources variability. The techniques for rainwater harvesting included excavation of shallow basins for collecting run-off water and construction of public owned irrigation schemes.

As rainfall changes over relatively long periods, the cultivation patterns of food crops tend also to change. When there is relatively low rainfall over a long period mainly over ten years, food crops, which are commonly grown in the uplands, can be grown in the lowlands and when there is relatively high rainfall food crops, which are commonly grown on lowlands can be grown on uplands. About 75% of the respondents indicated that cultivation patterns are the common and effective adaptation mechanisms to rainfall and water resources variability particularly in sustaining food production (Table 9).

Table 9: Adaptation strategies to climate change and variability in Sikonge District

Strategy	Frequency	% of response
Crop rotation	107	89.2
Rain water harvesting (in-situ)	35	29.2
Timing of farm operations	101	84.2
Planting drought tolerant varieties	100	83.3
Planting early maturing varieties	105	87.5
Planting high yielding varieties	100	83.3
Reduce the size or number of farms to cultivate	59	49.2
Use of manure (organic or inorganic)	101	84.2
Not cultivating in the given season	46	38.3
Use of cover crops	40	33.3
Mulching	27	22.5
Irrigation scheme	6	5.0
Small scale irrigation	18	15.0
Manual irrigation	73	60.8
Tie ridges	23	19.2
Sunken beds	32	26.7
Agro forestry	6	5.0

Source: Field data 2011

When there is persistent decrease of rainfall over long period of time, farmers devised cultivation techniques, which conserve moisture. One of the common used strategies was growing crops on ridges which help to tap surface run-off water and increase moisture availability for plant growth. Similarly, during heavy rainfall, ridges reduce surface run-off and therefore minimise its impacts on the land, such as soil erosion. Employing different cultivation techniques as adaptation strategy to rainfall and water resources variability however is not common in the study villages. Only 25% of the respondents indicated that they have been cultivating on ridges as a cultivation technique to reduce the negative impact of rainfall variability. Majority of the farmers grow their food crops in wetlands during the seasons with less rainfall. By so doing they cause erosion to the catchment areas which consequently leads to siltation in the water reservoirs.

Planting drought tolerant crops was the common and effective strategy to dealing with rainfall and water resources changes and variations employed by farmers in the study area. About 83% of the respondents revealed that they had been planting drought tolerant crops, such as cassava, pigeon pea and sweet potatoes, as a strategy to mitigate changes and variations in rainfall and water resources. Some respondents said they have been growing drought tolerant maize seed called *Katumani*.

The study found out that about 88% of farmers used to grow early maturing crop varieties. These varieties have been effective for the seasons when short rain seasons are experienced. Majority of farmers grew maize varieties which take as short as 90 or 75 days to mature. Other farming practices farmers mostly practiced include timing of farm operations, planting high yielding varieties, use of manure, crop rotation and manual irrigation.

According to Low (2005), some adaptation to climate variability are seasonal rainwater harvesting, growing of drought tolerant and fast maturity crops, control overgrazing and promotion of the use of alternative sources of energy such as solar cooker instead of inefficient woodstove and charcoal stove.

4.3.3 Adaptation strategies and vulnerability to food insecurity

The adaptation and coping strategies mentioned by households were categorized into four groups namely those which increase vulnerability both in the short-run and long-run, those which decrease vulnerability in the short-run but increase in the long-run and those which increase vulnerability in the short-run but decrease in the long-run. The last category of adaptation strategies is those which decrease vulnerability both in the short-run and long-run.

The categorized adaptation strategies were assigned numbers ranging from 1 to 4 basing on their severity in terms of causing vulnerability to food insecurity situation from worst to the best scenario. The first category of adaptation strategies that was related to increasing vulnerability to food security both in the short-run and long-run was assigned number 1. The second category of adaptation strategies that was related to decreasing vulnerability in the short-run but increase in the long-run were assigned number 2, the third category that was related to increasing vulnerability in the short-run but decrease in the long-run was assigned number 3 and the last which was related to decreasing vulnerability both in the short-run and long-run was assigned number 4.

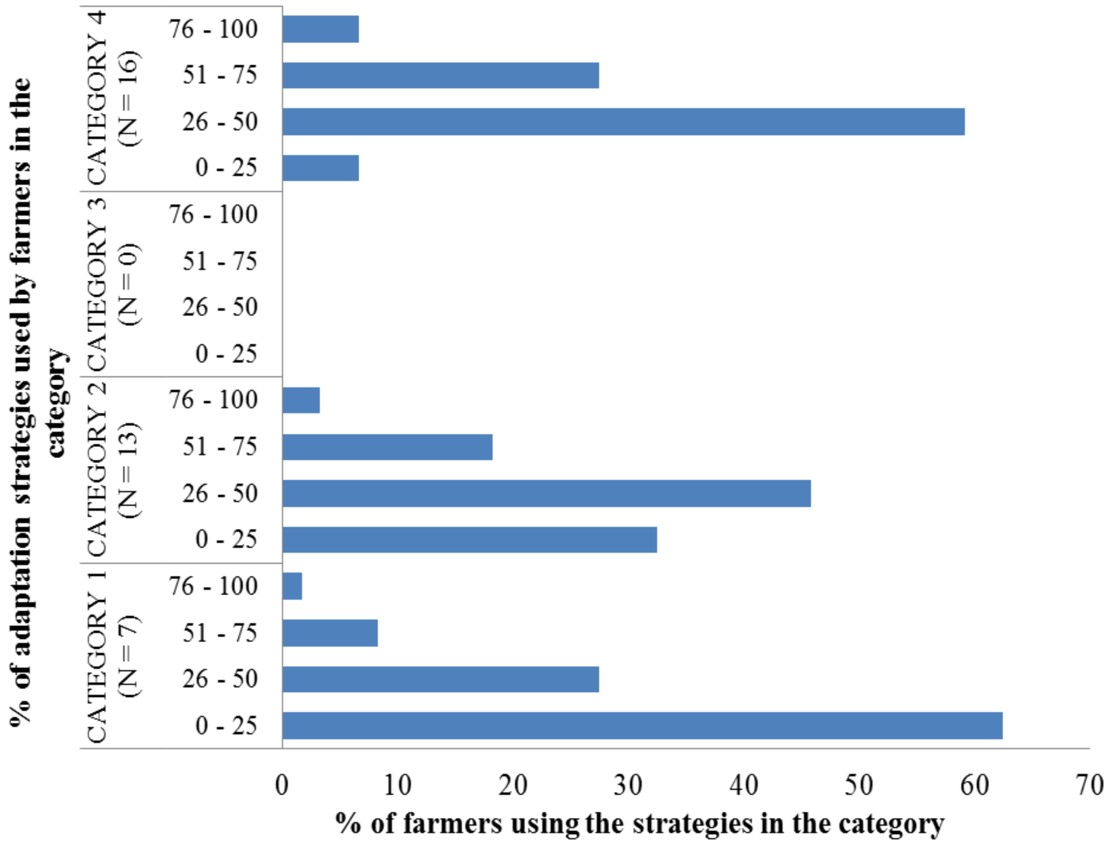

Figure 6: Adaptation strategies categories and their extent of use

It was observed that a total of 36 adaptation and coping strategies were used by farmers in the study area to make food available during the harsh conditions of food insecurity (Fig. 6). More than 81% of farmers used at least one of the strategies falling in category 1, these are the ones linked to be causing vulnerability to the household both in short-run as well as long-run. Seven adaptation strategies used by farmers fall in this category and it was observed that many farmers used few of the strategies in this category for example more than 62% of respondents used less than 25% of the strategies in the category (Fig. 6). The proportion of farmers using this category decreased across as number of strategies used increased. This may be due to the fact that the strategies like sending household members to beg which fall in this category are unreliable as far as food security is concerned.

Category 2 included the strategies related to decreasing vulnerability only in the short-run but increase vulnerability in the long-run. All respondents used at least one of the thirteen strategies falling in this category. Many respondents 46% used 26% - 50% strategies in the category 2 (Fig. 6). Strategies in this category are worthy while using than the strategies in category 1, since they ensure at least food security in the current time where the situation in the future is not guaranteed as it might change sometimes into better without even using personal efforts.

The category 3 strategies are those related with increasing vulnerability in the short-run but decrease it in the long-run. This one is like saving and investing for the future's sake or more like starving today so that you are going to eat the next time. The observation from the existing adaptation and coping strategies showed that there was none which was related to this category.

The last category that is category 4 was related to the strategies that decreased vulnerability both in the short-run as well as long-run. The adaptation strategies in this category were the most efficient and successful strategies. It comprised strategies like rain water harvesting, planting high yielding plant varieties and other similar strategies making a total of sixteen strategies. Every respondent used at least one of the sixteen strategies which make up this category. More than 93% farmers used at least 25% of the strategies belonging to this category (Fig. 6). Farmers using this category were guaranteed of food security at all times since most of the strategies here involved technological changes and environmental conservation which are normally advised for ensuring sustainability as far as food security is concerned. Since almost all respondents said to have used many of strategies in category 4 which were the best it can be concluded that adaptation strategies used by farmers were useful in bringing about household food security.

4.4 Adequacy of Off-farm Activities in Household Food Security

It was observed that major off-farm activities used to adapt and cope with food insecurity for the agricultural season of 2010/11 were selling of cash crops, selling of household assets, selling livestock products, selling cash crops and engaging in small business. Other activities were engaging in labour intensive activities, income received by households as social transfers, reliance on food aid, seeking for loans, purchasing food on credit and reduction in the number and size of the meals taken in a day.

Findings in Table 10 show that of all income generating activities in the area selling of cash crops was done by 88% of all respondents. Also farmers indicated to have raised large amount of income from selling of cash crops. That is to say as impacts of climate change and variability leads to severe decline in crop production, farmers will be affected much more and their adaptation capacity will be jeopardized since the cash crops which majority of them depend on will also be affected and produce less. Another reliable strategy was selling of household assets including livestock and animal products, land and even houses.

In addition other respondents mentioned that they turned to doing petty businesses like food vending, merchandise hawking, *kiosk* business and selling of honey. Some respondents indicated that they purchased food on credit and sometimes were forced to reduce the number and size of meals eaten per day.

Table 10: Incomes from off-farm adaptation and coping strategies by activity

Activity	N	%	Min	Max	mean	Std. Dev.
Small/petty business	51	42.5	20 000	5 000 000	525 843	889 021
Sell of cash crops	106	88.3	10 000	7 500 000	1 609 121	1 454 619
Sell of labour	41	34.2	20 000	220 000	92 425	42 707
Remittances	23	19.2	10 000	200 000	65 882	52 328
Loan/credit	43	35.8	25 000	700 000	220 000	204 868
Sell of hh assets	77	64.2	25 000	3 000 000	463 284	766 257
Food aid	20	16.7	20 000	600 000	172 846	244 473
Salary / wage	13	10.8	20 000	1 940 000	543 385	594 263

Source: Field data 2011

Further, the survey findings indicated that remittances from family members and relatives played an important role in household wellbeing during difficult periods. A study by Orindi and Murray (2005) indicated that people who receive remittances tend to be less affected by shocks in terms of access to food, health services and school attendance.

On the other hand it is imperative to note that some coping strategies needs to be managed very carefully as they may jeopardize future resilience of resources. Strategies like sale of household assets such as land and live stocks, total dependence on external food aid and consumption of seed stocks are not always reliable since they can cause more vulnerability to the household in the future. According to Low (2005), the sale of household goods is a strategy used to cope with short-term food insecurity. Household goods and assets such as land and livestock can be sold to pay off debts incurred during extreme events. However, the dismay fact is that this erodes the asset base and, ultimately, a household’s chances of long-term survival. Such short-term coping strategies should therefore be implemented with care in order to ensure that households do not descend into a state of helplessness (Low, 2005).

4.4.1 Comparison between maize produced and household food requirement

The study has revealed that for some households maize yields in the 2010/11 season was not sufficient to meet their annual food requirements. The data basing on maize production by the household when compared to the family requirements showed that more than 64% of household were food insecure. In this case most male headed households (65%) were food insecure (Table 11).

Also the findings show that households with large number of people that is more than 8 members were more vulnerable to food insecurity (72%) as compared to those with fewer members. This means that as household size gets larger there is a great chance of having higher dependency ratio which exposes the family in a situation of food insecurity. Furthermore, respondents who were engaged in agriculture activities only were more vulnerable to food insecurity (65%) than those who were engaged in both agriculture and livestock keeping. That is to say, households which depend on single activity were more prone to food insecurity compared to their counterparts since those used to keep livestock were capable to absorb shocks caused by short rainfall hence less agriculture production by selling their animals and get money for buying food while those depending on agriculture only are prone to reduced income emanating from selling of crops due to reduced production. This is in line with observation by Shalli, (2003) that income contributed by livestock sector was 27.7% while the livestock products contribution was about 30.7% of the annual diet. It is further postulated that if a house hold keeping local chicken at better husbandry, income could be increased to $ 600 per annum. The findings also showed that households with low asset base were more vulnerable to food insecurity (66%) compared to those ones with higher assets. This is caused by the differences in adaptability the higher asset households were able to sell some of the assets and buy food during the extreme events of crop failure while for those with low assets that was difficult.

Table 11: Household food security status with socio-economic characteristics

Socio-economic characteristics	Basing on crop production alone		Basing on crop production + food bought	
	Food secure N (%)	Food insecure N (%)	Food secure N (%)	Food insecure N (%)
Sex				
Male	35 (29.2)	66 (55.0)	80 (66.7)	21 (17.5)
Female	8 (6.7)	11 (9.2)	13 (10.8)	6 (5.0)
Marital status				
Single	13 (10.8)	16 (13.3)	20 (16.7)	9 (7.5)
Married	28 (23.3)	57 (47.5)	68 (56.7)	17 (14.2)
Divorced / widow	2 (1.6)	4 (3.3)	5 (4.2)	1 (0.8)
Level of Education				
Primary school	41 (34.2)	65 (54.2)	84 (70.0)	22 (18.3)
Secondary school	2 (1.7)	12 (10.0)	9 (7.5)	5 (4.2)
Household size				
1 - 8 people	36 (30.0)	59 (49.2)	78 (65)	17 (14.1)
9 – 20 people	7 (5.8)	18 (15.0)	15 (12.5)	10 (8.4)
Major economic activity				
Agriculture	23 (19.2)	43 (35.8)	49 (40.8)	17 (14.2)
Both agric & livestock	20 (16.7)	34 (28.3)	44 (36.7)	10 (8.3)
Asset wealth (Tshs)				
100 000 – 2 000 000	21 (17.4)	41 (34.2)	42 (35)	20 (16.7)
2 000 001 – 10 000 000+	22 (18.3)	36 (30)	51 (42.5)	7 (5.8)
Overall	**43 (35.8)**	**77 (64.2)**	**93 (77.5)**	**27 (22.5)**

Source: Field data 2011

Furthermore, sensitivity analysis showed that food insecurity would increase tremendously if the drought caused by climate change and variability leads to 25% crop loss or 50% crop loss (Table 12 and 13). This situation could lead to as much as 81% and 94% households respectively succumbing to food insecurity but also after adding purchased food with off-farm incomes the proportional of households which remained food insecure dropped to 28% and 43% respectively. Survey data show that income earned from off-farm activities rescued as many as 64 and 61 households at 25% and 50% crop loss respectively from falling into food insecurity situation.

Table 12: Household food security status with socio-economic characteristics after 25% decrease in crop production

Socio-economic characteristics	Basing on crop production alone		Basing on crop production + food bought	
	Food secure N (%)	Food insecure N (%)	Food secure N (%)	Food insecure N (%)
Sex				
Male	19 (15.8)	82 (68.3)	74 (61.7)	27 (22.5)
Female	4 (3.3)	15 (12.5)	13 (10.8)	6 (5.0)
Marital status				
Single	8 (6.7)	21 (17.5)	18 (15.0)	11 (9.2)
Married	13 (10.8)	72 (60.0)	64 (53.3)	21 (17.5)
Divorced / widow	2 (1.7)	4 (3.3)	5 (4.2)	1 (0.8)
Level of Education				
Primary school	21 (17.5)	85 (70.8)	78 (65.0)	28 (23.3)
Secondary school	2 (1.7)	12 (10.0)	9 (7.5)	5 (4.2)
Household size				
1 - 8 people	20 (16.6)	75 (62.5)	72 (60.0)	23 (19.1)
9 – 20 people	3 (2.5)	22 (18.3)	15 (12.5)	10 (8.4)
Major economic activity				
Agriculture	13 (10.8)	53 (44.2)	46 (38.3)	20 (16.7)
Both agric & livestock	10 (8.3)	44 (36.7)	41 (34.2)	13 (10.8)
Asset wealth (Tshs)				
100 000 – 2 000 000	12 (10.0)	50 (41.6)	37 (30.8)	25 (20.8)
2 000 001 – 10 000 000+	11 (9.1)	47 (39.2)	50 (41.7)	8 (6.7)
Overall	**23 (19.1)**	**97 (80.8)**	**87 (72.5)**	**33 (27.5)**

Source: Field data 2011

This huge drop in food insecure proportion is a good indicator showing that probably the contribution of off-farm income generating activities is significant in ensuring household food security in the area. In both scenarios of 25% and 50% crop loss due to influences of climate change, households which were more likely to succumb to food insecurity were those whose household heads were male (81% and 96%), lower asset level households (81% and 95%), of married couples (85% and 98%) and those with large household sizes (88% and 96%) respectively.

Table 13: Household food security status with socio-economic characteristics after 50% decrease in crop production

Socio-economic characteristics	Basing on crop production alone		Basing on crop production + food bought	
	Food secure N (%)	Food insecure N (%)	Food secure N (%)	Food insecure N (%)
Sex				
Male	4 (3.3)	97 (80.8)	58 (48.3)	43 (35.8)
Female	3 (2.5)	16 (13.3)	10 (8.3)	9 (7.5)
Marital status				
Single	3 (2.5)	26 (21.7)	16 (13.3)	13 (10.8)
Married	2 (1.7)	83 (69.2)	48 (40.0)	37 (30.8)
Divorced / widow	2 (1.7)	4 (3.3)	4 (3.4)	2 (1.7)
Level of Education				
Primary school	6 (5.0)	100 (83.3)	61 (50.8)	45 (37.5)
Secondary school	1 (0.8)	13 (10.8)	7 (5.8)	7 (5.8)
Household size				
1 - 8 people	6 (5.0)	89 (74.1)	58 (48.3)	37 (30.8)
9 – 20 people	1 (0.8)	24 (20.0)	10 (8.3)	15 (12.5)
Major economic activity				
Agriculture	5 (4.2)	61 (50.8)	39 (32.5)	27 (22.5)
Both agric & livestock	2 (1.7)	52 (43.3)	29 (24.2)	25 (20.8)
Asset wealth (Tshs)				
100 000 – 2 000 000	3 (2.5)	59 (49.2)	27 (22.5)	35 (29.1)
500 001 – 1 000 000+	4 (3.3)	54 (45.1)	41 (34.2)	17 (14.2)
Overall	**7 (5.8)**	**113 (94.2)**	**68 (56.7)**	**52 (43.3)**

Source: Field data 2011

Moreover, the data show that summing up all respondents' members of their households and summing up their overall maize yield in the 2010/11 crop season, there would be a deficit of 24% which is equivalent to 549 bags of maize to achieve food security. On the other hand by considering bags of maize purchased by incomes allocated for food from off-farm activities and adding to the maize food produced, the society would have an excess of 2448 bags which is equivalent to 105% of its total requirement of 2325 bags of maize per year. This gives evidence that although some individual households will succumb to food insecurity the overall community will be food secure. Therefore these findings underscore the importance of off-farm income generating activities in contributing to household food security in rural areas (Fig. 7). Therefore off-farm income generating activities done by farmers in the study area were adequate in sustaining food security in a changing climate.

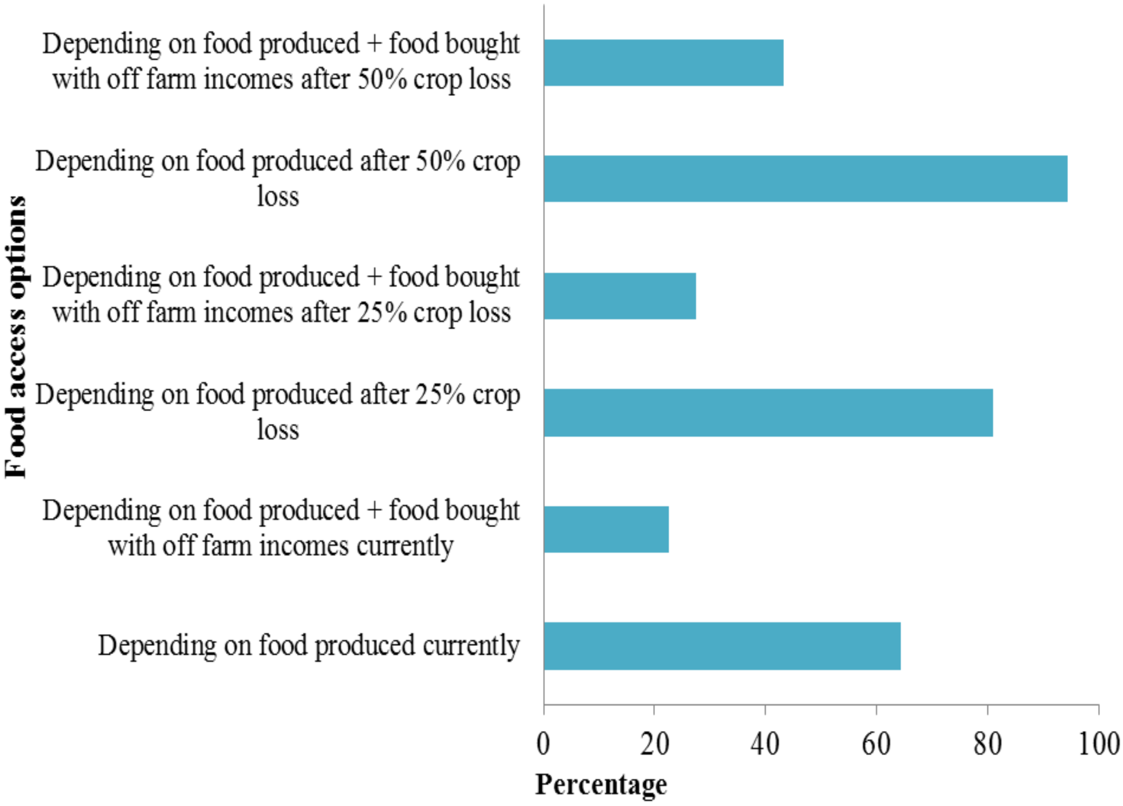

Figure 7: Food insecure household proportions under different food access options and risk scenarios

4.4.2 Relationship between food excess and social economic characteristics

When the household food excess data were regressed in OLS linear regression model with some chosen household characteristics namely; size of the household, asset level of the household, sex of household head, age and level of education attained; most of the household characteristics showed to have contributed significantly to the household food excess. The results are summarized in Tables 14 and 15 below.

Table 14: Model Summary

Model	R	R^2	Adjusted R^2	SE of the Estimate
1	0.633[a]	0.401	0.374	21.37835

a. Predictors: (Constant), sex of household head, age of respondent, level of education attained by the respondent, size of the household, asset level of the household

The R squared, the coefficient of determination, is the squared value of the multiple correlation co-efficient (Norusis, 2004). It shows that about 40% of the variations in independent variables which influence the variation in the dependent variable are explained by the model (Table 14). The standard error of the estimates is considerably lower, about 21.38.

Table 15: Parameter Estimates

Parameter	B	SE	T	Sig.
Constant	0.000	8.177	0.092	0.927
Age of household head	0.194	0.162	2.454	0.016*
Size of the household	-0.352	0.661	-4.536	0.000**
Asset level of the household	0.532	0.000	6.653	0.000**
Level of education attained	0.008	6.386	0.102	0.919
Sex of household head	0.110	5.644	1.433	0.155

a. Dependent Variable: household food excess

** = Significant at 99% level of confidence; * = Significant at 95% level of confidence

Among the household characteristics; age, household size and asset level of the household indicated to have significance effect on household food excess at 95%, 99% and 99% respectively (Table 15). Age and asset level seemed to increase linearly with food excess that is as age of household head increases there was a great chance of that household to have more food excess likewise household asset level. On the other hand household size seemed to contribute negatively to the food excess that is to say as number of household member increases the amount of food surplus of the household decreases.

The results further show that 0.5 unit increase in asset level of a household lead to 1 unit increase in amount of maize food in excess, a 0.19 increase in years of household head lead to an addition of 1 bag of maize in excess also an addition of 1 person in the household size leads to a deficit of 3 bags of maize food production. These results are correct with a precession level of more than 95%.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Rainfall and rainy days were found to be good predictors which largely influenced maize crop production in Sikonge District. The noted trend was that as rainfall and rain days increased maize harvest increased and vice versa. Maize production kept on decreasing since the trends on rainfall and rain days were decreasing. Further observation showed that seasonal trends were also changing the onset of rainfall season that had shifted from the normal onset which was in October in the previous years to September.

Major adaptation and coping strategies to climate change and variability adopted by farmers in the study area include switching to non-farming activities, casual laboring, selling of household assets, selling forest products, and purchasing food on credit. Others included growing early maturing and high yielding crop varieties, rainwater harvesting, change of cultivation seasons, change of cultivation patterns, improving cultivation techniques and growing of drought tolerant crops. Most of the strategies used by farmers in the study area are those linked to decreasing vulnerability both in the short-run and long-run.

Off-farm activities were significant contributors of household food security. Income generated from off-farm activities enabled most households to supplement their food needs hence graduated from food insecurity. On the other hand those households that depended solely on agriculture production were more prone to food insecurity as compared to those with off-farm activities.

5.2 Recommendations

The findings of this study underscore the need of initiating deliberate efforts to improve smallholder agriculture for sustainability and mitigation of the deleterious effects of climate change and variability. The effort should include enhancing diversification of agricultural production, investing in rain water harvesting technologies and irrigation infrastructures.

Mitigation strategies for negative consequences of climate change and variability are not only necessary but also cornerstone of sustainable agriculture. As such, the urgent need is foreseen to institutionalize integrated weather forecasting in order to enhance early warning and enable farmers adjust their farming systems accordingly. Situations like short rainfall, heavy rains or drought can be predicted and narrated to farmers hence enabling them to have a certain degree of leverage against negative effects of such unfavourable weathers.

Of paramount importance is the issue of provision of environmental management education to rural communities alongside sustainable use of forest resource and conservation of biodiversity all of which are necessary to reduce climate change and variability. Communities need to learn and adopt strategies that do not lead to further environmental degradation, hand in hand with increasing communities' awareness on climate change and variability and their roles in land resources management.

Civil Society Organizations and government agencies need to enhance sustainable coping and adaptive capacity for reducing vulnerability, targeting the most prone region and social groups. Future management plan of the adaptation strategies needs to be developed with the active participation of local communities. The collaborative management strategy would be the best approach in the future land resources management for ensuring sustainability.

There is a need for adaptation to rely on projections of future impacts. This might argue for immediate adaptation measures in case of such impacts as opposes to a “wait and see” strategy. There is a need to differentiate adaptation strategy across various sectors and regions depending upon the certainty of projections, the mix of benefits and adverse impacts, the urgency and timing of such impacts.

In this era of rapid climate change, there is a need to involve farmers actively in participating to other income generating activities. This can be achieved through acquiring trainings on other skills like carpentry, cloth making and the likes. This will help farmers to have occupations during drought seasons and helps to raise family income. Activities like livestock keeping such as dairy cattle and poultry projects are good to mix with plant husbandry.

5.3 Area for Further Studies

Basing on the findings from this study, further studies can be conducted on safety conditions of the food sources farmers opt for when they face extreme situations of food stress. Food sources like dried potatoes, cassava, collected wild food and the likes are not well understood as far as toxins contents is concerned.

Another area is on sustainability of family asset levels during short rain seasons. Families use to sell assets so as to raise enough money for buying family food stuffs. In so doing many families fall in a situation of losing family assets completely. Now the studies need to be conducted to understand what proportion of families adopting this coping technique can recover the lost household assets.

Also length of time household can cope and remain food secure without own food production due to rainfall scarcity is important to be studied. This will help the community to prepare for food sources for the case where climate related rainfall becomes extremely harsh.

REFERENCES

Adosi, J. (2007). *Climate Change Related Vulnerability, Resilience and Adaptation in Tanzania*. Tanzania Meteorological Agency. Dar es Salaam. 46pp.

AIACC (2006). Climate change induced vulnerability to malaria and cholera in the Lake Victoria Region: [htt://www.aiaccproject.org/working_papers/workingpapers.Html] site visited on 16/1/2012.

Albritton, D. L. and Meria, L. G. (2001). Climate change scientific basis. Summary for policy makers. [http://www.ipcc.ch] site visited on 26/2/2012.

Alderman, H., Haddinott, J. and Kinsey, E. (2007). Long-term consequences of early childhood malnutrition. *Oxford Economic Journal* 58(3): 450 – 474.

Alexandrov, V. and Hoogenboom, G. (2000). Evaluation of the CERES model for maize and winter wheat in southeastern Europe. In: *Proceedings of the international symposium on Modeling Cropping Systems*. (Edited by Donatell, M. *et al*.). 21-23 June 1999, University of Lleida, Catalonia, Spain. pp. 131 – 132.

Armentrout, J. M. (2008). *Response to Climate Change*: *Adaptation and Mitigation Requires.* A Robust Economy Report. Cascade Consultant Inc., Damascus. 47pp.

Arrow, K. J. and Fischer, A. C. (1974). Environmental preservation, uncertainty and irreversibility. *Quarterly Journal of Economics* 88: 312 – 319.

Bailey, D. K. (1998). *Methods of Social Research*. Macmillan Publishers, London. 478pp.

Black, R. E., Allen, L. H., Bhutta, Z. A., de Onis, M., Mathers, C. and Rivera, J. (2008). Maternal and Child Undernutrition: Global and regional exposures and health consequences. *Lancet* 371: 243 – 260.

Box, G. E. P. and Jenkins, G. M. (1976). *Time Series Analysis: Forecasting and control*. Wiley and Sons, San Francisco. 648pp.

Bradshaw, B., Dolan, H. and Smith, B. (2004). Farm-level adaptation to climatic variability and change: Crop diversification in the Canadian Prairies, *Climatic Change*. 67(1): 119 – 141.

Chibber, A. and Laajaj, R. (2007). *Disasters, Climate Change and Economic Development in Sub-Saharan Africa*: *Lessons and Future Directions*. Evaluation Brief 3. IEG/World Bank. Washington DC, USA. 46pp.

Cohen, J. and Cohen, P. (1983). *Applied Multiple Regression/Correlation Analysis for Behavioral Science*. Laurence Erlbaum Associates Publishers, New Jersey. 545pp.

Cox, D. R. and Snell, E. J. (1989). *The Analysis of Binary Data*. (2nd Edition). Chapman and Hall, London. 244pp.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika* 16(3): 297 – 334.

Dawis, R. V. (2000). Scale Construction and Psychometric Considerations. In: Tinsley, H. and Brown, S. (Eds). *Handbook of Applied Multivariate Statistics and Mathematical Modeling*. Academic Press, New York. pp. 65-94.

Devereux, S., Baulch, B., Hussein, K., Shoham, J., Sida, H. and Wilcock, D. (2004). Improving the analysis of food insecurity: Food insecurity measurements, livelihoods approaches and Policy: Applications in FIVIMS. [http://www.fivims.net/documents/Final%20Papers.pdf] site visited on 25/03/2012.

Devereux, S. (2006). *Distinguishing between chronic and transitory food insecurity in emergency needs assessments*. World Food Programme, Rome. 54pp.

District Agriculture Development Plan, (2010). *District Agriculture Development Plan. Sikonge District Council.* Regional Administration and Local Government Authority, Dodoma, Tanzania. 102pp.

Du, T. and Ziervogel, G. A. (2004). Vulnerability and food security: Background concept for informing the development of national FIVIMS for South Africa. [http://www.agis.agric.za/agiswasweb/FIVIMSZA.html] site visited on 16/2/2012.

Enfors, E. I. and Gordon, J. L. (2008). Dealing with drought: The challenge of using water system technologies to break dry-land poverty traps. *Global Environmental Change* 18(4): 607—616.

Ericksen, J. P. (2008). What is the vulnerability of a food system to global environmental change. *Ecological and Society Journal* 13(2): 1 – 14.

FAO (2003a). *World Agriculture*: Towards 2015/2030. FAO perspective. Earthscan Publications Ltd., London. 26pp.

FAO (2003b). The coping strategies index: A tool for rapidly measuring food security and the impact of food aid programmes in emergencies. *International Workshop on Food Security in Complex Emergencies: Building policy frameworks to address longer-term programming challenges*. 23 - 25 September 2003. Tivoli. 46pp.

FAO (2005). *Building on Gender, Agro biodiversity and Local Knowledge: A Training Manual, Information Division.* Food and Agriculture Organization, Rome. 250pp.

FAO (2007a). *Adaptation to Climate Change Mitigation and Adaptation in Agriculture, Forestry and Fisheries:* Perspective, framework and priorities. Report of the FAO Interdepartmental Working Group on Climate. FAO Publications, Rome, 14pp.

FAO (2007b). Climate change and food security: United Nations joint press kit for Bali. [http://www.fao.org/nr/ index- en.htm] site visited on 22/4/2011.

FAO (2008a). *High-level Conference on World Food Security: The Challenges of Climate Change and Bio-energy. Climate Change Adaptation and Mitigation:* Challenges and opportunities for food security. FAO Publications, Rome. 20pp.

FAO (2008b). Climate Change Adaptation and Mitigation: Challenges and Opportunities for Food Security. In: *The Challenge of Climate change and Biodiversity Conference*. 3-5 June, 2008, Rome, Italy. pp. 23 – 41.

FAO (2008c). *Climate Change and Food Security*: *A Framework Document*. FAO Publications, Rome. 107pp.

FAO (2008d). *Climate Change Adaptation and Mitigation in the Food and Agriculture sector:* Technical Background Document from the expert consultation held on 5 - 7 March 2008, Food and Agriculture Organization Rome. 17pp.

FAO (2010). *The State of Food Insecurity in the World: Addressing Food Insecurity in Protracted Crises*. Food and Agriculture Organization, Rome. 62pp.

FAO (2012). *The State of Food Insecurity in the World: Economic Growth is Necessary but not Sufficient to Accelerate Reduction of Hunger and Malnutrition*. Food and Agriculture Organization, Rome. 65pp.

Franz, W. E. (1997). *The Development of an International Agenda for Climate Change: Connecting Science to Policy*. In: Climate Change. Harvard University, Harvard. 34pp.

Gregory, P. J. (2004). Agronomic approaches to increasing water use efficiency. In *Water Use Efficiency in Plant Biology* (Edited by. Bacon, M. A.), Blackwell Publishing, Oxford. pp. 142 – 170.

Gregory, P. J., Ingram, J. S. I. and Brklacich, M. (2005). Climate change and food security. *Biological Sciences Journal* 360: 2139 – 2148.

Gyampoh, B. A., Amisah, S. and Idinoba, M. (2008). Coping with Climate Change: *How Local Communities use Traditional Knowledge in Rural Ghana. Adaptation of Forest and Forest Management to Changing Climate with Emphasis on Forest Health. In: A Review of Science, Policies and Practices Worksho*p. 25 – 28 August 2008, Umea, Sweden. pp. 70 - 75.

Hatibu, N., Mutabazi, K., Senkondo, E.M. and Msangi, A.S.K. (2006). Economics of rainwater harvest for crop enterprises in low land areas of East Africa. *Journal of Agricultural Water Management* 80: 74 – 86.

Hanke, J. E. and Wichern, D. W. (2009). *Business Forecasting*. (9th Edition.), Pearson International, London. 512pp.

Heltberg, R. (2007). Helping South Asia cope better with national disasters: The role of social protection. *Development Policy Review* 25(6): 681 – 698.

Heltberg, R., Jorgensen, S. L. and Siegel, P. B. (2008). *Climate Change, Human Vulnerability and Social Risk Management.* Social dimensions of climate change, social development department. The World Bank, Washington, DC, USA. 56pp.

Hoppe, R. (2002). Structural and financial characteristics of US. Farms. [http://www.ers.usda.gov] site visited on 13/05/2009.

Horton, S., Shekar, M., McDonald, C., Mahal, A. and Brooks, J. K. (2009). *Scaling Up Nutrition: What Will It Cost?* The World Bank, Washington DC, USA. 136pp.

IFAD (2008). *Climate Change: Action Plan Secretariat Report*. IFAD Publications, Rome. 11pp.

IFPRI (2007). *Micro-Level Analysis of Farmers Adaptation to Climate Change in Southern Africa.* Discussion Paper No. 00714. International Food Research Institute, Washington, DC, USA. 40pp.

Ingram, J. S. I., Gregory, P. J. and Brklacich, M. (Eds.) (2005). *GECAFS Science Plan and Implementation Strategy*. ESSP Report No. 2. Centre for Ecology and Hydrology (CEH), Wallingford. 36pp.

International START (2006). Climate change induced vulnerability to malaria and cholera in the Lake Victoria Region. The International START Secretariat. [http://www.aiaccproject.org] site visited on 18/5/2011.

IPCC (2001). Climate change 2001: Impacts, adaptation and vulnerability. Contribution of working group II to the third assessment report of the Intergovernmental Panel on Climate Change, Geneva: UNEP/WMO. [www.grida.no/climate/ipcctar/w82/ 642.htm] site visited on 15/7/2012.

Parry, M. L., Canziani, O. F., Palutikof, J. P., Van der Linden, P. J. and Hanson, C. E. (Eds.) (2007). *Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge. 976pp.

Juliana, A. (2007). *Report on Climate Change Related, Vulnerability, Resilience and Adaptation in Tanzania*. Tanzania Meteorological Agency, Dar es Salaam, Tanzania. 39pp.

Justus, J. R. and Fletcher, S. R. (2006). Global climate change: Major scientific and policy issues: [http://www.mnp.nl/crs/clobal_org] site visited on 25/11/2011.

Kandinkar, M. and Risbery, J. (2000). Agricultural impacts of climate change. If adaptation is the answer, what is the question? *Journal of Climate change* 45: 529 – 539.

Kashuliza, A. K., Tarimo, A. J. P. and Ashimogo, G. C. (2002). The challenges of research in improving agricultural productivity in Tanzania. In: *Proceedings of the 2nd University-wide Scientific Conference,* Held in Morogoro, 9 – 10 May, 2002. pp. 11 – 28.

Keenja, C. (2001). *Food Security in Tanzania:* The way forward. Paper presented in the 8th Sokoine Memorial Lecture Series, 11 April 2001, Morogoro, Tanzania. 75pp.

Khashei, M., Bijari, M. and Ardali, G. A. R. (2009). Improvement of auto-regressive integrated moving average using Fuzzy Logic and Artificial Neural Network. *Journal of Neurocomputing* 72: 956 - 967.

Kitchin, R. and Tate, N. J. (2000). *Conducting Research into Human Geography: Theory, Methodology and Practice*. Prentice-Hall, Harlow. 289pp.

Kurukulasuriya, P. and Rosenthal, S. (2003). Climate change and agriculture: A review of impacts and adaptations. Climate change series, No. 91. Yale University. Washington DC, USA. 106pp.

Kurukulasuriya, P. (2006). Will Africa agriculture survive climate change? *World Bank Economic Review* 20(3): 367 – 388.

Kurukulasuriya, P. and Mendelsohn, R. (2006). Endogenous Irrigation: Impact of climate change on farmers in Africa. CEEPA Report No. 18. CEEPA Publications, Pretoria. 27pp.

Low, P. S. (2005). *Climate Change and Africa*. Cambridge University, New York. 283pp.

Lyimo- Macha, J. G., Batamuzi, E. K., Tarimo, A. J. P. and Malimbwi, R. E. (2005). Farmer forums for improved food security: Experiences from TARP II SUA project. *Journal of Continuing Education and Extension* 2(1): 17 – 30.

Maddison, D. (2006). *The Perception of an Adaptation to Climate Change in Africa. Report.* Discussion Paper No. 10. CEEPA Publications, Pretoria. 47pp.

Majule, A. E., Mbonile, M. J. and Campbell, D. J. (2004). Ecological gradients as a framework for analysis of land use change**.** Michigan State University. [www.lucideastrafrica.org] site visited on 5/12/2011.

Massawe, S. (2007). Assessment of food market structures and their implication to house hold food security in Rufiji District. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 107pp.

Maxwell, S. and Frankenberger, T. (1992). Household food security: Concepts, indicators and measurements. [www.ifad.org] site visited on 18/01/2012.

Mendelsohn, R. (1999). Efficient adaptation to climate change. *Climatic Change* 45: 583 - 600.

Mendelsohn, R., Morrison, W., Schlesinger, M. and Andronova, N. (2000). Country-specific market impacts on climate change. *Climatic Change* 45(3): 553-569.

McCullagh, P. and Nelder, J. A. (1989). *Generalized Linear Models*. (2nd Ed.), Chapman Hall, London. 532pp.

McFadden, D. (1974). Conditional Logit Analysis of Qualitative Choice Behavior. In: *Frontiers in Economics*. (Edited by Zarembka, P.). Academic Press. New York. pp. 105 – 142.

MAFS (2005). Agriculture Statistics for Food Security. [www.minirank.com.summary/ www.agriculture. go.tz] site visited on 6/8/2011.

Morton, J. F. (2007). The impact of climate change in smallholder and subsistence Agriculture. [http://www.pnas.org] site visited on 20/6/2011.

Munishi, P. K. T., Ntikha, O. A., Muyungi, R., Muheto, R. and Andrew, S. M. (2006). Current vulnerability and adaptation to potential increase in climatic hazards and associated risks for selected sectors in Tanzania. In: *Scientific Conference on Environmental Sustainability in Tanzania.* (Edited by Munishi, P. T. K. *et al*.), 23 – 26 January 2006, Moshi, Tanzania. pp. 2 – 15.

Myaka, F. A., Chibunda, R. T., Kidunda, R. S. and Rwamugira, W. (2003). Factors limiting crops and livestock productivity and their effect on household food security: *Research on Production, Processing, Marketing and Utilization.* (Edited by Batamuzi, E. K. and Tarimo, A. J. P.). TARP II – SUA, Morogoro, Tanzania. pp. 1 – 12.

Nagelkerke, N. J. D. (1991). A note on the general definition of the coefficient of determination. *Biometrika* 78(3): 691-692.

Ngaira, J. K. (2007). Impact of climate change on agriculture in Africa by 2030. *Scientific Research and Essays* 2(7): 238 – 243.

Nkomo, J. C., Nyong, A. O. and Kulindwa, K. (2006). The impact of climate change in Africa: The stern review on the economics of climate change. [http://www.scidev.net/dossiers/index.cfm?fuseaction=dossierReaditem&type=1item id=2129&language=17dossoer=4] site visited on 16/09/2011.

Norusis, M. (2004). *SPSS 13.0 Advanced Statistical Procedures Companion*. Prentice Hall, New Jersey. 631pp.

Nyong, A., Adesina, F. and Osman, B. E. (2007). Mitigation and adaptation strategies for global climate change: The value of indigenous knowledge in climate change. *Global Climate Change* 12(5): 778 – 797.

Olmos, S. (2001). *Vulnerability and Adaptation to Climate Change:* Concepts, issues, assessment methods. Climate Change Knowledge Network Foundation Paper. Oslo. 21pp.

Orindi, V. A. and Murray, L. A. (Eds.) (2005). *Adaptation to Climate Change in East Africa: A Strategic Approach.* Gatekeeper Series No. 117. National Academic Press, Washington DC, USA. 12pp.

Pender, J., Nkonya, E., Jagger, P., Sserunkuuma, D. and Ssali, H. (2004). Strategies to increase agricultural productivity and reduce land degradation: Evidence from Uganda. *Agricultural Economics* 31: 181–195.

Prabhakar, S. R. K. and Shaw, R. (2008). Climate change adaptation implications for drought risk mitigation: A perspective for India. *Journal of Climatic Change* 88: 113 – 130.

Reilly, J., Neil, H. and Sally, K. (2001). *The Potential Consequences of Climate Variability and Change for the United States and Agriculture*. Cambridge University Press, New York. 136pp.

Rutatora, D. F. and Rwenyagira, B. W. (2005). Agricultural extension reform in Tanzania: Vision and guiding principles: *Journal of Continuing education and Extension* 2(1): 1 – 16.

Rutatora, D. F., Tarimo, A. J. P., Matee, A. Z. and Mtengeti, E. (Eds.) (2004). Prospective and approaches for sustainable rural development in Africa at Sokoine University of Agriculture. *Proceeding of The International Conference,* Morogoro, Tanzania. 18 – 20 February 2004. 405pp.

Saris, A., Savastano, S. and Christiaensen, L. (2006). The role of agriculture in reducing poverty in Tanzania: *A household perspective from rural Kilimanjaro and Ruvuma. Paper Presented in CSAE Conference*, 21 – 26 March 2006, CTD/FAO, Rome. 17pp.

SAS Institute (1985). *SAS User's Guide: Statistics, Version 5 Edition*. SAS institute Inc., North Caroline. 956pp.

Schipper, E. (2006). Conceptual history of adaptation to climate change under the UNFCCC. *Review of European Community and International Environmental Law* 15(1): 82 – 92.

Schmidhuber, J. and Tubiello, F. N. (2007). Global food security under climate change. The National Academy of Sciences of the United States of America. [http://www.pnas.org] site visited on 22/11/2011.

Secretariat of the United Nations, (2008). *Climate Change and Disaster Risk Reduction.* ISDR Briefing Note. UN/ISDR, Geneva. 12pp.

Seo, S. N. and Mendelsohn, R. (2006). *Climate Change Adaptation in Africa*: A Microeconomic Analysis of Livestock Choice Report No. 19. CEEPA Publications, Pretoria. 29pp.

Shah, M. M., Fischer, G. and Van Velthuizen, H. (2008). Food security and sustainable Agriculture. The challenges of climate change in Sub-Saharan Africa. *Workshop on Commission on Sustainable Development No. 16 Review Session. International Institute for Applied Systems Analysis*. New York. 40pp.

Shalli, M. S. (2003). The contribution of agroforestry against rural household food insecurity in Kibaha District, Coast Region. Tanzania. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 98pp.

Shauri, T. (2010). Profitability and risk reduction efficacy of adaptation strategies under climate variability in dry land farming system in Same District, Tanzania. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 95pp.

Srinivasan, A. (2005). *Adaptation to Climate Change: A critical challenge for Asian Development.* Mainstreaming adaptation to climate in developmental policy of National and Local Levels in Asia. IHDP Press. Jakarta. 419pp.

SUA (2006). *Research Agenda for 2005 – 2010.* Sokoine University of Agriculture, Morogoro, Tanzania. 25pp.

Swai, B. S., Mwakifwamba, M., Munishi, P. K. T. and Ntikha O. A. (2004). *A Review of Past Assessments Studies Strategies and Action Plans on Climate Change in the Forestry and Land Use, Wetland, Agriculture and Livestock, and Wildlife Sectors.* Department of Environment, Vice President's Office Dar es Salaam, Tanzania. 49pp.

Tubiello, F. N. and Fischer, G. (2007). Reducing climate change impacts on agriculture: global and regional effects of mitigation. *Technological Forecasting and Social Change* 74: 1030 – 1056.

UNDP (2007). *Human Development Report 2007/2008, Fighting Climate Change: Human Solidarity in a Divided World*. Palgrave Macmillan, New York. 398pp.

URT (2000). *Poverty Reduction Strategy Paper.* Vice President's Office, Dar es Salaam, Tanzania. 49pp.

URT (2002a). *Tabora Region Socio-economic Profile.* National Bureau of Statistics. Dar es Salaam, Tanzania. 297pp.

URT (2002b). *Tanzania Mainland, Basic Data Agriculture Sector 1994/1995 – 2000/2001*. Ministry of Agriculture and Food Security, Statistical Unit, Dar es Salaam. 72pp.

URT (2003a). *Government Statement on Recent Macroeconomic Developments.* Presidents Office Planning and Privatization, Dar es Salaam, Tanzania. 14pp.

URT (2003b). *Tanzania Census 2012: Population and Housing Census General Report*. Government printer, Dar es Salaam, Tanzania. 203pp.

URT (2005). *National Strategy for Growth and Reduction of Poverty (NSGRP).* Government Printer, Dar es Salaam, Tanzania. 38pp.

URT (2006). *National Sample Census of Agriculture 2002/2003, Smallholder Agriculture, Volume II: Crop Sector-National Report*. Government Printer, Dar es Salaam, Tanzania. 108pp.

URT (2008a). Meteorology for Sustainable Development. Government Printer, Dar es Salaam, Tanzania. 17pp.

URT (2008b). *Micro - economic Policy Framework for the Plan/Budget 2008/2009 – 2010/2011*. Government Printer, Dar es Salaam, Tanzania. 57pp.

URT (2009). *Poverty and Human Development Report 2009.* Government Printer, Dar es Salaam, Tanzania. 190pp.

URT (2012). *The Budget Speech by the Minister of Finance to the Parliament at the 2012/2013 Fiscal Year Budget at the Parliament venue in Dodoma*. Government Printer, Dar es Salaam. 108pp.

URT (2013). *Tanzania Census 2012: Population and Housing Census General Report*. Government printer, Dar es Salaam, Tanzania. 574pp.

Valenzuela, O., Rojas, F., Guillen, A., Herrera, L. J., Pomares, H., Marquez, L. and Pasadas, M. (2008). Soft computing technique and ARMA Model for time series prediction, *Journal of Neurocomputing* 71: 519 - 537.

Von Braun, J., Sheeran, J. and Ngongi, N. (2008). *Responding to the Global Food Crisis: Three perspectives. Global Food Prices*. High Food Prices: The What, Who, and How of Proposed Policy Actions. IFPRI Policy Brief. IFPRI Publications, Washington DC, USA. 32pp.

WMUU, (2007). *Hali ya Uchumi wa Taifa katika Mwaka 2006.* Wizara ya Mipango, Uchumi na Uwezeshaji, Mpiga chapa mkuu, Dar es Salaam, Tanzania. 13pp.

WHO (2009). Trade, foreign policy, diplomacy and health: Food security. [http:/ /www. who.int/trade/glossary/story028/en] site visited on 12/8/2012.

Yanda, P, Z., Kangalawe, R. Y. M. and Sigalla, R. (2006). Climatic and Socio-economic Influences on Malaria and Cholera Risks in Lake Victoria Region of Tanzania [www.aiaccproject.org/working_papers/working%20papers/AIACC.WP43Yan dapdf] site visited on 22/6/2011.

APPENDICES

Appendix 1: Household interview schedule

A: Household characteristics

1. Date of interview ……………………………….
2. Name of village ………………………………….
3. Name of hamlet ………………………………….
4. Respondent number …………………………….
5. Sex of respondent Male ❒ Female ❒

6. Age of respondent **…………………………………..**

7. Marital status of respondent Single ❒ Married ❒ Divorced ❒ Widow ❒

8. Relationship of respondent with household head

Household head ❒ Husband ❒ Wife ❒ Child ❒ Relative ❒

9. Level of education of respondent

Primary ❒ Secondary ❒ Higher education ❒ others specify ………………………..

10. Household size **…………………………...…………**

B: Socio-economic activities

11. What is the major economic activity of the household?

Agriculture ❒ Livestock keeping ❒ others specify ……………………………

12. Production trends of major crops grown by the household in the past three seasons

No	Crop	2007/2008		2008/2009		2009/2010	
		Area (ha)	Yields (bags)	Area (ha)	Yields (bags)	Area (ha)	Yields (bags)
1.	Maize						
2.	Paddy						
3.	Sorghum						
4.	Cassava						
5.	S. potatoes						
6.	Tobacco		(Kgs)				
7.	Sunflower						
8.	Groundnuts						
9.	Others ....…						

13. Please indicate the number of Livestock owned by the household

TYPE	Cattle	Sheep	Goats	Pigs	Donkeys	Chickens	Others
NUMBER							

C: Awareness about effects of climate change and variability

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

15. Have the changes in climate and variability affected you in anyway? Yes ❒ No ❒

16. If yes, for the following which one has affected you?

Drought: [ ]	Floods: [ ]	others (specify) …………..

D: Coping strategies employed

17. During food insecurity do you adopt the following short term coping strategies?

No	Strategy	Specify
1	**Dietary Change Coping Strategies**	
	Rely on less preferred and less expensive foods?	Yes ❒ No ❒
2	**Increase Short -Term Household Food Availability**	
	Borrow food, or rely on help from a friend or relative	Yes ❒ No ❒
	Purchase food on credit?	Yes ❒ No ❒
	Gather wild food, hunt, or harvest immature crops?	Yes ❒ No ❒
	Consume seed stock held for next season?	Yes ❒ No ❒
	Sale of assets to gain income for buying food?	Yes ❒ No ❒
3	**Decrease Numbers of People**	
	Send children to eat with neighbours?	Yes ❒ No ❒
	Send household members to beg?	Yes ❒ No ❒
4.	**Rationing Strategies**	
	Limit portion size at mealtimes?	Yes ❒ No ❒
	Restrict consumption by adults in order for small children to eat?	Yes ❒ No ❒
	Feed working members of HH at the expense of non-working members?	Yes ❒ No ❒
	Ration the money you have and buy prepared food?	Yes ❒ No ❒
	Reduce number of meals eaten in a day?	Yes ❒ No ❒
	Skip entire days without eating?	Yes ❒ No ❒
5.	**In case of total failure of coping strategy**	
	Total dependence on external food aid?	Yes ❒ No ❒
6	Other (Specify)	

18. Have you changed any of your farming practices in order to adjust to the changes in climate and variability? Yes ❒ No ❒

19. Please mention the strategies you use in your crop production to cope with climate change and variability during the rain seasons (tick where appropriate)

[*Try to observe by yourself the practices in the field*]

Practices changed/used	
a) Crop rotation	Yes ❒ No ❒
b) Rain water harvesting (in situ)	Yes ❒ No ❒
c) Timing of farm operations	Yes ❒ No ❒
d) Planting drought tolerant varieties	Yes ❒ No ❒
e) Planting early maturing varieties	Yes ❒ No ❒
f) Planting high yielding varieties	Yes ❒ No ❒
g) Reduce the size or number of farms to cultivate	Yes ❒ No ❒
h) Use of manure (organic or inorganic)	Yes ❒ No ❒
i) Not cultivating in the given season	Yes ❒ No ❒
j) Use of cover crops	Yes ❒ No ❒
k) Mulching?	Yes ❒ No ❒
l) Others *(specify)*	Yes ❒ No ❒
Long term investment in land	
m) Irrigation schemes	Yes ❒ No ❒
n) Small scale irrigation	Yes ❒ No ❒
o) Manual irrigation	Yes ❒ No ❒
p) Tie ridges	Yes ❒ No ❒
q) Sunken beds	Yes ❒ No ❒
r) Mulching	Yes ❒ No ❒
s) Agro-forestry	Yes ❒ No ❒
t) Others *(specify)*	

20. Please mention other strategies/activities that you used for the past 12 months (the year 2010) as an alternative or a supplement to food production to cope with food insecurity? [*Use numbers by the order of use from 1, 2…]*

No	Other activity	Specify
1	Small/petty business (i.e kiosk, mama ntilie, machinga etc)	
2	Cash crops (such as tobacco, sunflower etc)	
3	Sell of labour (in any sector/sub-sector, but it is a day work)	
4	Migration (to urban, to other village etc, permanently or temporarily)	
5	Remittances (from family member, friends, non-family member etc)	
6	Seek for loan/credit assistance	
7	Sell of household assets (house, land, livestock, crops etc)	
8	Food aid (from government, NGOs, relatives etc)	
9	Salary/wage (for those who have employment)	
10	Reducing household food consumption (i.e. reduce number of meal per day)	
11	Others (Specify)	

E: Contribution of other strategies/activities to food security

21. From the above mentioned strategies, what are the incomes obtained in monetary terms from the first five strategies in the family last year?

No	Activity	Output/return in Tshs.
1		
2		
3		
4		
5		
Total		

22. Among the coping and adaptation strategies mentioned in part **D** above mention any three which have been most effective to ensure your household food security?

1 ……………………………………………………………….

2 ……………………………………………………………….

3 ………………………………………………………………..

F: Assets

23. Please indicate the type of assets owned by the household

NO	Type of asset	Number	Monetary value
1	Houses		
2	Car/tractor		
3	Motorbike		
4	Bicycle		
5	TV		
6	Radio		
7	Land/plot		
8	Oxen cart		
9	Sewing machine		
10	Furniture: Chair ……… Table ………. Bed …...……. Others ………		
11	Power tiller		
12	Ox plough		
13	Hand hoe/bush knife		

24. What is the type of main house owned by the family?

brick/stone and iron roofed ❒

brick/stone and grass roofed ❒

brick/stone and mud roofed ❒

wood, mud and iron roofed ❒

wood, mud and grass roofed ❒

wood, mud and mud roofed ❒

Thank you very much!!

Appendix 2: Checklist for secondary data collection

1. Data of Maize yield in Sikonge District for the period from 1980 – 2011.
2. Data of area under maize cultivation in Sikonge District for the period of 1980 – 2011.
3. Data of average annual rainfall in Sikonge District for the period from 1980 – 2011.
4. Data of rainy days in Sikonge District for the period of 1980 – 2011.
5. Last season’s price of the major food crops in Sikonge District.

Appendix 3: Maize production and Rainfall in Sikonge district from 1980 to 2010

Year	Annual rainfall (mm)	Annual rain days (days)	Production area (Ha)	Production (Tons)	Production (T/Ha) in %
1980	940.8	54	7349	13 904	189
1981	872.3	45	7623	6514	85
1982	928.4	77	7187	10 901	152
1983	610.7	49	7363	5321	72
1984	989.9	83	9015	7582	84
1985	983	74	8445	7769	92
1986	1311.8	90	12 670	24 429	193
1987	904.6	67	8416	7244	86
1988	1040.6	71	10 359	17 839	172
1989	753	54	10 104	12 349	122
1990	738.5	43	8980	9315	104
1991	626.8	31	8483	6908	81
1992	887.6	46	7466	7175	96
1993	432.5	19	6263	3629	58
1994	471.2	20	6465	3751	58
1995	740	41	13 088	16 338	125
1996	1397	93	7062	11 113	157
1997	537.2	22	6737	5 420	80
1998	1230.1	87	9144	16 554	181
1999	364.3	28	6881	2976	43
2000	721.5	38	6878	5021	73
2001	680.5	37	5903	4861	82
2002	370.9	25	15 811	6440	41
2003	444.1	40	22 960	15 977	70
2004	718.7	35	14 900	17 080	115
2005	203.4	18	15 800	5840	37
2006	1129.2	85	10,160	14 176	140
2007	653.1	30	15 170	8759	58
2008	827.2	44	24 020	28 918	120
2009	685	40	15 690	11 362	72
2010	714	42	15 280	15 810	103

Source: Tanzania Meteorological Agency and Ministry of Agriculture, Co operative and Food security (December 2011)

Appendix 4: Average monthly rainfall for ten years

Decade	1980 – 1990		1991 - 2000		2001 – 2010	
Monthly	Rainfall (mm)	Rain days	Rainfall (mm)	Rain days	Rainfall (mm)	Rain days
January	154	12	162	9	164	11
February	121	10	170	8	216	11
March	143	11	177	9	222	11
April	124	8	133	8	66	6
May	29	2	59	4	13	1
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	1	0	0	0	2	0
September	3	0	0	0	8	2
October	38	4	11	3	27	4
November	118	8	126	8	122	10
December	218	15	305	16	216	10
Total	**948**	**71**	**1144**	**64**	**1054**	**66**

Source: Tanzania Meteorological Agency