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PERCEPTIONS OF CLIMATE CHANGE, ENVIRONMENTAL VARIABILITY AND THE ROLE OF AGRICULTURAL ADAPTATION STRATEGIES BY SMALL-SCALE FARMERS IN AFRICA: THE CASE OF MWANGA DISTRICT IN NORTHERN TANZANIA

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Abstract

The potential impacts of climate change and environmental variability are already evident in most parts of the world, which is witnessing increasing temperature rates and prolonged flood or drought conditions that affect agriculture activities and nature-dependent livelihoods. This study was conducted in Mwanga District in the Kilimanjaro region of Tanzania to assess the nature and impacts of climate change and environmental variability on agriculture-dependent livelihoods and the adaptation strategies adopted by small-scale rural farmers. To attain its objective, the study employed a mixed methods approach in which both qualitative and quantitative techniques were used.

The study shows that farmers are highly aware of their local environment and are conscious of the ways environmental changes affect their livelihoods. Farmers perceived that changes in climatic variables such as rainfall and temperature had occurred in their area over the period of three decades, and associated these changes with climate change and environmental variability. Farmers' perceptions were confirmed by the evidence from rainfall and temperature data obtained from local and national weather stations, which showed that temperature and rainfall in the study area had become more variable over the past three decades. Farmers' knowledge and perceptions of climate change vary depending on the location, age and gender of the respondents. The findings show that the farmers have limited understanding of the causes of climatic conditions and environmental variability, as some respondents associated climate change and environmental variability with social, cultural and religious factors.

This study suggests that, despite the changing climatic conditions and environmental variability, farmers have developed and implemented a number of agriculture adaptation strategies that enable them to reduce their vulnerability to the changing conditions. The findings show that agriculture adaptation strategies employ both planned and autonomous adaptation strategies. However, the study shows that increasing drought conditions, rainfall variability, declining soil fertility and use of cheap farming technology are among the challenges that limit effective implementation of agriculture adaptation strategies. This study recommends further research on the varieties of drought-resilient crops, the development of small-scale irrigation schemes to reduce dependence on rain-fed agriculture, and the improvement of crop production in a given plot of land. In respect of the development of adaptation strategies, the study recommends the involvement of the local farmers and consideration of their knowledge and experience in the farming activities as well as the conditions of their local environment. Thus, the findings of this study may be helpful at various levels of decision making with regard to the development of climate change and environmental variability policies and strategies towards reducing farmers' vulnerability to current and expected future changes.

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DECLARATION

I declare that, except where explicit reference is made to the contribution of others, this thesis is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

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Julius W. Mngumi

Glasgow, May 2016

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Dedications

To my family members and fiancée, Esther Mwaisumo, for encouraging me to believe in my dreams!

List of Acronyms and Abbreviations

CAMARTEC	Centre for Agriculture Mechanization and Rural Technologies
CARTAS	Catholic Relief Organisation
DADPS	District Agricultural Development Plans
DALDO	Department of Agriculture and Livestock Development office
DRD	Department of Research and Development
EABL	East African Breweries Limited
EAML	East African Malting Limited
ENSO	El Niño-Southern Oscillation
FAO	Food and Agriculture Organisation of the United Nations
FIDE	Friendship in Development Trust
GHG	Greenhouse Gas
GMO	Genetically Modified Crops
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IPCC	Inter-governmental Panel on Climate Change
MAFSC	Ministry of Agriculture, Food Security and Cooperatives
MSB	Maize Stock Borer
MSU	Maize Streak Virus
NGSR	National Grain Strategic Reservoir
NGO	Non-Governmental Organisation
NMRP	National Maize Research Programme
NSGRP	National Strategy for Growth and Reduction of Poverty
PADEP	Participatory Agricultural Development and Empowerment Project
PPP	Public Private Partnership
SBL	Serengeti Breweries Limited
SMECAO	Same and Mwanga Environmental Conservation Advisory Organisation
TANSEED	Tanzania Seed Company
TMA	Tanzania Meteorological Agency
TIP	Traditional Irrigation Programme
TMV	Tanzania Maize Variety
VPO	Vice Presidents Office
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
URT	United Republic of Tanzania
WEMA	Water Efficient Maize for Africa
WFP	World Food Program

Chapter 1
Introduction

1.1. Climate and climate change

The dynamic interaction between the atmosphere, oceans, cryosphere and the terrestrial and marine biospheres determines the global climate at the Earth's surface (Githeko et al., 2000; Chakraborty et al., 2000). The increasing accumulation of greenhouse gases in the global atmosphere and increasing regional concentrations of aerosol particulates are now understood to have detectable effects on the global climate system (Sivakumar et al., 2005). Scientists believe that changes in the atmospheric composition due to increasing concentrations of greenhouse gases (mainly carbon dioxide, methane and nitrous oxide), changes in land cover and agricultural activities are responsible for warming the earth surface, causing global increases in temperature (IPCC, 2007; Collier et al., 2008; Yanda and Mubaya, 2011; Omambia et al., 2010). Although there are still debates among scholars with regard to whether climate change is induced by anthropogenic activities or is as a result of natural climate variability, the balance of scientific opinion is that changes in the composition of the atmosphere are attributed to human activities that lead to global warming (IPCC, 2001; 2007; 2014). However, the IPCC report (2014) argues that the total anthropogenic GHG emissions have continued to increase from 1970 to 2010, with the highest amount noted between 2000 and 2010. The report further notes that the release of CO_2 into the atmosphere from the burning of fossil fuels and industrial activities contributed about 78% of the total GHG emissions from 1970 to 2010, with a similar increase from the period 2000 to 2010 (IPCC; 2001pp 640; 2007 pp 639). The rising temperatures heat the land mass and the surrounding oceans, causing increases in surface temperatures and changes in precipitation, which are important drivers of global climate change (Collier et al., 2008; Challinor et al., 2007). Whilst the trends and patterns of climate change projections are generally consistent, they are subject to varying degrees of uncertainty due to limitations in measurements and knowledge of the interactivity between earth systems (Challinor et al., 2007; Adger et al., 2003).

According to the IPCC (2007), global temperatures near the earth surface increased by 0.74°C from 1906 to 2005 and are estimated to increase by about 6.4°C on average during the 21st century. Recent evidence and predictions from computer models indicate that climate changes are accelerating and will lead to wide-ranging shifts in climate variables (IPCC, 2007; Chaudhary and Aryal, 2009). The global climatic models (GCMs) project an increase in the global mean temperature of between 1.5 and 5.8°C by the end of 2100, which is attributed to population growth, energy use and land-cover changes. However, the IPCC report (2014) argues that the previous three decades, from 1983 to 2012, are most likely to be the warmest periods of the last 1 400 years in the Northern Hemisphere, whereas the globally average surface temperature data for the land

and sea combined show a warming of 0.85 [0.65 to 1.6]° C over the period from 1880 to 2012. The projected increase in temperature will affect ecosystems and biological behaviour (Chaudhary and Aryal, 2009; IPCC, 2014). Some of the effects that have widely been discussed include snow melting and glacier retreat, drought and desertification, floods, frequent fire, sea level rise, species shifts and heightened diseases increase (IPCC, 2001; 2007; 2014). Specifically, researchers suggest that, with the warming conditions, precipitation patterns are likely to change, with increases up to 20% projected in some parts of the world, although drought conditions will also be exacerbated, particularly in Africa (Rosenzweig et al., 2001; Collier et al., 2008; Hulme et al., 2001). Changes in temperature and precipitation also are projected to influence extreme weather events (floods, drought and storms); affect food production (availability) and prices; water availability and access; nutrition and health status (FAO, 2008; IPCC, 2007; Omambia et al., 2010). Therefore, the socio-economic impacts are likely to be significant and will impact humans through a variety of direct and indirect ways (Heltberg et al., 2009; IPCC, 2007). Generally, the impacts of climate change and climate variability are projected to have enormous and devastating global consequences on the global scale, but the most adverse impacts are predicted to occur in developing countries due to their fewer resources to cope with, and adapt to, the changing conditions, which is due to their geographic location (within vulnerable and fragile environments) and their over-reliance on agriculture, which is a climate-sensitive sector (Stern, 2007; IPCC, 2007; Omambia et al., 2010). The vulnerability to climate change, in turn, will pose multiple threats to economic growth and poverty reduction in Africa (IPCC, 2007; Stern, 2011).

1.2. Climate change in Africa

Africa is the largest tropical landmass, split almost equally by the equator into both hemispheres (Sivakumar et al., 2005). Due to its extensive landmass, stretching from about 35°N to 35°S, climate regimes vary from humid equatorial regimes, arid and semi-arid regimes to sub-tropical Mediterranean-type climates with different degrees of temporal variability in rainfall and temperature (Hulme et al., 2001; Collier et al.; 2008, Haile, 2005). Climate change is expected to make some regions wetter (such as the eastern parts of Africa), while other regions like the southern and northern parts of Africa will get drier and more adversely affected by the changes (Collier et al., 2008; Hulme et al., 2001).

The climate of Africa is influenced and modified by four major global drivers, which are the Inter-Tropical Convergence Zone (ITCZ), the El Niño-Southern Oscillation (ENSO), circulation patterns in the Indian Ocean, and the West African Monsoon, all of which determine the annual seasonality and variability of rainfall and temperature across the African continent (Collier et al., 2008; Rosenzweig et al., 2001; Haile, 2005; Stringer et al., 2009). In addition, the climate of Africa is further significantly modified by the presence of large contrasts in topography and the existence of water bodies such as lakes and rivers across the continent (Semazzi and Sun, 1997, in Sivakumar et al., 2005). Increases in temperature will affect the natural interactions of these diverse drivers, causing droughts, floods, heat waves, wind storms and other extreme weather events within the climates of Africa (Collier et al., 2008; Nordhaus, 2007). For instance, increased fluctuations and variability in rainfall in many parts of Africa, including the Sahel region, eastern and southern parts of Africa, have been associated with the changing temperature conditions in ENSO (Haile, 2005; Sivakumar et al., 2005; Plisnier et al., 2000), and the occurrence of the recent drought conditions in equatorial and sub-tropical Eastern Africa from the 1980s to the 2000s is thought to be caused by the increased sea surface temperatures in the southwest part of the Indian Ocean (Funk et al., 2005).

The overall temperature throughout the African continent has increased by approximately 0.7°C during the 20th century, and some general circulation models project an increase in warming across the continent, ranging from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario) (Hulme et al., 2001; Sivakumar et al., 2005; IPCC, 2007). The warming rate in the 20th century was at the rate of ~0.05°C per decade (IPCC, 2007). While future changes in mean seasonal rainfall in Africa are less well-defined (Sivakumar et al., 2005), researchers such as Hulme et al. (2001) and Henson (2011) suggest that warming conditions will result in rainfall increases around the equatorial region of East Africa. Rainfall in the wet season may increase between 5 to 20%, although drought conditions may also be exacerbated by 5 to 10% in the dry seasons. Henson (2011) points out that too much rain at once can cause disastrous floods, while too little can make an area unproductive or even uninhabitable (Henson, 2011: 65). Although warming trends on the African continent seem to be the same, climate change on a large continent like Africa will not always be uniform; rather, different areas will experience different climate change impacts over time and space. For instance, some areas will get wetter and others will become drier, hence varied responses to the impacts between individuals, households, classes, businesses, states, and ecosystems in different places on the continent (Rosenzweig et al., 2001; Thornton et al., 2010; IPCC, 2007; Yanda and Mubaya, 2011).

However, there is general agreement on the proposition that most African countries are vulnerable to the effect of climate change and climate variability due to their dependence on rain-fed agriculture and natural resources, which constitute a large part of local livelihoods (IPCC, 2001; 2007). According to the IPCC report, agriculture contributes about 70% of the GDP of some African economies (IPCC, 2007). However, climate change and climate variability are projected to reduce yield from rain-fed agriculture by up to 50% by 2020 for some of the countries in Africa. More agricultural losses are expected to occur in areas such as the Sahel, East Africa and Southern Africa, coupled with changes in the length of growing period, flooding and drought. Also, projections suggest that between 75 and 250 million people in Africa will experience increased water problems by 2020 as a result of climate change, which will lead to increased water demand

and the exacerbation of water-related problems (IPCC, 2007). Furthermore, limited resources exacerbate the vulnerability of the less-developed countries to the impacts of climate change and variability. Poverty, which is linked to a higher dependence on natural resources, also constrains most of the community's adaptive options in less-developed countries (Omambia et al., 2010). Developing countries, especially in Africa, possess many coping and adaptation strategies in order to manage a range of issues including climate extremes (e.g., drought and floods). However, under possible increases of such stresses, most of these strategies are likely to be insufficient to adapt to climate variability and change, given the problems of endemic poverty, poor institutional arrangement, poor access to information and growing health burdens (IPCC, 2007). This study therefore seeks to understand rural farmers' knowledge of climate change and climate variability and their adaptation strategies, as well as the limitations encountered in the adaptation processes.

1.3. The research problem

The anticipated changes in climatic conditions and the associated significant impacts on many agricultural systems suggest a broad and pressing need for adaptation. For farming households, the nature of these responses will depend on their recognition and perception that the climate is changing, and their ability to adjust their behaviour in response, perhaps through altering farm management practices or diversifying into other income-generating activities. In Tanzania, agriculture studies commissioned by the government have identified climate change risks and noted needs and opportunities for planned adaptations (URT, 2007; 2012). However, this does not mean that local farmers' perceptions and their need to adapt to the changing environmental conditions actually correspond with the government's plans.

While adaptation is often considered a government policy response in agriculture, it also involves decision making by agro-business and producers at the farm level. Hence, adaptations in agriculture vary with respect to the climatic stimuli to which adjustments are made (i.e. various attributes of climate change, including variability and extreme events) and according to the different farm types and locations, and the economic, political and institutional circumstances under which the climatic stimuli are experienced and management decisions are made.

Many potential agricultural adaptation options have been suggested, representing measures or practices that might be adopted to alleviate the likely adverse impacts. They encompass a wide range of forms (technical, financial, managerial), scales (global, regional, local) and participants (governments, industries, farmers). Their applications have been influenced by phenomena of interest (biological, economic, social, etc.) and by time scale (instantaneous, month, years, centuries) (Smit and Wandel, 2006). Most of these strategies represent only potential adaptation measures, rather than ones actually adopted. Climate change impact analyses often assume certain adaptations, although the adaptation process itself remains unclear. There is a need to understand what types and forms of adaptation are possible, feasible and likely; who would be involved in their implementation; and what is required to facilitate or encourage their development or adoption. Hence, understanding farmers' knowledge and perceptions of the impacts of climate change may stimulate adaptation initiatives and incorporate information and insights from the stakeholders who make decisions in the agriculture sector, and from producer organisations, farm groups and government agencies. In order to understand the possible adaptation measures capable of reducing vulnerability to the impacts of climate change and improving agriculture-dependent livelihoods, more realistic adaptation strategies will help in reducing vulnerability to climate change. However, vulnerability to climate change and the potential for agricultural systems to adapt to climate change in Mwanga District in the Kilimanjaro region is at once both promising and poorly understood. This study investigates the nature and impacts of climate change as perceived by poor rural farmers, and assesses different adaptation strategies and constraints facing their agriculture in adapting to climate change.

1.3.1. The purpose of the study

The purpose of this study was to investigate farmers' perceptions of agriculture adaptation strategies and the constraints on them in relation to climate change.

Specifically, the study sought to:

- Assess the nature, impacts and risks of climate change in relation to agriculture, based on the knowledge and perceptions of the rural farmers of the physical impacts of climate change. The key question here relates to the knowledge and perceptions of the households of the impacts of climate change and climate variability on agriculture activities.

- Assess different types of local indigenous farming knowledge and practices in agriculture, and their success, under current environmental changes.

- Assess potential adaptation options for the increasing resilience of the agriculture sector in the light of current and projected future impacts of climate change. The study sought to understand the role of various interest groups (district, ward and village authorities) in decision making as key to climate change adaptation, and the extent to which the decisions influence the on-going efforts towards reducing the communities' vulnerability to the impacts of climate change, and hence attaining sustainable development.

- Examine the perceived barriers and challenges facing agriculture adaptation to climate change. Agricultural adaptation to climate change is a complex phenomenon that faces challenges from complex natural (fragile) and social systems.

The key research questions therefore were:

- How do farmers perceive climate change?
- What is the role of local farming knowledge in climate change and adaptation?
- What are the adaptation strategies to climate change?
- What are the limitations faced by agriculture in adapting to climate change?

1.4. The research approach: vulnerability framework

This study used a vulnerability framework approach to examine the knowledge and perspectives of farmers on the concept of climate change and its impacts on agriculture. According to Willows et al. (2003), vulnerability refers to the magnitude of harm that would result from a particular hazardous event. The concept recognises, for example, that different sub-types of a receptor may differ in their sensitivity to a particular level of hazard. Therefore climate vulnerability defines the extent to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. It depends not only on a system’s sensitivity but also on its adaptive capacity. Hence arctic alpine flora or the elderly may be more vulnerable to climate change than other components of our flora or population.

This study used the vulnerability framework as developed by Turner et al. (2003). The framework assesses the vulnerability of marginalised local communities to the effect of external shocks and stresses. The vulnerability framework systems, according to Turner et al. (2003), are divided into three major components (Figure 1.1). The first component is exposure, which assesses the extent to which individuals, households, classes, businesses, states, flora/fauna and ecosystems are affected by the occurrence of hazards. This element considers components such as frequency, magnitude and duration of the exposure to the hazards. The hazards include shocks, such as unexpected occurrence of floods and drought, and stress on the system due to soil degradation, changes and differences in rainfall patterns, etc. The second element is the sensitivity of the system, which considers two major components, which are human and environmental conditions. This element deals with the characteristics of both components on how they contribute to the system’s responses when exposed to hazards. The last element is resilience of a system, which considers the future actions that can improve the ability of the system to cope with outside hazards. This considers coping and adaptation measures implemented in order to reduce farmers’ vulnerability to the hazards. These include government policies and autonomous decisions made by individuals farmers or communities. This study therefore focuses on the impacts of climate change as perceived by local farmers, and the adaptive strategies, ranging from individual households to the government policies and programmes implemented in order to improve agriculture-dependent livelihoods by increasing farmer’s resilience to current and projected future climate change.

This study used the vulnerability framework to assess the extent to which agriculture-dependent farmers are vulnerable to the exposure of the different impacts of climate change and variability in environmental conditions, such as floods, droughts and rainfall variability. It further assessed the effectiveness of different programmes and policies implemented by the central government in increasing farmers' resilience to climate change impacts.

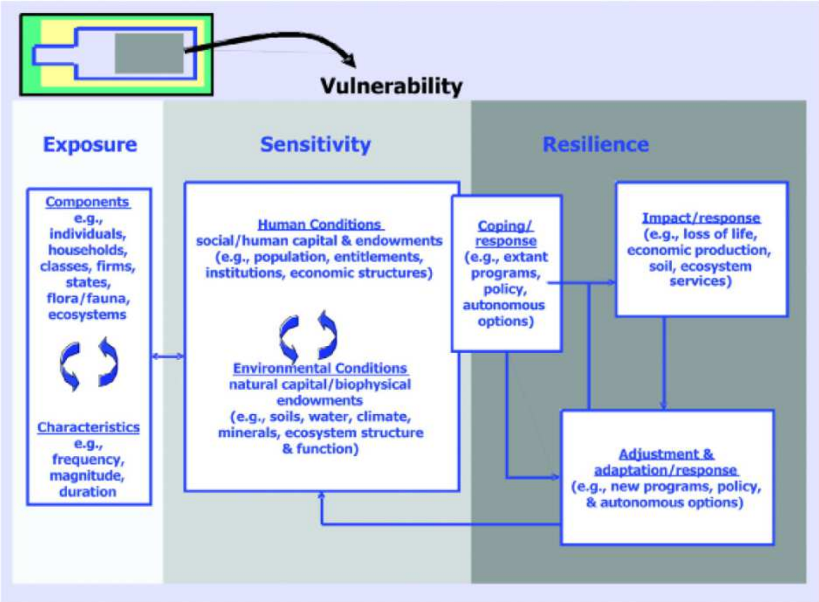


Figure 1.1 Turner et al.'s vulnerability framework

Source: Adopted from Turner et al. (2003)

1.5. Organisation of this thesis

This thesis is organised into eight chapters. Chapter One has shown the basis on which the rest of the thesis was developed. Chapter Two discusses the conceptual framework underpinning climate change and impacts on agriculture. It does this by bringing together the literature surrounding the discussion of climate change and climate variability impacts on agriculture-dependent livelihoods. The first part examines the impacts of climate change and climate variability on agriculture in Africa. The second part of the chapter discusses the concept of agricultural adaptation strategies, with a focus on different adaptation strategies made by different people in various parts of the world. Part three of the chapter deals with the role of indigenous farming knowledge and the debates surrounding the concept of local knowledge in farming activities.

The third chapter of this thesis sets out the methodological underpinning of this research. It discusses the study area and selection of the study site and choice of the methodology employed for data collection and the analysis of the research findings. The last section of the chapter discusses the limitations of the methods and problems encountered during data collection, and how they were handled without affecting the quality of the data collected.

Chapters Four, Five, Six and Seven present the findings of the study. Chapter Four deals with the knowledge and perceptions of the small-scale rural farmers of the concept of climate change and its impacts on agriculture-dependent livelihoods. Chapter Five examines different local and indigenous farming methods in respect of their contributions to farming activities and how they are influenced and modified under the conditions of environmental change. Chapter Six examines different adaptation strategies, with a focus on those that have been adapted by farmers in managing farming activities under changing climatic conditions. Chapter Seven discusses the barriers for agriculture in its adaptation to climate and climate variability. Finally, Chapter Eight presents the conclusions and recommendations drawn from this study, and makes suggestions for future work that can be done to further the debates surrounding the problem under study.

Chapter 2
Literature Review

2.1. Impacts of climate change on agriculture in Africa

Climate change impacts are “the effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts (all impacts that may occur given a projected change in climate, without considering adaptation) and residual impacts (the impacts of climate change that would occur after adaptation” (IPCC, 2007: 876).

The expected changes in climatic conditions will adversely affect farming activities and hence result in reduced agricultural production, particularly food production, hence food insecurity, increased incidence of both flooding and drought, the spread of diseases and increased risk of conflicts over scarce resources such as land and water (Africa Partnership Forum Support, 2007; IPCC, 2014). However, while developed regions of the world are concerned more about abatement strategies (mitigation), Africa is concentrating more on developing coping and adaptation techniques geared towards the likely future climatic conditions, and on mitigating the sources of emission (Downing et al., 1997). This is the case because many of the developed regions of the world expect the consequences of climate change to occur far into the future, while Africa is already experiencing the adverse consequences of climate change in the present (Collier et al., 2008).

The wet and dry conditions will have negative impacts on the availability of water resources, food and agriculture security, human health and biodiversity due to the fact that Africa is ill-equipped with resources that could be used in managing increased precipitation during the wet season, as well as increased drought conditions during the already dry seasons (IPCC 2007; 2014).

Climate change is likely to cause greater environmental and social stress in many parts of Africa already having difficulties in coping with environmental stress (Sivakumar et al., 2005). Overall the continent is reported to have experienced decreased rainfall over the last 60 years, and models suggest that changes in the frequency and intensity of extreme events such as floods may occur when there is only a small change in climate (Sivakumar et al., 2005). However, the IPCC (2007) predicts a decline in precipitation in most of the subtropical regions – some by as much as about 20%, with varied increases in the number of extreme precipitation events. Changes caused by increased frequencies of drought will pose a great risk to agriculture, because many crops will fail to cope with the increasing temperatures and changes in precipitation, posing greater risk to agriculture in Africa, where rain patterns are more variable (Henson, 2011) and climatic conditions are at a marginally productive stage (Sivakumar et al., 2005). Although records indicate that there has been an increase in rainfall, particularly in East Africa, over the last century (Hulme et al., 2001; Collier et al., 2008; Stringer et al., 2009; Cooper et al., 2008; IPCC, 2007), not all places have necessarily experienced similar conditions as predicted by the models. For example, although simulation models suggest that countries in the Sahel and the Horn of Africa may receive more rainfall during the wet seasons and increased dry conditions during the already dry seasons, the Sahel has experienced many multidecadal periods of drought with increases in temperature of up to 1.5°C since the last glaciation (Collier et al., 2008; Rosenzweig et al., 2001; Haile, 2005), causing widespread famine requiring humanitarian food aid (Haile, 2005). Hulme et al. (2001) show that the warming conditions are also expected to cause an increase in the mean sea level along the coastline of Africa, where a rise in sea level of about 25 cm is projected, which will affect the coastal resources and the livelihoods of the dependent populations.

Agriculture in most parts of the world depends directly on climate (Adger et al., 2003), and especially so in Africa. Climate change and variability are threatening agricultural systems, and hence livelihoods, as well as the food security of people in Africa whose lives depend on agriculture (Chandrappa et al., 2011). Agriculture constitutes a large share of the African economies through a mixture of subsistence and commercial production (Sivakumar et al., 2005). However, farmers all over the world, and not just in Africa, are facing challenges in meeting food demands from the growing population under the current climatic conditions, while at the same time promoting sustainable development (Bryan et al., 2011). Climate extremes and variability, evident through increases in the frequency and intensity of droughts, flooding, heat waves and storm damage, will have severe impacts on agriculture and therefore food production, because most food crops are sensitive to the direct effects of higher temperature, decreased precipitation and flooding, as well as being indirectly affected through soil functions, nutrient dynamics and pest attack (Rosenzweig et al., 2001). However, the IPCC (2014) report suggests with higher confidence that there now is a global temperature increase of ~4°C, above the late 20th- century level. Combined with increasing food demand, this will result in more food insecurity globally. Wheat, rice and maize production in the tropical and temperate regions is projected to be negatively impacted by local temperature increases of 2°C or more above late 20th- century levels. According to the U.N. Food and Agriculture Organization (FAO, 2004), the number of African food crises per year has tripled from the 1980s to the 2000s.

2.1.1 Effects on precipitation

According to the World Meteorological Organization (in Henson, 2011) estimated deaths of more than a million people in African Sahel occurred in 1972-1975 and 1984-1985 due to a devastating drought (rainfall was estimated to have declined by about 30% in 1984/1985). The current rainfall data indicate a gradual increase in precipitation in the Sahel region, especially in the years 1994, 1999 and 2003 which received more rainfall than before 1970, while other years have remained dry, occasionally caused by strong El Niño conditions such as in 1997/1998 (Henson, 2011). The reduction of, and variability in, rainfall and increases in temperature will worsen food security in the region, and consequently affect the livelihoods of the majority of subsistence farmers and pastoralists whose lives depend critically on rainfall (Haile, 2005).

In general, an increase in temperature will affect and modify rainfall intensity, evaporation rates, run-off and soil moisture storage (Rosenzweig and Hillel, 1995), which will affect crop yields negatively because many crops in Africa are grown close to their thermal tolerance threshold limits (Henson, 2011; Collier et al., 2008; Rosenzweig and Hillel, 1995). Increased heat and drought will stress crops by limiting transpiration resulting in a rise in plant temperatures which will affect the flowering, pollination and grain-filling of those crops which are most sensitive to water and heat stress conditions. Such crops include wheat, groundnuts, soybean, maize and fruit trees (Collier et al., 2008; Rosenzweig et al., 2001). Indeed, under intensified and prolonged drought conditions some of the regions may become unsuitable for farming activities. This will cause a reduction in farming land and/or a reduced length of growing season, as well stopping the production of some food crops and prompting food shortages (Collier et al., 2008), and search for other alternative food crops. According to Sivakumar et al. (2005), the expected decline in precipitation in Africa will turn sub-humid dry lands into semi-arid, and semi-arid areas into arid. Similarly, Collier et al. (2008) argue that an increase in drought conditions may perhaps make maize production in many parts of southern Africa, groundnuts in Sahel and wheat in northern Africa very difficult or impossible. A study commissioned by the United Nations for the 2002 World Summit on Sustainable Development (in Henson, 2011) evaluated the relationship between winners and losers in agriculture for a mid-range scenario of global emissions increase by 2080. The study revealed that between 42 and 73 countries in the tropics (many in Africa and Asia) could reduce their potential to grow cereal crops to about 5%, and between one and three billion people living in these countries would lose 10 to 20% of their cereal crop. Africa in particular could lose 2 to 9% cent of its agricultural GDP (Henson, 2011).

2.1.2 Effect of increase in temperature

The globally projected temperature increase by 1.4 to 5.8°C over the period 1990 to 2100 (Griggs and Noguer, 2002) will result in large changes in the frequency of extreme events which can have severe impacts on agriculture in Africa (Rosenzweig et al., 2001; Chakraborty et al., 2000). Increases in surface temperatures will increase soil temperatures which will in turn affect plant metabolism through the degradation of plant enzymes, limiting photosynthesis and affecting plant growth and yields (Sivakumar et al., 2005). Increases in soil temperature will increase potential evapotranspiration which may cause damage especially to those crops with surface root systems which utilise mostly precipitation moisture. It may also increase leaf-surface temperatures hence affecting crop metabolism and yields making crops more sensitive to moisture stress conditions. A study conducted by Wijeratne (1996) on the impacts of climate change on the tea industry of Sri

Lanka suggested that tea yield is sensitive to temperature, drought and heavy rainfall, hence an increase in the frequency of droughts and extreme rainfall events could result in a decline in tea yield and could be greatest in the low latitude countries. In addition, a study by Arndt et al. (2012) on the impacts of climate change on crops production in Tanzania, showed that maize yields in the northern part of Tanzania increased substantially during the wet season and decreased by similar amounts in the hot and dry scenarios. Their study suggested further that maize yields were favoured under cool and wet scenarios, hence they projected only a very small increase in yields in those regions under hot and dry scenarios.
The projected increases in temperature, along with increased rainfall variability may affect crop yields especially when fluctuations occur at the different stages of crop development (germination, growing, flowering and ripening/harvesting stages), while a combination of higher precipitation with higher temperature may accelerate crop death (Rosenzweig et al., 2001). For example, as argued by Rosenzweig et al. (2001) and Henson (2011), higher temperatures during the germination stage of above 35°C cause seedling death in soybeans, while saturated soils with temperatures of about 32°C increase the risk of seedling diseases. Temperatures above 30°C for more than eight hours can reverse vernalisation in wheat. At the reproductive stage, air temperatures ranging from 35°C to 36°C or higher can cause maize pollen to lose its viability, affecting post-blooming in soybean, result in groundnuts producing less yield and rice pollen becoming sterile after only an hour of 35°C. Soil temperatures higher than 20°C depress potato bulking while moisture deficit is very detrimental to crop yields in this growth stage, especially for maize. At the mature stage, soil saturation causes long-term problems related to rot and fungal development and increased damage from diseases, while dry conditions increase aflatoxin (fungi-related) concentrations in maize (Rosenzweig et al., 2001). A study by Toukoua (1986, in Van Duivenbooden et al., 2002) in Niger showed that crops are sensitive to increased temperatures and declines in precipitation where the average yields of groundnuts decreased from 850 kg/ha in 1966-1967 to /ha by 1981 mainly due to drought and related disease. Similarly, a study conducted by Kangalawe (2012) in the southern highlands of Tanzania suggested that a higher reliance on weather for agricultural activities has occasionally subjected the country to food shortages and insecurity especially more in years with low rainfall.

Clearly, at all stages of crop development, the occurrence of extreme events (precipitation and temperature), depending on the duration and stage of crop development, will increase plant vulnerability, resulting in crop damage and reduced yields (Collier et al., 2008; Rosenzweig et al., 2001). For example, precipitation is an important determinant factor of crop yields during the growing period, but increased precipitation during the grain-filling period may reduce yields due to continuing plant growth with grain-filling process (Rosenzweig et al., 2001).

The spatial and temporal distribution, and proliferation, of agricultural pests, insects, weeds, fungi and pathogens are influenced by temperature, precipitation, humidity, dew, radiation, wind speed and circulation patterns (Rosenzweig et al., 2001; Collier et al., 2008; Githeko et al., 2000). The pests destroy crops and pathogens, and cause plant diseases which are a significant constraint on agricultural activities and hence food security in Africa (Chakraborty et al., 2000). These organisms do well in warm and humid conditions and estimated increases in average temperatures by 1.0 to 3.5°C by 2100 may favour their growth, survival, development and spread to a wide geographical range (Githeko et al., 2000). Enhanced soil moisture in warm and humid conditions encourages the growth and spread of spores and the proliferation of fungi and bacteria, as well as the spread of nematodes and roundworms that inhabit water pore spaces in soils, while hot and dry conditions favour diseases such as powdery mildews (supported by availability of dew formation at night); potato leaf roll caused by aphid-borne viral; aflatoxin attacking maize; rice attack by blast, blight, sheath and culm; wheat attacked by wheat scab; and spider mites that attack soybean (Collier et al., 2008; Sivakumar et al., 2005; Chakraborty et al., 2000). A more widespread distribution of diseases and pathogens will increase in many parts of the tropical regions of Africa if the climate becomes warmer and wetter (Sivakumar et al., 2005).

Similarly, prolonged drought conditions can change the physiology of host species which may cause changes in the insects that feed on them, and reduce populations of friendly insects (predators or parasitoids) such as spiders, lace wings, lady bugs, bees, butterflies and birds that influence pollination and pest attack (Githeko et al., 2000; Rosenzweig et al., 2001). Also, an increase in drought conditions reduces the resistance of a host-plant to diseases thus increasing the rate of disease attack (Sivakumar et al., 2005). On the other hand, increases in temperature and precipitation may impact on the effectiveness of pesticides used to control pest outbreaks through chemical alteration and dilution of the pesticide, causing increased resistance to pests and diseases. This may result in a greater use or application of agricultural pesticides, hence increasing health risks to farmers, as well as ecological and economic costs, which the majority of the subsistence farmers in Africa will not be able to afford (Collier et al., 2008; Rosenzweig et al., 2001; Chakraborty et al., 2000). The increase and spread of pests, insects and diseases will increase challenges in farming activities in Africa which the majority of subsistence farmers will find difficult to meet.

Changes in climate will also encourage weed growth that will compete with crops for soil nutrients, light, moisture and space. However, drought conditions increase the competition for soil moisture, humid conditions increase the proliferation of weeds, and warmer temperatures favour the maximum increase of biomass of grass weed, resulting in increasing economic burden for small-scale farmers due to increased costs associated with weed control and other farming costs (Rosenzweig et al., 2001).

2.1.3 Effect on livestock

Rising temperatures and declining rainfall will affect livestock in Africa, where two-thirds of domestic livestock are herded through nomadic systems, although significant numbers are also kept under zero-grazing conditions, by reducing the availability of fodder and drinking water, and through increased heat stress. Also, in some areas a significant share of fodder comes from crop residues, hence the declining agriculture will also affect livestock farming in many parts of Africa (Sivakumar et al., 2005). Similarly, increased warm conditions will favour the increased distribution, incidences and intensity of diseases such as rift-valley fever, rinderpest and tick-borne diseases, which will attack livestock and also reduce suitable rangeland area for nomadic livestock herding (FAO, 2008). According to the FAO (2008), the changing conditions will increase animal diseases and/or newly emerging diseases, particularly in Africa, which is already undergoing an enormous burden of animal disease. Thornton et al. (2006) argue that increasing drought conditions in East Africa will reduce water availability, hence increase the rate of infections due to increased interactions between livestock and wildlife. However, the IPCC report argues that, due to the effects of climate change, the 21st century is projected to experience increases in ill-health in many regions, and particularly in developing countries with low incomes as compared to a baseline without climate change (IPCC, 2014).

2.1.4 Effect on the rise of carbon dioxide levels

The rising level of carbon dioxide in the atmosphere is predicted to double the yields of carbon-responsive crops through the carbon fertilisation effect, which increases the photosynthesis efficiency rate, reduces transpiration and improves water-use efficiency in plants (Henson, 2011; Challinor et al., 2007; Nordhaus, 2007). Such crops include wheat, rice and soybean, but non-carbon-responsive crops, such as maize, sugarcane and sorghum, are likely to experience reduced yields (Nordhaus, 2007; Collier et al., 2008; Rosenzweig et al., 2001; Challinor et al., 2007; Downing et al., 1997). The most significant effects are expected to occur in parts of east and north-east Africa, where rainfall is projected to increase by 10 to 20% and the carbon fertilisation effect may well produce higher agricultural productivity benefits to farmers in the region, while in regions like north Africa, reductions in wheat production by 18% are expected, in southern Africa a reduction of 22% in maize production, and 50% in Sudan and Senegal (Collier et al., 2008). However, to reap significant gains from the CO_2 fertilisation effect, subsistence farmers will be required to shift from non-carbon-responsive to carbon-responsive crops (Collier et al., 2008). However, the positive fertilisation effect of CO_2 on some crops may be jeopardised by other climate change impacts, such as drought, floods, pests, plant diseases and storms (IPCC, 2007). Similarly, Stern (2007) argues that the benefits of CO_2 fertilisation effects are likely to be short-lived, as conditions begin to exceed the tolerance threshold for crops at higher temperatures, especially in many low latitude regions where water is already scarce, which will limit the carbon fertilisation effect and lead to substantial declines in crop yields (Stern, 2007). Also, increased concentrations of CO_2, aerosols and dust can lower the level of ozone (O_3) in the atmosphere (tropospheric ozone), and since ozone levels in the lower atmosphere are shaped by both emissions and temperature, climate change will mostly increase ozone concentrations on the ground, which may limit crop growth and offset any beneficial yield effects that could be increased from the result of elevated CO_2 levels (Parry, 2007).

2.1.5 Effect on stream flow and water bodies

Rising temperatures and decreasing volumes of precipitation are expected to reduce the present and future recharge of many rivers and streams in Africa (Collier et al., 2008) due to increased evaporation, which will affect many irrigation schemes. Many of the rivers in Africa are ephemeral, flowing during and shortly after the rainy season (Nyong et al., 2007). A decline in precipitation with prolonged drought conditions will decrease water levels in reservoirs, lakes and ponds, increase groundwater depletion through evapotranspiration, hence affecting water quality (e.g. salt concentration, increased water temperature, pH dissolved oxygen, turbidity) and contributing to land subsidence. The decline in water availability will affect irrigation activities, not only due to increased demands for domestic water and irrigation, but also from increased competition between agriculture, urban demands and hydroelectric power production, as well as industrial users (Rosenzweig and Hillel, 1995; IPCC, 2014). Currently, two-thirds of rural and a quarter of urban dwellers in Africa lack access to clean and safe drinking water (Simms et al., 2005), and climate change will exacerbate the problem. For instance, drought is expected to present significant water problems in Egypt due to periodic fluctuations in Blue Nile flows, and new dam renaissance in Ethiopia on the Blue Nile in 2014 will cause water shortages in Egypt and affect irrigation activities and power production at the Aswan High Dam (Adger et al., 2003). Similarly, studies have shown both long-term change and rapid fluctuations in Lake Victoria's water levels in East Africa and reduced flows of the Zambezi and Limpopo rivers in Southern Africa due to rainfall variability, which presents challenges for irrigation activities and other water-dependent projects (Collier et al., 2008; Adger, 2003). In addition, the increasing temperatures and decline in rainfall in the already dry season in Tanzania will reduce the annual flow of River Pangani by 6 to 9% and River Ruvu by 10% (URT, 2003). The decline in water caused by decreasing rainfall and increase in temperature will cause economic impacts such as water shortages, low agricultural production and variable hydropower production (Orindi and Murray, 2005).

2.1.6 Effect on economic zones

The projected increase in temperature may alter the distribution of agro-ecological zones, where highland zones may become more suitable for annual cropping as a result of increases in temperature (Sivakumar et al., 2005). Downing (1997), basing his study on an index of potential food production, suggests an expansion of agricultural suitable land in the highlands of Kenya by 2% with warming of 2.5°C, and a decline in crop growth in the lowlands due to the increase in temperature where plant metabolism and growth would fail at 40°C. Some areas could experience temperature stress at certain growing periods, which could necessitate a shift in planting dates so as to reduce the risk. In its 2007 report, the IPCC stressed that increased dependence on rain-fed agriculture could reduce agricultural production in some African countries by up to 50% by 2020. The 2014 IPCC report shares a similar view by suggesting that changes in climatic conditions will result in a shift in the production areas of food and non-food crops around the world, which will result in slower economic growth, lower agricultural incomes and threats to food security, and are likely to create new poverty traps and hence potentially increase human migration in the affected regions.

2.2. Impacts of climate change on the agricultural economy of Africa

The economy of Africa depends on agriculture as its single largest economic sector, employing about 60% of the population and contributing to about 50% or more of the gross domestic product (GDP) of most countries in Africa (Collier et al., 2008). Hence agriculture contributes to development as an economic activity, as a livelihood and as a provider of ecosystem services (World Bank, 2008). Most importantly, the sector is also responsible for providing food security from domestic production for both rural and urban populations (Tingem et al., 2009; Bryceson, 2000), where production is determined by rainfall, and hence so is the economic and social well-being of the community (Haile, 2005; Adger et al., 2003). Current and future projected changes in climatic conditions are expected to cause profound effects on the agricultural sector, thus affecting the availability of low-cost, high quality food for humans (Rosenzweig et al., 2001).

2.2.1 Effect on infrastructure

Extreme weather events will cause damage to infrastructure, mostly roads and railway lines, and hence transport costs for farmers will increase, which is noted to be among the root causes of poverty due to the failure to transport farm produce to the market at a competitive price (Kangalawe, 2009; Haile, 2005). Most of the road systems in East Africa are currently predominantly unpaved and seasonal, and therefore vulnerable to flood erosion (Collier et al., 2008). Floods will erode bridges, block accessibility and communication within the country, limit the flow of goods and services to those regions experiencing the most severe impacts of climate change, and increase infrastructure construction and maintenance costs, which the majority of the countries in Africa south of the Sahara cannot afford. The lack of storage facilities in remote areas also contributes to high post-harvest agricultural losses affecting the livelihoods of farmers (Haile, 2005).

2.2.2 Effect on disease and health

The increase in carbon dioxide in the atmosphere is projected to affect the breeding and proliferation of pests, insects, pathogens and the severity of diseases in the presence of the host plant and expansion in the geographical range of disease-carrying insects from the plains ecosystem to the highland, exposing people to new diseases with no knowledge on how to manage them (Henson, 2011; Kangalawe, 2009; Yanda et al., 2006; Githeko et al., 2000; IPCC, 2014). This will increase the economic cost to poor rural farmers with limited resources and knowledge on how to treat, prevent and eliminate these diseases, insects, pests and pathogens. For instance, as argued by Haile (2005), an increased incidence of malaria will affect the health of the productive agricultural labour force in the community, so contributing to food insecurity and increasing the financial economic burden on the household in taking care of chronically sick patients, with a concomitant increase in treatment costs (Haile, 2005). However, Collier et al. (2008) argue further that not only will the increases in temperature cause an increased spread of diseases and insects spreading diseases, but also other factors such as poor drug-treatment implementation, drug resistance, land-use change, poverty and other demographic factors play a greater role.

Another economic setback to subsistence farmers will present itself from the increased use of chemicals to control pests, insects and diseases, which may the affect health of the farmers, friendly insects (lacewings, earthworms, birds, bees and butterflies) and the quality of crops. Chemicals may also affect air quality and pollute rivers through run-off, affecting freshwater sources, destroying freshwater ecosystems and causing danger to the health of humans and other species (Collier et al., 2008; Rosenzweig and Hillel, 1995). The impact on human health could be severe in sub-Saharan Africa, where much of the water infrastructure is poorly developed and water for domestic use is drawn directly from the catchment source or from an open channel and used without treatment.

2.2.3 Effect on ecosystem

Higher temperatures affect soil functions, hence soil quality and fertility, because warmer conditions and moist soils accelerate the speed of soil processes and the natural decomposition of organic matter, which may require the additional application of fertiliser to manage declining soil fertility (Rosenzweig and Hillel, 1995). Drier conditions limit organic matter decomposition processes and plant root development, which cause poorer soils that in turn affect crop growth and yields, hence increasing the economic burden on subsistence rural farmers in Africa.

Climate change and variability may cause an expansion of agricultural production to regions currently occupied by natural ecosystems, such as forests, grasslands or other non-agricultural vegetation that provides ecosystem benefits in the natural environment (Bryan et al., 2011). However, putting into cultivation new land that was not previously under cultivation can release additional GHGs into the atmosphere, can affect flora and fauna in the area and can increase economic costs by destroying water catchment areas and the role of forest in modifying the micro-climate and carbon sink (Beniston, 2003; Bryan et al., 2011).

A decline in and variability of precipitation will cause a decline in surface and underground water flow in Africa, increasing demands for water for irrigation, domestic and industrial uses. This will cause increased costs for drilling and pumping water from the ground, causing additional investment in the dams, reservoirs, canals, wells, pumps and pipes needed to maintain and develop irrigation, which may be too expensive to afford by African countries south of the Sahara (Rosenzweig and Hillel, 1995).

Despite the impacts of climate change on agriculture and on the economy, more generally of the agriculture-dependent countries in Africa and elsewhere in the world, communities and households have developed a long record of coping with and adapting to climate change risks and variability over generations, where household asset portfolios and livelihood choices are shaped by the need to manage climatic risks, even though climate change events continue to threaten their lives and livelihoods (Heltberg et al., 2009). The next section of the literature review discusses the ways in which different communities in different parts of the world, especially agriculture-dependent communities, have developed coping and adaptation strategies in managing the impacts of climate change and variability in their agriculture-dependent livelihoods.

2.3. Adaptation and responses to combat the impacts of climate change

Most livelihoods in Africa depend on agriculture as the major source of food, income, authority, stability and resilience (Challinor et al., 2007). However, most of the agricultural activities are practised in small-scale subsistence farms and entirely depend on natural conditions, most notably rainfall and temperature (FAO, 2008; Parry, 2007; Adger et al., 2003). The farming environment is characterised by low production rates caused by harsh weather conditions, such as high average temperatures and low, variable rainfall, which have always kept African crop yields low. This exacerbates food insecurity (Di Falco et al., 2011). The projected anthropogenic climatic changes will further pose additional threats to agricultural production and food insecurity, particularly to the resource-poor African households whose current food requirement options are limited (FAO, 2008; Thornton et al., 2009; Cline, 2007; Perry et al., 2005). A small shift in local temperature (currently projected to increase by 1 to 2°C by 2030) will affect the traditional equilibrium, such as that between food crops vs. energy crops and cultivated lands vs. rangelands. This will likely result in conflicts between sectors, as well as increasing vulnerability for agriculture-dependent subsistence farmers (FAO, 2008; IPCC, 2007; Ziervogel and Calder, 2003). Hence, mitigation and adaptation measures in the agricultural sector are essential to lessen the impacts of climate change and to meet the demand for food, whilst still protecting the livelihoods of subsistence farmers (Bryan et al., 2011). However, the IPCC report of 2014 argues that the projected increase in temperature that causes changes in climate systems will require the development of new mitigation and adaptation strategies beyond the existing ones. Projected changes in climatic conditions will mean that current adaptation and mitigation measures are not sufficient to manage the projected changes in climatic system, thus efforts are required to develop new strategies beyond the existing ones.

Mitigation and adaptation are the two main strategies for addressing, managing and tackling the impacts caused by climate change (Solomon, 2007). Simon (2011) defines mitigation as actions aimed at reducing GHG emissions or vulnerability to the effects of such emission. Twomlow (2008) considers mitigation to be the strategy aimed at minimising future climate change through reducing current emissions which is attained by weakening the link between economic growth and greenhouse gas emissions. Mitigation actions include energy efficiency measures, use of cleaner fuels, promoting car-pooling and use of public transport, fitting catalytic converters to car exhausts and scrubbers to power station chimneys, use of natural ventilation to reduce the need for air conditioners and planting trees (Simon, 2011). Adaptation, on the other hand, refers to actions targeting changes to lifestyles, livelihoods and lived environments in order to be better able to cope with environmental changes (Simon, 2011). Adaptation focuses on the implementation of policies and changes in management activities, institutional settings and infrastructure that enable effective responses to climate change (Parry, 2007; Twomlow et al., 2008). In its 2007 report (p. 6), the IPCC defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". Adaptation, as defined here, focuses not only on financial adaptation measures, but also on social, economic and institutional responses. Some of the adaptation response initiatives include constructing flood defences, increasing the capacity of drainage and storm water systems in areas experiencing higher or more intense rainfall, relocating dwellings, infrastructure and key livelihood assets away from flood-prone areas or slopes, enhancing and diversifying water supplies in areas experiencing reduced or more irregular rainfall, and more multifunctional land-use zones (Simon, 2011). Both adaptation and mitigation can reduce the impacts of climate change on agriculture and hence contribute significantly to reducing farmers' vulnerability to climate change and increasing the food security of households (Di Falco et al., 2011). However, mitigation focuses on broad issues of reducing or stabilising current greenhouse emissions and hence reduces the possible future impacts of climate change, while adaptation focuses on managing the current, visible impacts of climate change caused by past and current GHG emissions. Given the differences, the focus of this study was on the "climate-proofing" strategies that are adopted by household farmers in protecting their farming activities against the impacts of climate change and hence increasing their resilience level and reducing the risk of food insecurity (Di Falco et al., 2011).

Adaptation can take different forms depending on “who or what adapts and adaptation to what?” (Smit et al., 1999a: 200). Smit et al. (1999a) argue that, in unmanaged natural systems, adaptations are autonomous and reactive, while in public agencies adaptations are usually planned and may be anticipatory. Hence adaptation can be classified into different types, such as being based on purposefulness. A common division of adaptation is made between autonomous and planned adaptation. Autonomous adaptation, also known as spontaneous adaptation, “does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems” (McCarthy et al., 2001: 982), whilst planned adaptation is “the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state” (McCarthy et al., 2001).

Based on timing, adaptation can be categorised into anticipatory (also known as proactive) and responsive responses (also known as reactive) (Cooper et al., 2008; Smit et al., 1999a). Anticipatory adaptation takes place before the impacts of climate change are observed, while reactive adaptation takes place after the impacts of climate change are observed (McCarthy et al., 2001). The ability of a country to respond to the impacts of climate change using a variety of strategies that require financial, social, economic and institutional capacity is known as the adaptation capacity (IPCC, 2007). The IPCC (2007) defines adaptation capacity as the ability of a system to adjust to climate change, including climate variability, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. It requires the entire capabilities, resources and institutions of a country or region to implement effective adaptation measures. Africa and other low-income countries have limited resources to cope with and adapt to the impacts of climate change (IPCC, 2007; FAO, 2008). Given this statement, a small change in climate will result in severe and pronounced impacts on the livelihoods and ecosystems of low-income countries.

However, despite limited adaptation capacity, many of the agriculture-dependent household societies have long been developing adaptation strategies that have helped them to cope and survive the impacts posed by changing weather conditions (FAO, 2008). On the basis of three adaptation categories, Cooper et al. (2008) describe response management options taken by household farmers in making adjustments in their technology, production and consumption decisions. They suggest that, during anticipatory responses, management options (such as choice of risk-tolerant varieties, investment in water management and diversification of both farming and other associated livelihood enterprises) are taken prior to the onset of the season. With in-season responses, management options include the adjustment of crop and resource management in response to specific climate shocks, and reactive responses that minimise the livelihood impacts of adverse climatic shocks (e.g. distress sale of assets, borrowing, and cutting expenditure on non-essential items). Milton and Kristjanson (1988, in Cooper et al., 2008), provide an example of such a matrix to describe coping strategies in the semi-arid tropics of West Africa, and also describe the spatial scale at which the various strategies operate (see Table 2.1). In addition, Cooper et al. (2008: 28) argue further that “while this matrix provides a useful general regional picture, it is recognised that there will be region-to-region, village-to-village and household-to-household variations in coping strategies that have evolved”. A similar view is suggested in the FAO 2008 report on climate change adaptation.

Table 2.1: Coping strategies used by farmers in semi-arid West Africa

(Matlon and Kristjanson, 1988)

Scale	Timeframe		
	Before the season	**During the season**	**After the season**
Plant	Variety selection for stress tolerance/resistance	Replanting with earlier maturing varieties	
Plot	Staggered planting date. Low density planting. Intercropping. Run-off management. Delayed fertiliser use	Changing crops when re-planting. Increasing or decreasing plant density at re-planting or by thinning	Grazing of failed plots for animal maintenance
Farm	Diversified cropping. Land type diversification. Plot fragmentation	Shifting crops between land types	Late planting for forage
Household, village, region,	Cereal stocks. Livestock/assets. Social and off-farm employment networks	Matching weeding labour input to expectations of the season	Asset sales for cereal purchases. Food transfer. Migration employment.

Adaptation can also be classified as private and public. Private adaptation is a response by an individual household or a firm to an environmental change for one’s own benefit (Mendelsohn et al., 2000). As argued by McCarthy et al. (2001), private adaptation is initiated and implemented by individuals, households or private companies, while public adaptation is initiated and implemented by governments at all levels. Most rural farmers develop short-term coping strategies that enable them to manage short-term climate change impacts, as opposed to long-term strategies in terms of which they can make use of the benefits associated with the changing conditions (Twomlow et al., 2008). Hence, this makes it necessary to differentiate between the two strategies for managing the impacts of climate change – short-term coping strategies and longer term adaptation strategies.

Coping strategies refer to “the strategies that have evolved over time through peoples’ long experience in dealing with the known and understood natural variation that they expect in seasons combined with their specific responses to the season as it unfolds", whilst adaptation strategies refer to long-term (beyond a single season) strategies that are needed for people to respond to a new set of evolving conditions (biophysical, social and economic) that they have not previously experienced. The extent to which communities are able to successfully respond to a new set of circumstances that they have not experienced before will depend upon their adaptive capacity (Twomlow et al., 2008: 782).

As argued by Scoones (1998), indigenous farmers in dry-lands have always been adjusting their livelihood strategies to large variations in climate, both short and long term. Some innovative households in the communities have improved on traditional practices and developed various coping strategies that enable them to survive under extreme climatic events.

Many sources suggest the existence of different coping strategies for farmers, as indicated in Table 2.2.

Table 2.2: Adaptation strategies most commonly cited in the literature to combat the vagaries of climate

- Increase irrigation area to boost crop production
- Introduction of low water-use crops and adaptation of sustainable water resource management policies (seasonal rainfall harvest; water quality control)
- Increase capital investment in reservoirs and infrastructure (construction of dam)
- Reduction of water loss through water conserving technologies
- Make water resource management an attractive career and field of investment
- Institute policy mechanisms to control unsustainable forest clearing and forest consumption (plans for reforestation and afforestation projects with a primary concentration on Hashab trees)
- Promote techniques for tackling emergency food shortage
- Adjust farming areas and reduce animal population
- Promote use of liquid petroleum gas for cooking and solar cookers instead of inefficient woodstoves and charcoal stoves
- Improve early warning systems
- Better agricultural practices
- Train agricultural labours and farming community with alternate lively hood skills

Source: Twomlow et al., 2008: 781

Historically, the majority of agriculture-dependent societies have autonomously adjusted their lifestyle to respond to changing natural conditions by developing both short- and long-term adaptation strategies in farming systems from the past to the present (FAO, 2008; Adger et al., 2003; Challinor et al., 2007). They have been able to achieve this through the dynamism of rural societies that respond to changes in population density and land tenure, as well as planting new crops and diversifying food production to meet changing demands over time (Adger et al., 2003; Challinor et al., 2007). Under extreme and prolonged drought conditions, small-scale subsistence farmers are forced to adopt other alternative livelihood strategies to cope with the changing conditions to meet their immediate food requirements for their families. Such alternative livelihood strategies include short-lived economic responses, such as the exchange of valued assets in the house for food (e.g. livestock with land, selling firewood and charcoal), making bricks, selling local beer, consumption of reserve seeds, pulling children out of school, and looking for off-farm employment in low-paying sectors such as house workers and bar and guest house attendants. Under extreme and prolonged conditions, households may be forced to abandon their farm and migrate to other areas (Haile, 2005; Ziervogel and Calder, 2003).

Despite all these challenges in farming activities, household farmers are adapting to these changes, although their changes are marginal rather than transformational in nature, with little uptake of existing improved soil, water and land management practices (Kristjanson et al., 2012). With the current climate trends, the ability of small-scale subsistence farmers to cope with the current and expected future climate changes and variability is limited (Cooper et al., 2008; FAO, 2008). Researchers (Bryan et al., 2011; Parry, 1990; IPCC, 2001) argue that, with limited resources, small-scale subsistence farmers can only cope with the extreme events (such as drought, floods or wind storms to a certain level, especially when the impact is short-lived and not abrupt) by developing appropriate adaptation strategies that can help reduce the impacts on crop yields. However, beyond this, their livelihoods cannot be sustained. For example, when prolonged drought conditions occur in consecutive years, the household's capacity and assets to cope with the event are eroded beyond the threshold level, and the household is forced to find other livelihood opportunities in the absence of any effective local or national level mechanism, such as the replenishment of seed stocks (Challinor et al., 2007). The current trends in climate change are expected to be more severe and of a more prolonged nature, which will modify and affect the available and known adaptation strategies of small-scale household farmers. They may face new conditions which they are not equipped to handle (FAO, 2008; Adger et al., 2003). This is shown by the occurrence of the severe drought in the Sahel in the 1970s and 1980s, and also more recently in the Horn of Africa, where small-scale subsistence farmers and communities in the area were not able to cope with such extreme events without outside support (Challinor et al., 2007). Due to these reasons, the current and immediate focus on adaptation strategies in many low-income countries should be on anticipated and planned adaptation strategies, with a consideration of both varying vulnerabilities of the local environment and among households, thus making adaptation options highly local and place specific (FAO, 2008).

However, the decision of farmers to adopt some strategies in response to long-term changes in temperature and rainfall is influenced by the provision of information from both informal and formal institutions, as well as access to credit and extension services (Di Falco et al., 2011). The majority of small-scale farmers do not have access to the necessary resources, information and services (credit, weather information and extension services) that are crucial in decision making –

decisions on changing crop types, investing in the purchase of seeds and specific soil conservation measures to suit the expected weather conditions (Di Falco et al., 2011). A lack of these basic factors is considered by many researchers (Bryan et al., 2011; Di Falco et al., 2011; Haile, 2005; Ziervogel and Calder, 2003) to be the most crucial obstacles to adaptation decisions made by the household farmers. Information on what weather conditions are expected in the coming season can help farmers make informed decisions on what adaptation strategies they can opt for, changing what to plant and when (time to acquire types of seeds of crops suited to the expected conditions and plant), deciding on which farming and soil conservation measures to invest in for improved crop productivity, which could lead to improved adaptation strategies to climate change and variability and hence increased food productivity (Ziervogel and Calder, 2003; Bryan et al., 2011). A study by Di Falco et al. (2011) in Ethiopia showed that farmers who had access to extension services, credit and information about expected weather conditions implemented adaptation measures and had more produce from their farms than households that did not have access to such resources and hence did not implement any adaptation strategies on their farms.

Many studies (Krishna, 2011; Stringer et al., 2009; Beckford and Barker, 2007; Challinor et al., 2007; Thomas et al., 2007; Haile, 2005; Ziervogel and Calder, 2003) show how farmers have developed innovative responses to changing environmental conditions and adapted more sustainable and resilient production systems, even in the relatively marginal environments that characterise much of their farming landscapes. Farmers have learnt to cope with the changing conditions affecting their agricultural activities (such as warmer temperatures, reduced soil moisture and changes in weather extremes) through testing and experimenting with new agricultural practices over decades, reducing the severity of the impacts beyond those predicted by some of the global climatic models (GCMs) (Cooper et al., 2008; Kristjanson et al., 2012; Adger, 2003), and hence providing them with benefits while responding to reduced emissions of greenhouse gases (Bryan et al., 2011).

There is plenty of evidence from the literature illustrating the link between enhanced farming practices and coping with and adapting to climate change and climate variability (Kristjanson et al., 2012; Thornton, 2006a; Adejuwon and Odekunle, 2006; Hellmuth et al., 2007). These changes in agricultural practices include improved crop, soil, land, water and livestock management systems, such as introducing crop cover, micro-catchments, ridges, crop rotation and improved pastures, planting trees and introducing new technologies, such as improved seeds, shorter cycle varieties and drought-tolerant varieties (Kristjanson et al., 2012). Although adaptation strategies (farming systems) are not the same and probably not applicable in all areas, households have commonly adapted and managed climate change impacts in a variety of ways. For example, a study conducted in East Africa shows that small-scale subsistence farmers are widely adapting to the decline in inter-annual rainfall, rainfall variability and increases in temperature by introducing irrigation practices, using mulch and crop cover to reduce soil moisture losses and applying improved soil, water and land management practices such as the use of terracing, which increases water infiltration rates in the soil and reduces surface soil erosion from run-off (Kristjanson et al., 2012). A study conducted in South Africa shows that the rural households of subsistence farmers in the Limpopo and KwaZulu-Natal provinces adopt similar coping strategies across the region (Thomas et al., 2007). For example, during the period of low and late rainfall, farmers reduced investments in agriculture, changed their farming practices by planting quickly maturing crop varieties, drought-tolerant maize varieties and other crop species and late-maturing fruit trees. Similarly, a study conducted in the south of Jamaica by Beckford and Barker (2007) showed that, through continued farm-level experimentation, subsistence farmers were able to adapt to the declining soil moisture and rainfall variability by applying mulching, where farm preparation is done under a permanent cover of dried grass, which retains soil moisture and slows down the rate of weed germination, reducing soil erosion especially on sloping land, and increasing the rate of infiltration during the rainy season. Also, households breed indigenous crop species and practise horticulture, especially in vegetable farming, including carrots, tomatoes, lettuce, cauliflower and cucumber, locally produced condiments (especially scallion, thyme and sweet peppers), melons and legumes. Farmers in this area also practise mixed crop-farming methods, where a combination of crops such as cassava and pigeon peas (gungo peas) are planted on one farm, where cassava provides shade and prevents direct solar radiation of the peas, and provides ground cover and nutrients to the soil from the foliage decomposition, which improves soil fertility. Farmers also grow plants such as yams for which plastic sheeting is used to conserve soil moisture (Beckford and Barker, 2007). The same farming strategy was observed by Thomas et al. (2007) in the Limpopo, North West and KwaZulu-Natal provinces of South Africa, where, during the diminishing rainfall towards the end of the growing season, farmers planted potatoes and irrigated vegetables that compensated for lower maize production. It was revealed that households that practised horticulture and irrigation in the area were able to reduce food insecurity and the vulnerability to unpredictable weather patterns by reducing dependence on rain-fed agriculture. Under increased drought conditions, farmers stop crop production and focus on livestock keeping, where they rear cows, goats, sheep, pigs and poultry, and spend money on feed for the livestock (Thomas et al., 2007).

Farmers also adapt to changing rainfall patterns and rainfall variability by changing the timing of either farm plot preparation or planting dates where they can plant earlier or later during the season (Kristjanson et al., 2012; Stringer et al., 2009). In Malawi, for example, maize, which previously was grown in November, is now planted in December and some households cultivate new hybrid maize for food that takes a shorter time to grow to maturity (Stringer et al., 2009). Late planting is argued to be a common adaptation strategy adopted by a majority of farmers in East Africa (Kristjanson et al., 2012).

Under early and intense rainfall events, small-scale farmers manage soil erosion (which washes away fertile soil) by digging furrows to divert run-off, planting aloes and grasses that bind soil together, maintaining traditional strips, ploughing the farm across the slope rather than down the slope, and managing gullies that reduce the size of the farm and limit ploughing by filling the gullies with stones (Stringer et al., 2009). In southern Africa, farmers manage early and intense rainfall by planting earlier, before the normal planting period commences, which is achieved through sharing of information about expected weather conditions, hence implementing proper and appropriate weather-adaptation strategies that control soil erosion and increase infiltration rates in the soil by building stone bunds (Thomas et al., 2007). Similar responses are adopted by small-scale subsistence farmers in India (Krishna, 2011), where, through terracing, farmers have managed to control and prevent soil erosion and landslides, and thus improve farm-water management and increased rice production along the terraces. In Nepal, farmers inhabiting the mountainous regions control soil erosion by ploughing the sloping land in a sword-like fashion, while Quezungal farmers in the Honduras plant their crops under the trees, where tree roots anchor the soil, preventing it from been washed away by rain, and thus reduce crop damage during natural catastrophes (Krishna, 2011).

A study by Stringer et al. (2009) in Swaziland showed that farmers managed drought conditions by staggering planting dates in different fields at different times to minimise risk to the whole crop, and managed weed infestation by practising regular weeding, crop rotation and planting early so that maize cobs grow before weeds flower. They managed soil fertility by practising crop rotation and intercropping maize and cowpeas to increase soil nitrogen levels. In Asia, the Mimbres people manage drought conditions by inhabiting the moist valley bottoms, which buffer them against drought conditions, and during floods they move to the higher and drier elevations, where they have established satellite settlements and continue with farming activities (Krishna, 2011). The Benalui foragers and Kenyah Badeng farmers in Borneo manage drought conditions by sharing their resources among the group, i.e. when adverse climatic conditions affect one group, the group acquires resources from non-affected communities (Krishna, 2011). In addition, the Kenyah communities in Borneo change their lifestyle and food habits during prolonged drought conditions, and plant new crops such as maize in the drying river beds and extract starch from wild sago palms during drought and floods caused by El Niño events (Krishna, 2011).

Under prolonged and extreme drought conditions, farmers can shift from dependence on agriculture as a key source of income and livelihood and engage in non-agricultural activities, such as microenterprises like handicrafts in tourist areas; making and selling clothes; sale of livestock; inter-household labour exchange; planting irrigated vegetable gardens and selling excess vegetables; selling products from communal land; relying on income transfer and remittances from relatives living outside their area; migrating to towns and other climate unaffected areas;

developing formal village trading networks; and searching for alternative food sources, e.g. maize from the government and aid agencies (Stringer et al., 2009; Thomas et al., 2007). These adaptation options are also known as livelihood diversification strategies, where households reduce dependence on agriculture and focus on livelihood sources other than agriculture. Most studies conducted in East Africa on climate change adaptation show that diversification of options at the household level is critical for incomes and food security for the family (Thornton et al., 2006; 2011). Kristjanson et al. (2012) argue that households that are more innovative and engage in more cropping and non-agricultural activities tend to be better off and more food secure than those that are less innovative and engage in fewer cropping and non-agricultural activities (Kristjanson et al., 2012). Similarly, farmers in Asia have diversified their crops and now plant sweet potatoes and vegetables, which augment rice production (Krishna, 2011).

Climate change also threatens livestock farming and households have developed strategies to manage this sector under climate-change scenarios. In Botswana, for example, households practise shifting grazing and borehole rotation, water transportation to dry areas in the dry season, herd separation to avoid overgrazing on less good rangeland, pollarding to maintain the tree cover and regularly between kraals (Stringer et al., 2009). In East Africa, livestock change and management strategies include selling livestock to create herds of a manageable size with the focus on fodder and water availability, changing herds' composition by introducing newly reared animal breeds, improving animal feed by growing fodder crops and adapting new feeding strategies like "cut and carry" and stall-feeding systems, which are most popular in Tanzania and Uganda (Kristjanson et al., 2012).

Governments are also concerned about the impacts of climate change and assist subsistence farmers in coping with, and adapting to, the impacts of climate change. For example, in South Africa, the government supports farmers in the Limpopo, North West and KwaZulu-Natal provinces through poultry and egg schemes and small-scale horticulture projects, where farmers grow tomatoes that supplement the staple crops of sorghum and maize as general poverty-alleviation projects (Thomas et al., 2007). Similarly, farmers in this area have established a maize cooperative that addresses marketing risks and reduces collective production and transport costs. Also, according to Stringer et al. (2009), the government in Botswana assists farmers in managing water shortages through planned strategies such as inter-basin water transfers, improved water recycling, water conservation measures and purchasing water from neighbouring countries. Through planned adaptation strategies, the government assists farmers by introducing high yielding, drought-resistant and disease-tolerant seed crop varieties for maize, along with training farmers and extending personnel to meet the goal of maize self-sufficiency, legume and sorghum improvement and production campaigns. Similarly, the government has promoted non-food crop production like cotton varieties that are pest- and disease-resistant and superior in yield and quality, and encourages high-quality domestic production of maize and beans, strengthening of linkages between sectors, identification and development of effective production technologies, increasing finance for fertilisers and hybrid seeds and encouraging farmers to increase agricultural productivity per hectare (Stringer et al., 2009).

It is clear that resilience to risks associated with climate variability in Africa is influenced by the adaptation and coping strategies taken at local, sub-national and transnational levels. As pointed out by Heltberg et al. (2009: 99), “an important question is at what level households, communities, local governments, national governments or internationally – to focus adaptation interventions. The answer has important implications for who implements, finances and benefits from adaptation interventions”. This is because adaptive capacity varies considerably among regions, countries and socioeconomic groups, and the ability to cope with, and adapt to, changing climatic conditions is a function of governance and national security strategies, wealth and economic development, technology, information, skill, infrastructure, institutions and equity (Challinor et al., 2007). Similarly, Conway and Shipper (2011: 228) argue that “practical adaptation measures require a better understanding of how society interacts with climate in the present, coupled with information about the nature of future climate risks, which can be set within the context of rapidly evolving livelihood systems and priorities for human development”.

Despite the fact that there are variations in adaptation capacity among regions, Challinor et al. (2007) and Ziervogel and Calder (2003) argue that the key ingredient farmers need is relevant knowledge and information through education and weather forecasting about climate variability, so that they can make informed decisions based on the expected weather changes by modifying their production systems (Kristjanson et al., 2012; Di Falco et al., 2011). Similarly, some of the adaptation strategies come from outside the local system, such as new varieties of more drought-tolerant crops and/or with shorter growing seasons. These strategies are made available to farmers through farmer field schools and other farmer-centred approaches to learning and communication (Challinor et al., 2007).

However, a successful adaptation strategy requires the blending of local and scientific farming techniques through participation in order to help farmers manage climate variability and change. As argued by Collier et al. (2008), although small-scale farmers have gained considerable experience in coping with temporary shocks, their knowledge has not yet been combined with a sustained ability to adapt to changing conditions associated with climate change. For example, most farmers who have adopted fallowing through agroforestry are said to benefit from improved soil moisture capacity due to increased infiltration rates and reduced run-off, hence providing greater soil erosion control (Challinor et al., 2007). Furthermore, Collier et al. (2008) suggest that farmers, through the help of the government, should reduce their dependence on climate-sensitive resources. This is achieved through the government investing in irrigation projects and in the non-agricultural sector, like manufacturing and service sectors, which have the capacity to absorb the shocks caused by climate change impacts on agriculture. Similarly, governments should increase expenditure on long-term "climate-proof" infrastructure development and improvement, such as roads, in order to facilitate the accessibility and movement of goods and services from one location to another at a reduced cost, without being affected by extreme weather events from the changing climate (Collier et al., 2008).

2.3.1 Limitations in adapting to climate change

There is no doubt that Africa has a low and limited capacity to adapt to climate variability and change due to a lack of capital, skills and appropriate adaptation technology (IPCC, 2001). Adapting to climate change requires changes in farming systems and infrastructures, switching crop types to more drought- and heat-tolerant crops, and those areas expected to experience increases in precipitation and temperature will require a shift to higher thermal-requirement crops so as to make fuller use of the extended and more intense growing season, and control of increased populations of pests, insects, weed and pathogens, most of which require extensive research that most African countries lack (Parry, 1990).

In the process of adaptation, farmers face problems in competing with imported food (cheap food, e.g. rice) to cater for the food shortages in the country. Imported food is sold at a cheaper price than locally produced food, limiting the ability of those farmers who are already trying to cope and adapt to climate change and climate variability to maintain their livelihoods. However, since livelihoods at household level are affected by declining income and food security from farming, many will opt for a diversification out of agriculture (Krishna, 2011; Kristjanson et al., 2012). As argued by Bryceson (2000), farmers who diversify their means of survival by moving completely or partially out of agriculture are more capable of moving out of poverty. It is evident that most households will adapt to climate change by further seeking to diversify into non-farm livelihood activities *in situ*, or by moving or sending more family members to urban centres and depending on urban-rural remittances, with agriculture remaining as a semi-subsistence activity while cash is generated elsewhere (Challinor et al., 2007; Dietz et al., 2004). The same was observed by Ziervogel and Calder (2003) in South Africa, where Basotho males who worked in the mines supported a large majority of the population with their pay from mining works.

Adaptation to climate change and variability may require the growing of less-favoured crops by the farmers, as changing conditions may not favour the growing of crops that farmers are accustomed to. This is because the adaptation process does not seek complacency with what is suitable to the farmers, but what is favoured by the conditions. This may lead to significant disruptions of the rural livelihoods, because the adaptation process is never perfect (Parry, 1990; Rosenzweig and

Hillel, 1995). For example, the growing of more drought- and famine-tolerant crops would not be preferred by most rural farmers, because it does not ensure equal levels of either food production or nutritional quality, nor does it guarantee equal profits for farmers.

However, the literature suggests that adaptation to climate change does not happen automatically, but requires investment in agricultural research and infrastructure (Rosenzweig and Hillel, 1995), in identifying possible current adaptation options that can be taken by farmers in coping with changes, their current and expected future hazards as well as types of crops and their best farming practices under climate change conditions. This is very expensive, and most African countries cannot afford this due to limited resources, such as institution infrastructure, access to capital, information and technology, and increased vulnerability to climate change by the agricultural sector, which is dependent on climate (IPCC, 2001; Smit et al., 1999b). However, the only available options for most African farmers in coping with and adapting to the impacts of climate change are through their traditional agricultural farming techniques, although timely response actions may be limited due to their infrastructure and economic means (IPCC, 2001; Smit et al., 1999b).

2.4 Traditional indigenous knowledge as a tool for coping with climate variability and change

The changing climate affects the ability of rural communities to satisfy those needs that are environmentally based (Krishna, 2011). Despite the fact that changes have being occurring over generations, rural farmers have also been adapting to these changes throughout their life by the use of local environmental knowledge (Beckford and Barker, 2007; Gyampoh et al., 2009). The knowledge is cheap, readily available to rural farmers and a climatically smart tool for sustainable development and the management of climate change and variability (Odero, 2011). However, environmental problems are local in nature (Krishna, 2011) and vary greatly spatially (geographically), temporarily and agronomically (Stigter et al., 2005), but rural farmers, through continued experimentation, trial and error and sustained interactions with their local environment, have developed a vast local knowledge about nature in their locale that they use in coping with and solving their problems, among which are climate-related problems (Krishna, 2011; Beckford and Barker, 2007).

Despite a variety of terminology used to refer to local environmental knowledge, such as indigenous knowledge, traditional local knowledge, aboriginal knowledge, rural peoples' knowledge, folk knowledge, traditional wisdom, traditional science, people's science, etc. (Krishna, 2011; Briggs, 2005; Thompson and Scoones, 1994; Senanayake, 2006; Beckford and Barker, 2007; Scoones, 1998; Ellen and Harris, 1996; Odero, 2011), all the terminology has similar meanings and is used interchangeably to refer to the local environmental or traditional knowledge and skills held by indigenous people, developed outside the formal scientific domain, embedded in culture and steeped in tradition via the oral tradition (Sen, 2005; Beckford and Barker, 2007; Odero, 2011). In this study, all the terminology will be used interchangeably.

However, there are many definitions of indigenous traditional environmental knowledge. For example, Warren et al. (1995) and Krishna (2011) define local environmental knowledge as a knowledge that is unique and specific to a given culture or society, developed through careful observation and experience of the natural ecosystem. It contrasts with the international knowledge system generated by universities, research institutions and private firms (Warren et al., 1995). Stringer et al. (2005) refer to indigenous knowledge as an environmentally derived technology concerned with farming needs towards operational resources for farm risk management decisions, while Beckford and Barker (2007) define indigenous knowledge as dynamic and complex bodies of knowhow, practices and skills that are developed and sustained by people/communities with shared histories and experiences. Furthermore, as argued by Beckford and Barker (2007), the knowledge developed provides a framework for decision making in a plethora of social, economic and environmental situations and livelihoods among rural people. In many African countries, knowledge plays a vital role in managing and improving agricultural performance where the agricultural sector forms the backbone of the economy (Hart, 2007; Lwoga et al., 2010b). For example, in Tanzania the agricultural sector employs 70% of the workforce, accounts for more than 25.7% of the gross domestic product and amounts to 30.9% of the country’s exports (URT, 2009).

However, local environmental knowledge consists of unique and specific features that delineate it from other forms of knowledge. For example, according to Raseroka (2008) and Subba (2006), local traditional environmental knowledge is specific and unique to a given geographical location, as it is recorded and stored in people’s memories and activities. As knowledge, it is expressed in the form of folklore, songs, stories, dances, proverbs, rituals, local languages, myths, beliefs, games, cultural values, community laws, agricultural knowledge of local flora and fauna and their linkage to medical and culinary activities, local history of the earth, stars and water systems, equipment, materials, etc., as well as through artefacts such as masks, pottery, carvings, etc. Although Seloma (2007, in Raseroka, 2008) suggests that the artefacts may be utilitarian and satisfy aesthetic aspects of culture, they may also reflect a people’s philosophy of life, values and experiences, innovations and productivity. Similarly, the knowledge has the feature of intangible cultural heritage embedded in archaeological knowledge (Segobye, 2006), dynamic and self-regenerating to cope with and adapt to the changing environmental conditions, as well as adapting the external knowledge to suit local situations (Raseroka, 2008).

However, the dissemination of local traditional environmental knowledge is dependent on memory, shared local language and the oral tradition and interpretation of material culture. The dissemination of information and sharing within indigenous traditional knowledge systems in Africa is predominantly dependent on person-to-person communication, or the use of a technology that transmits voice over distances. Such technology in traditional African societies includes horns, water and drums, which amplify voice across distance and transmit information from community to community over valleys or across expanses of water, such as lakes and large rivers (Raseroka, 2008).

Such traditional technological skills give local environmental knowledge unique characteristics that are distinctive from other forms of technological skills in modern science and other forms of knowing. The literature provides widespread and persuasive characteristics that distinguish local environmental knowledge from other forms of knowledge. According to Ellen and Harris (1996), local environmental knowledge originates from a specific group of people with specific experiences developed within the area in which they live. Relocating this knowledge to another locale has the consequence of dis-locating it. The knowledge is transferred through word of mouth, imitation and/or demonstration, which means that writing it down may lead to the loss of some of its fundamental properties. However, writing it would make it more portable and reduce the losses and dislocation that the knowledge faces. Similarly, the knowledge is the result of everyday activities and is continuously reinforced by experience and trial and error. The experiences are the outcomes of intelligent reasoning over many generations, where its failure has direct effects on people's lives, while success is very often a good measure of Darwinian fitness (Ellen and Harris, 1996) or, as Hunn (1993: 13) puts it: "tested in the rigorous laboratory of survival". Although the knowledge may be considered to be static due in nature, in reality it is constantly changing by being produced as well as reproduced, discovered as well as lost (Ellen and Harris, 1996). As argued by Hunn (1993: 13), "tradition is a fluid and transforming agent with no real end, when applied to knowledge; negotiation is a central concept". Knowledge is considered to be widely shared within the community from generation to generation, meaning it sometimes has been referred to as "people's science" due to its generation contexts of everyday production (Ellen and Harris., 1996; Lwoga et al., 2010a). However, its dissemination is not linear or equally shared; rather, it has segments within social groups (Lwoga et al., 2010a). The uneven dissemination of knowledge within a community arises due to issues related to power relationships and cultural differences, such as gender and age, as well as preservation through the distribution of the memories of different individuals (Wall, 2006). This may also lead to a rise of groups of specialists which may exist, not only by the virtue of experience, but also by virtue of ritual or political authority. Even though indigenous environmental knowledge is considered characteristically situated within broader cultural traditions, differentiating the technical from the non-technical and the rational from the non-rational is problematic (Thompson and Scoones, 1994: 18).

Subba Rao (2006) argues that local environmental knowledge is more than just technologies and practices, and hence it can be grouped into different categories depending on the function that it performs: (i) information (trees and plants that grow well together; indicator plants – plants that show soil salinity or are known to flower at the beginning of rains); (ii) practices and technologies (seed treatment and storage methods; bone-setting methods; disease treatments); (iii) beliefs that play a fundamental role in people's livelihoods and in maintaining their health and environment (holy forests are protected for religious reasons and maintain a vital watershed; religious festivals can be an important source of food for people who otherwise have little to eat); (v) materials (house construction materials; materials for basketry and other hand or craft industries); (vi) experimentation (farmer's integration of new tree and/or plant species into existing farming systems; healers' tests of new plant medicines); (vii) biological resources (animal breeds, local crop and tree species); (viii) human resources (specialists such as healers and blacksmiths; local organisations such as kinship groups, councils of elders or groups that share and exchange labour); (ix) education (traditional instruction methods; apprenticeship; learning through observation); and (x) communication (stories and messages carved on palm leaves; folk media).

Despite the varied types of local environmental knowledge with their attached functions as used by the community as a tool for survival, this knowledge has important values in meeting livelihood needs and demands for food for the local community through traditional farming systems based on local environmental knowledge (Dankelman, 2010; Gyampoh et al., 2009; Beckford and Barker, 2007). As argued by Lwoga et al. (2010a), Beckford and Barker (2007), Flavier et al. (1995) and Warren et al. (1995), indigenous traditional local knowledge is valuable, adaptable and necessary for coping with risks and uncertainties in the changing world because it forms the basis for local-level decision making in rural communities with respect to agriculture, food security, human and animal health care, education, natural resource management and a host of other activities in rural communities. However, Beckford and Barker (2007) caution against a misguided notion of traditional knowledge being treated as a panacea for all the ills of local agriculture. Indeed, indigenous traditional knowledge cannot be used as a substitute for modern scientific knowledge, nor as a replacement, but both can be used concurrently in solving environmental problems towards attaining sustainable agricultural development. Thus, as argued by Lwago et al. (2010), for sustainable agriculture the communities have to be placed within a knowledge-creating setting that continuously creates, distributes and shares knowledge within and beyond the communities' boundaries and integrates it with new agricultural technologies, innovations and knowledge.

Traditional farmers can cope with the impact of anthropogenic climate change by employing agricultural, indigenous traditional farming knowledge as a means of adapting to climate change and variability (Odero, 2011). This has been possible through continued interaction with the local environment, where farmers have gained extensive knowledge about crops, including resistance to reduced soil moisture, increased heat and pest and diseases varieties; water harvesting technologies to cope with declining water; soil moisture conservation and retention techniques; soil conservation through minimum tillage and other techniques; management of fragile soils; food storage and preservation techniques such as fermentation, ash, honey, herbal plants, sun drying and smoking to ensure food security; indigenous seed selection less vulnerable to pests and diseases and tolerant of higher temperatures and resistant to drought effects, intercropping and diversification of crops; weather prediction systems through early warning systems to determine short-, medium- and long-term climate variability and changes and expected impacts such as floods, drought and storms; change of diet preference; control and management of crop pests and diseases; and management of food shortages through the identification of emergency crops/food like local and wild edible fruits and vegetables to ensure survival during food shortages (Odero, 2011; Senanayake, 2006; Stigter et al., 2005; Gyampoh et al., 2009). Through lively and active interactions with their environment, households make informed decisions about their environment and the possibilities that it can provide for their living.

Through indigenous local environmental knowledge, farmers have been able to identify changes occurring in their environment and plan their social and communal activities, such as planting, harvesting and hunting, in response to changes in weather and climate in different seasons of the year, making informed environmental decisions for their survival through exploiting their natural resource base over generations, in spite of the variations occurring due to climate change (Stigter et al., 2005; Krishna, 2011). However, current climatic conditions appear to be changing more rapidly than in the past, limiting the application of local environmental knowledge as adaptation strategies (Stigter et al., 2005; Krishna, 2011; Gyampoh et al., 2009).

The newly expanding changes associated with variability in precipitation trends and increased droughts and flood events affect the livelihoods of rural farmers (Dankelman, 2010) by impacting on food security, farmers' skills and innovative practices in farming activities, and their traditional knowledge useful in meeting their survival needs (Krishna, 2011). However, farmers all over the world are adapting to the impact of changing climate and continue to develop their vast knowledge, techniques and strategies for coping with the changing conditions (Gyampoh et al., 2009). Most of the coping strategies are developed under limited resource availability, hence making some of them not sustainable but aimed only at survival in a transitional period (Dankelman, 2010). For example, farmers may decide to eat less or skip meals altogether, or use food with low calories, spend more time in work or in obtaining their needs (e.g. under water scarcity, rural inhabitants walk longer distances to fetch water), search for non-farm jobs where they may work under unsafe and poor conditions, borrow money (lent under high interest rates) for the purchase of food, or withdraw young girls and boys from school to save money on school fees and spend it on food. Under prolonged conditions, they may be forced to migrate to a safer environment (Dankelman, 2010).

Farmers have an extensive base of knowledge and practices that illustrate the use of their local knowledge and skills in developing cost-effective and sustainable survival strategies for households' poverty-reduction and income-generating strategies, and for the general well-being of the individual and the community at large. Local environmental knowledge practices generally can adapt in response to gradual changes in social and natural environments, since indigenous practices are closely intermingled with people's cultural values and passed down from generation to generation (Dankelman, 2010; Lwoga et al., 2010b; Ellen and Harris., 1996). Some of the traditional indigenous coping strategies that have proved to be successful and sustainable include the following: Local farmers are adapting to climate change by switching their farming practices to traditional crop varieties that are flood or drought tolerant and less vulnerable to pest attack and diseases (Dankelman, 2010). They have developed local indigenous generic crop varieties that can grow under limited rainfall conditions that not only tolerate increased drought conditions and heat stress, but also improve soil quality and fertility (Dankelman, 2010). For example, in India, farmers plant a locally adapted variety of pigeon pea (*Cajanus cajan*), which uniquely combines optional nutritional profiles, high tolerance to environmental stresses, high biomass productivity and moisture contribution to the soil (Altieri and Koohafkan, 2008). They also plant other drought-resistant crops, such as sweet potatoes, cassava, millet and sorghum (Altieri and Koohafkan, 2008). In the Philippines, the Tagbanuas communities use indigenous traditional farming knowledge called swidden farming (adjusting planting and clearing period) to cope with the impact of climate change on agriculture, and to manage food shortages by changing their dietary preferences to eating root crops such as kurut and burut (Krishna, 2011).

In managing the impact of increasing (higher) temperature conditions and intense sunshine, traditional farmers practise intercropping of heat-tolerant plant and early-maturing crops (maize), which enable them to manage their microclimate (Stigter et al., 2005; Dankelman, 2010). By intercropping, farmers grow a combination of crop varieties together on the same field in a single growing season, but harvested at different times (Altieri and Koohafkan, 2008; Stigter et al., 2005). For example, maize and beans may be grown in the same field, but beans are planted in the middle of the growing season and harvested before the maize (Altieri and Koohafkan, 2008). Alternatively, traditional early-maturing maize is intercropped with late wheat, something commonly practised on the North China Plain (Stigter et al., 2005). Traditionally, the practice of mixing crop varieties is important to small-scale farmers, and especially so for subsistence food production, as it can delay the beginning of diseases, reduce the spread of disease-carrying spores and create less favourable conditions for the spread of certain pathogens. The technique does not require or depend on the application of chemical fertilisers, pesticides or other modern farming technologies (Altieri and Koohafkan, 2008). Hence, farmers are able to attain numerous production and conservation goals concomitantly, and are assured of greater yield stability with a lower productivity decline during drought conditions than tends to be the case in monoculture (Altieri and Koohafkan, 2008). This practice protects crops, conserves diversity and sustains vital economic, environmental, human and natural resources, as well as mitigating the effects of local climate variability in small-scale farming systems (http://www.agroforestry.co.uk/agover.html; Altieri and Koohafkan, 2008). Similarly, traditional farmers manage floods events, which may occur during or in between growing periods and cause damage to crops, by planting crops that can grow within the length of the remaining growing season after floods (Altieri and Koohafkan, 2008).

Through conservation farming techniques, such as intercropping and mixed cropping, farmers plant crops to suit expected weather conditions predicted though weather forecasts confidently in the local environment, and also practise minimum tillage to conserve and reduce soil moisture loss. Practising conservation farming reduces the risk of low crop yields by spreading out the impacts of rainfall variability and temperature change achieved by planting different types of crops with different behaviour to cope with the predicted weather condition. This is possible through flexibility in traditional indigenous weather forecasts, which is firmly tied to the experience of the local environment (Stigter et al., 2005). However, Stigter et al. (2005) argue that the fitting of crops to the anticipated weather conditions under present climate change is now more doubtful and hence requires to be undertaken along with scientific weather forecast.

Farmers have developed a vast knowledge of crop combinations and mulching geared towards controlling flood impacts and soil erosion (Beckford and Barker, 2007). For example, using local environmental knowledge, farmers plant trees and crops on the same piece of land where trees provide shade, protect crops against temperature extremes and direct exposure to sun radiation, reduce the effect of wind on plants, conserve soil moisture, improve soil nutrients through nitrogen-fixing plants, and intercept hail and rain drops from destroying crops, while other crops provide ground cover (Olokesusi, 2004; Beckford and Barker, 2007). For example, a study in Jamaica by Beckford and Barker (2007) shows that farmers have developed sophisticated agronomic cultivation methods on symbiotic crop selection and combinations to be grown together, where cassava and pigeon peas (gungo peas) are planted together, while crops like sweet potatoes are planted alone in the field.

On the other hand, farmers in Asia control floods and reduce run-off and soil erosion by constructing drainage ditches and tunnels to manage storm water, practise agro-farming, reforestation and bush fallowing in certain parts of the field, apply mulching and leave plant residues standing after crop harvest (Stigter et al., 2005). For example, the indigenous people of Yunnan province, through the use of their traditional terracing farming technique, have been able to make farming activities possible in the Hani area, where the steepest slopes reach 75° (Jiao et al., 2012). In India, traditional farmers manage run-off water through a traditional system known as *zabo,* which means “impounding runoff”, and *cheo-ozihi* systems are commonly used in Nagaland, where run-off water is led through various terraces and collected in pond-like structures and is used for drinking water and irrigation during dry weather (Krishna, 2011). In Tanzania, the Matengo farmers in the Mbinga district of Ruvuma region use a technique known as *ngoro,* or Matengo pit system, where they excavate pits with the depth ranging between 0.3 m and 1.0 m, and plant maize, beans, wheat, sweet potatoes and tobacco on a rotation basis (Rutatora, 1997). The system has helped the Matengo people to establish their lives in the highlands, where altitudes range from 1 400 to above 2 000 m, but they produce adequate food crops in this mountain area and control soil erosion (Pike, 1938; Stenhouse, 1944). Similarly, terrace farming is also commonly practised among the Mapan and Chingwan in the Wakkos district of Pankshin in Plateau State in Nigeria along a rugged high-altitude area, whilst in the Ader Doutchi Maggia area of the Niger Republic, a traditional farming system of stone lines known as *gandari* is used to preserve water, check soil erosion and trap soil blown by the wind (Olokesusi, 2004).

Mulching is also popularly practised by Nigerian farmers in combating soil temperature extremes, conserving soil moisture and soil erosion, as well as in suppressing harmful pests and weed growth. They also plant creeping ground pumpkins that check soil erosion by covering the ground during the intense rainy season, when run-off is high (Nyong et al., 2007; Olokesusi, 2004). Also, farmers adapt to drought conditions by planting drought-tolerant crops, such as *Dioscorea* spp. and *cocoyam,* which also create shade and increase compost organic matter in the soil when used as green manure through leaf foliage, which improves agriculture yields (Nyong et al., 2007). This also reduces pressure on the forest, because households extract firewood from these crops (Nyong et al., 2007). They also plant quick-maturing types of millet that provide insurance against short rainy seasons (Olokesusi, 2004).

Fulani farmers in south-west Niger cope with both the long-term decline and variability in rainfall through planting drought-resistant cereals, such as millet and sorghum, which are intercropped with cowpeas, groundnuts and hibiscus. Low soil bio-productivity is managed by applying organic manure, although in only limited amounts, and farmers rely on short-fallow rotation on the farm to regenerate nutrients naturally. They also rear small ruminant animals. Cotton has not been cultivated since the 1980s due to a decline in annual rainfall, and many farmers now have to rely on off-farm incomes to supplement their household cash flow (Osbahr and Allan, 2003).

Declining soil moisture, as a result of increases in temperature and rainfall variability, has made traditional farmers reduce their dependence on rain-fed agriculture by establishing manually watered homestead gardens located close to their houses (Gyampoh et al., 2009; Altieri and Koohafkan, 2008). These gardens are rich in plant species diversity, benefiting the household with highly nutritional food, medicinal herbs, sources of firewood, spices, ornamentals and an income source from the sale of some produce (Altieri and Koohafkan, 2008). These gardens are maintained and managed at the homestead level, where soil nutrients are improved through the use of household waste and irrigation by using water after household uses. They are also important sites for experimentation with many varieties of plants (Altieri and Koohafkan, 2008) before they are adapted to be grown in the fields under known weather conditions. In Ghana, for example, farmers manage rain deficit and water shortages through a water-reuse strategy, where they have established homestead garden and nurseries irrigated by using water first used in the household for washing clothes and domestic utensils. They also practise rotational water distribution to reduce and control water used per person per day, and have revived rainwater harvesting from roofs, which previously was abandoned when communities installed wells and boreholes, which have now dried due to drought. However, rainwater harvesting is not enough for household use due to the low and variable rainfall (Gyampoh et al., 2009). Because of increased sunshine and drought, cocoa plants are more prone to wilt and so farmers have shifted from cocoa cultivation to drought-resistant crops, such as cassava and vegetables, which are cultivated close to the river plain where plants can get more water. Soil erosion, river siltation and deforestation, which reduce stream flow, are managed through education offered by the village authority on the effect of tree-cutting, hence encouraging households to plant more trees and conserve water resources and control forest fires by promoting community-based forest management. They also impose fines on those who indiscriminately set fire to the forest or cut trees along the water sources. Farmers also manage the impact of increased sunshine by planting trees on their farms to create shade for their crops and reduce increased loss of soil moisture and the impact of direct sun radiation of the crops (Gyampoh et al., 2009).

In Sri Lanka, farmers manage water scarcity using traditional water harvesting during the rainy season through the practice called ‘bethma’, combined with temporary land redistribution and field rotation (Stigter et al., 2005). In West African countries like Niger, Burkina Faso and Nigeria, farmers use traditional planting pits as reservoirs for water collection, something which has increased yields by reducing dependence on direct rainfall (Stigter et al., 2005). Similarly, in some parts of West Africa and Sudan, farmers use a traditional method called “demi-lunes” for better water harvesting, and this has proved to be very successful in managing water shortages in these areas (Stigter et al., 2005). In Zimbabwe, traditional methods such as permaculture, water harvesting and infiltration pits, together with drought-tolerant crops, are used to combat declining soil moisture for agriculture, hence reducing dependence on rain-fed farming (Altieri and Koohafkan, 2008; Shumba, 2001). Farmers in the Kalahari have established manually irrigated homestead gardens and have shifted from keeping cattle to more drought-resistant ruminant animals like goats (Krishna, 2011). In Nepal and Bangladesh, farmers have shifted from crop cultivation to rearing goats and poultry (Nepal) and ducks (Bangladesh), which are easily marketable products (Dankelman, 2010).

Under prolonged drought conditions, traditional farmers are forced to become migrant labours and/or engage in food trading (Olokesusi, 2004), or migrate to safer places and establish temporary shelter. For example, the Makushi people of Guyana migrate from their savannah homes during drought conditions to the forest, and plant cassava along the floodplains normally too wet for the crops (Krishna, 2011). These traditional farming systems, sometimes referred to as "ethno-engineering" (Jodha, 1990), have been developed and adapted by local farmers over generations to manage agricultural production through retaining water on the farm by increasing the rate of infiltration, providing efficient checks against soil erosion and loss of soil fertility, and preventing soil degradation towards enhanced and more reliable crop production, while coping with the challenges posed by their natural environment (Reij C, 1988; Olokesusi, 2004). This shows how local people notice the changes in their environment and adapt their livelihoods and habitat accordingly to the changing conditions.

As the IPCC (2007) reports clearly indicate, rainfall variability, floods, droughts and wind storms are the key factors that influence agricultural production and hence food security in Africa. These factors affect crops yields, which result in famine and other food impacts. However, in coping with food shortages, local farmers who depend on natural resources have acquired knowledge on other traditional non-farmed crops and vegetables that they eat during times of food shortages as a means of dietary change and adaptation to climate change (Odero, 2011; Gyampoh et al., 2009; Dankelman, 2010) As argued by Altieri and Koohafkan (2008), many farmers in developing countries obtain a significant portion of their food requirements from wild plants gathered from the forest, especially during drought and other environmental stress periods. They gather edible nuts, edible flowers, leafy vegetables, berries, roots, tubers, mushrooms, honey, bush meat (snails, game and insects), etc. from around crop fields, bush lands or forests surrounding their villages to ensure household food supplies (Altieri and Koohafkan, 2008; Okafor, 1991). As argued by Walter and Hilton (1993), 25 000 forest plant species in Tanzania are edible, and Okafor (1991) has suggested that they are important and cheap sources of vitamins, minerals, carbohydrates and fats. These foods are considered to be starvation or famine crops with a low calorie content or quality, and sometimes are hard to find and traditionally not preferred (Krishna, 2011); such non-traditional foods include water hyacinth (Dankelman, 2010).

Fleuret (1979) argues that peasant farmers in north-eastern Tanzania gather wild vegetables (*michicha*) from the forest during food shortages. These particular vegetables are rich in carotene, calcium, iron and protein, which provide rural households with a healthy diet during food shortages. Gathering is also practised in Mexico among the Puerpecha Indians, who use more than

224 species of wild native and naturalised vascular plants for dietary, medicinal, household and fuel needs. Similarly, Mexican Sierras depend on edible weed seedlings in the period before maize, beans and cucurbits mature in the field, and they eat quelites as an alternative food when crops are destroyed by hail or drought (Altieri and Koohafkan, 2008).

Through continued interactions with the local environment, farmers have developed complex cultural models of weather conditions from which they are able to predict the onset of different seasons and implement decisions about their farming activities, such as when and what types of crops to plant according to the expected weather conditions (Stigter et al., 2005; Nyong et al., 2007). Through this, traditional farmers have managed to cope with changing and varying climatic conditions over time. Traditionally, farmers predict seasonal weather by using different phenological markers and indicators, such as astrological and vegetation (e.g. baobab, acacia) indicators, seasonal patterns of migration or appearance of certain birds, blooming of certain trees, mating of certain animals and changing directions of wind (Odero, 2011; Haile, 2005; Nyong et al., 2007; Stigter et al. 2005; Krishna, 2011). With this information, they anticipate the beginning of the growing period and start farm preparation, or predict and stay alert for the occurrence of extreme events like floods, storms or drought (Altieri and Koohafkan, 2008). In the Philippines, for example, the chirping of kiling birds indicates the end of the typhoon season, which coincides with October in the Roman calendar, marking the beginning of sowing rice on the seedbeds. Through the use of traditional indigenous knowledge, along with careful experimentation and observations of weather and climate, small-scale farmers in Gujarat in India predict the coming of the rain (monsoon rain) to determine the growing season by looking at the flowering peak of blooming of the *Cassia fistula* tree, as the monsoon begins 45 days after peak flowering (Anonymous, 2001; Stigter et al., 2005). They also note the changing direction of the wind to determine the strength of the monsoon; when the wind blows from the north or west, this suggests a good monsoon, whereas if the wind blows from the east, this indicates drought (Anonymous, 2001; www.economist.com/node/873712). Consequently, these farmers can predict to a greater or lesser extent seasonal rainfall anomalies, and so prepare themselves for the expected event, e.g. flood or drought, by determining the sea surface temperature (SST) of the Indian and Atlantic Oceans, which influence the temperature of ENSO, leading to either drought or floods (Haile, 2005). In Indonesia, Punan farmers observe the phases of the moon to determine the commencement of activities like farm preparation, planting of tree crops and hunting (Krishna, 2011).

Nevertheless, under current climate change scenarios, weather predictions and the anticipation of the commencement of the farming season through indigenous traditional knowledge is becoming less reliable because, in some instances, these events may be occurring earlier than normal and hence they do not coincide with the start of the growing season, which may mislead the farmers (Krishna, 2011; Gyampoh et al., 2009). Also, the beginning of the rainy season is now less predictable; it may begin at the start of the normal planting season and be followed by a long break before resuming again, subsequently affecting crop growth and yields (Gyampoh et al., 2009). Hence the need to incorporate the useful elements of local knowledge with scientific meteorological knowledge in predicting weather, and hence climate variability and change, becomes important (Beckford and Barker, 2007).

Researchers have also documented a vast environmental knowledge and skills owned by traditional farmers in determining soil fertility and nutrients in their locale for the purposes of maximising soil use and increasing agricultural productivity at the farm level, and hence food security (Briggs, 2005; Beckford and Barker, 2007). As argued by Briggs (2005), small-scale cultivators use traditional knowledge for classifying and determining soil characteristics and fertility by using colour, presence of organic matter (flora and fauna) and soil texture over space which is a useful component in determining crop growth and yields. Beckford and Barker (2007) argue that, despite the geological history and geomorphological settings, which result in highly variable and differentiated soil types in Jamaica, local farmers have a deep knowledge of the variations in soils and their physical characteristics within their localised areas. For example, farmers in Rio Grande Valley differentiated and classified soils on the basis of crop yield, soil texture and colour, and use characteristics like smell and the absence of earthworms to indicate infertile and possibly acidic soils, as well describing soils according to different categorises of soil textures such as sandy, clay, gravely and soft fine soil. They also have knowledge about land degradation and can identify possible and expected causes using key indicators such as declining yields, the formation of rills and cracks in the soil, and increased stoniness of the surface layer of the soil (Beckford and Barker, 2007).

In west Niger, farmers determine soil fertility by using soil colour. Red soils are considered to be moderately fertile, sandy soils are considered to contain little organic matter, black soils are considered to be highly fertile and rich in organic matter, while white soils are infertile with no organic matter (Lamers and Feil, 1995). Traditional farmers in south west Niger in the village of Fandou Béri classify soils in their village area according to the location and potential for production. They identify soil names, texture and colour, and relate each soil type to both soil properties and amount of rainfall. In Swaziland, farmers determine soil fertility through feel and the availability of organic matter, where soils rich in earthworm casts are considered fertile with low acidity conditions, while those without earthworms are considered to be infertile and highly acidic (Osunade, 1995). In Nigeria, farmers considered alluvial soils in river floodplains to be very fertile (Kundiri et al., 1997). Similarly, rural farmers in Tanzania through their local knowledge can also identify and describe soil fertility by correlating it with soil colour and crop yields. They considered fertile soils to have cool and moderate temperatures with good crop yields, low fertile soils which carried low yields are considered to be warm, and those found in areas that are experiencing degradation are considered to be hot soils with poor yields (Östberg, 1995). Through this, farmers are able to choose and make decisions on the types of crops that they can grow on each soil, depending on nutrient availability, soil moisture and temperature tolerance levels.

The literature shows many examples of indigenous adaptation strategies that have been developed by farmers all over the world through their continued interactions with their environment and experimentation of their farming systems in coping with, and reducing the severity of, the impacts of climate variability and change (Altieri and Koohafkan, 2008; Stigter et al., 2005; Nyong et al., 2007; Gyampoh et al., 2009). Many of these strategies have been documented and added to the UNESCO world heritage site system in 1992 while some have been chosen by FAO's "Globally Important Agricultural Heritage Systems (GIAHS)" initiative to be used as pilot studies due to their outstanding aesthetic beauty, maintenance of globally significant agricultural inheritance, sustained provision of multiple goods and services, food and livelihood security, and quality of life for millions of people in the world (Altieri and Koohafkan, 2008). These systems exhibit important elements of sustainability, even in times of unpredictable climate variability, as they are well-adapted to their local environment, depend on indigenous resources, are small-scale and decentralised, tend to conserve the natural resource base and exhibit resilience to environmental changes (Altieri and Koohafkan, 2008). Examples of Globally Important and Agricultural Heritage Systems of relevance to climate change include the raised field agriculture in Mexico, Peru, Bolivia, China and Thailand (see Erickson, 1988), the Mountain agriculture in the Andes, the Quezungal farming system in Honduras (see Bergkamp et al., 2003; http://www.adaptationlearning.net/using-traditional-techniques-protect-watersheds) and Ifugao rice terraces farming system in the Philippines. These traditional farming systems are the representations of the heritage systems which have resulted over centuries in adapting to the local environment by local farmers to meet their agricultural needs. However, they are proven adaptive management systems that can be used for the protection of the endangered agricultural landscape (Jiao et al., 2012).

Indigenous knowledge systems have a broad perspective of the ecosystems and of sustainable ways of using natural resources. Neglecting such knowledge, and replacing it with modern ideas of theoretical knowledge and academic ways of learning, creates a grave risk that much indigenous knowledge disappears and, along with it, valuable knowledge about ways of living sustainably, both ecologically and socially (Senanayake, 2006). Due to this, there is current interest in indigenous knowledge, driven by research into sustainable development practices in developing countries and the scientific community's concern about loss of bio-diversity of species and ecosystems, and the future implications of that for the whole planet (Sen, 2005). According to the 1998/1999 World Bank Development Report, knowledge, not capital, is the key to sustainable social and economic development. Hence, building on local knowledge, which is the core component of any country's knowledge system, is the first step to mobilise such capital. In this case, for any development strategies and activities aimed at benefiting the local poor people directly, and its success in attaining its goals and objectives, there is a need to consider local people's traditional knowledge in its set-up and implementation in all phases, as indigenous knowledge provides the basis for grassroots decision-making by offering traditional models for development that are both ecologically and socially sound (Senanayake, 2006). Failure to recognise the role of local knowledge as a problem solving strategy may hinder the success of the project due to the fact that some of the local knowledge is embedded in the cultural values of the community and has become part of the everyday life of individuals in the community, to the extent that separating such knowledge from the community may prove to be very difficult resulting in project failure (World Bank Report, 1999). Similarly, as argued by Rappaport (1979) and Boyden (1987) (in Jiao et al., 2012), a society's ability to adapt to the natural environment and the kind of economic relationship it maintains are influenced by their culture's ethical values and beliefs. This being the case, indigenous knowledge constitutes the basic part of the lives of the rural poor because their lives and livelihoods depend almost entirely on specific skills and knowledge for their survival. Hence, mainstreaming this knowledge and integrating it with modern scientific knowledge could be most advantageous to small-scale farmers in different parts of the world, particularly in Africa (Kiplang'at et al., 2008). However, validating environmental traditional knowledge in any development strategies, in terms of its significance, relevance, reliability, functionality, effectiveness and transferability should involve the indigenous people themselves (who are the users) at the original site of application of the indigenous knowledge. Although its transferability and application may prove difficult because of the tacit nature of most of the indigenous knowledge in certain circumstances, its transferability and tacit nature can be managed through direct practices, motivation, documentation, suitable award and apprenticeship (Lwoga et al., 2010a; Eftekharzadeh, 2008; Sen, 2005).

Despite the successful and the widely recognized role of local environmental knowledge in managing natural resources and agricultural production under climate change and climate variability scenarios over generations in many developing countries (Hart, 2007; Stigter et al., 2005), the knowledge faces challenges as a panacea to some climatic and other environmental related problems (Stigter et al., 2005; Beckford and Barker, 2007; Briggs, 2005). The knowledge is blamed being vague and unsatisfactory by failing to boost food production and economic transformation in Africa (Briggs and Moyo, 2012). This may result in the knowledge being pushed to the margin of development practices in a very near future (Sillitoe and Marzano, 2009). However to some extent rural farmers are responsible in making local environmental knowledge unsuccessful (Briggs and Moyo, 2012). Briggs (2005) argues that local knowledge lacks support from development practitioners, and even households themselves may have little confidence in their own knowledge that might provide a solution to their environmental problems, even though it has done so for over generations. This makes local knowledge gradually disappear in most African countries without any tangible efforts to recognise or manage it (Lwoga et al., 2010b).

Local knowledge is preserved in the memories of elders which means it gradually disappears due to memory lapses and deaths due to the fact that most of the indigenous practices are handed down orally or by demonstration from generation to generation, and when those owning the knowledge die, or refuse to pass it to another generation, the knowledge undergoes extinction (Lwoga et al., 2010a). This is because most of the knowledge has not been captured, documented, recorded and stored in a systematic way. This is reflected in an old African proverb which says “when a knowledgeable old person dies, a whole library disappears” (Grenier and International Development Research Centre, 1998: 1). Hampate (1987) points to an urgency to preserve indigenous knowledge as foot prints that may provide paths to future analysis and appreciation of the knowledge and wisdom that sustained local African cultures over time, but which are being rapidly eroded by the impermanence of memory and the absence of independent, codified records of the orally transmitted past by traditional community chroniclers, as opposed to formal knowledge which is successful due to its open systems with formal structures and rules to which members of organisations adhere (Mosia and Ngulube, 2005).

Similarly, the way the local knowledge is transmitted, accessed and shared in the society is not smooth but rather fragmented due to various factors such as age, gender, status, wealth and political influence, as well as attitude, perceptions, norms, values and belief systems inherited by the communities(Lwoga et al., 2010b; Wall, 2006; Meyer, 2009). The knowledge is also threatened by the processes of urbanisation and growth of towns into cities, which attract more migrants from African rural areas into cities and towns, hence limiting constant refreshment, transmission and or appropriate modification of indigenous knowledge (Raseroka, 2008). As argued by Thomas (2012), much traditional knowledge is no longer transmitted to the youth as the society becomes more involved in the market economy replacing locally used crops and plants by cultivated or market-based consumer goods. Also, most of the societies owning local knowledge in Africa were once colonised (Mudiwa, 2002), hence the influence of colonialism and colonial economy, which devalued all belief systems and local ways of knowing through the attribution of such descriptors as “pagan, savage and ungodly etc.”, and thus rationalisation of various processes for “civilizing the conquered natives”, contributed to the loss of important traditional values that cannot be restored (Raseroka, 2008). As argued further by Raseroka (2008), indigenous systems worldwide and in Africa in particular have become a field of interest due to the fact that communities are generally under threat from the new economic systems that continue to undermine their livelihoods, belief systems, value and interests. Similarly, with the continued contact with western world and its food, resources will continue to contribute to the reduction of local knowledge on crops and plant crops and plants (Thomas, 2012; Ladio, 2001).

Another limitation arises on how both indigenous and scientific knowledges are viewed, which can increase the perceived inferiority of traditional knowledge in relation to modern scientific knowledge. Traditional knowledge is viewed to be closed, parochial, unintellectual, primitive and emotional, part of a residual, traditional and backward way of life, while contemporary knowledge is considered to be open, systematic and objective, centred on rationality and intelligence and centred within the developed world (Briggs, 2005; Thompson and Scoones, 1994). So whenever the two branches of knowledge are operating within the same environment, contemporary knowledge tends to dominate local traditional knowledge (Briggs, 2005).

Currently, it may be difficult to delineate what are considered to be local traditional farming methods per se because of current development interactions which may have caused much influence of the local farming practices with scientific practices (Beckford and Barker, 2007; Briggs, 2005). This is due to the fact that local small-scale farmers have contact with the scientific community (agricultural extension officers and NGOs) who may have influenced much of their knowledge system and practices, making it very difficult to disentangle the two farming practices due to their influences and similarities (Beckford and Barker, 2007). For example, as argued by Briggs (2005), indigenous traditional knowledge of identifying soil fertility frequently contains both local and contemporary skills making it difficult to differentiate between the two, hence devaluing the local traditional soil classification methods and considering local environmental knowledge as trial and error procedures with little justification and controlled experimentation.

However, both indigenous and scientific knowledges have their limitations in providing informed solutions to social environmental management practices. For example, in a study conducted in Mexico on the monitoring of forest, it was realized that local knowledge lacked the ability to monitor large areas of the forest in response to wood cutting pressure, while formal contemporary science lacked the ability to deal with the socio-economic consequences of woodcutting (Klooster, 2002). Nevertheless, both modern and indigenous traditional knowledge systems should complement rather than compete with each other by incorporating respective economic, social and political perspectives that are useful and beneficial to the management of natural resources for the survival of the community (Briggs, 2005; Beckford and Barker, 2007). The knowledge should be at the centre in creating solutions for some environmental problems, for it has evolved from the local community as opposed to scientific knowledge (Briggs, 2005). This is supported by Warren and Cashman (n.d.) who argue that success in development is more likely to be attained when local people are involved in the planning and implementation of development projects; and project officials who are familiar with indigenous knowledge are better equipped to facilitate participation by the local people.

When viewed in terms of values, traditional indigenous knowledge has an advantage of being directly linked to household daily activities, i.e. it is concerned with the immediate and concrete necessities of people's daily livelihoods and can provide a short-term and immediate solution to "a means of survival" in the community, making it meaningful. It may also be useful under transitory conditions, as opposed to contemporary science developed through research and principles for solving global problems without a local origin nor link to social, cultural, political and physical environment of a specific local area and removed from the daily lives of the people (Briggs, 2005; Agrawal, 1995). Many researchers have acknowledged the dynamism of local knowledge in providing solutions and coping with new environmental and economic hardships in society (Briggs, 2005; Beckford and Barker, 2007), with further acknowledgement that some local farmers in Jamaica were successfully in their farming systems by combining local farming methods with scientific knowledge (Beckford and Barker, 2007).

Scientific knowledge is developed through quantifying a relatively small number of variables, such as temperature, with an assumption that knowledge can be treated as something that can be transferred from one place to another, while many indigenous ways of knowing are dynamic, developed under many qualitative variables focusing on practical experiences, hence differentiating the traditional indigenous ways of knowing things as opposed to the scientific ways of acquiring knowledge (Peloquin and Berkes, 2009). As argued by Lwoga et al. (2010a), amongst other knowledge systems that exist in Africa, local knowledge is used as an important resource for agricultural development across generations. For example, according to Mushi (2008), the traditional sector accounts for more than 90% of the seeds planted in Tanzania.

Modern technology can benefit small-scale farming by providing information on expected environmental conditions with regards to their physical, agricultural, social and economic systems. This might include information such as expected rainfall totals, rainfall variability and intensity, commencement date, distribution as well as the end of the rains and prospect for dry spells and their length (Stigter et al., 2005). Similarly, farmers can be alerted about expected catastrophic events such as floods or droughts, and hence that they can prepare themselves by planting crops that can withstand the expected extreme conditions, thus reducing loss of crops and property, as well as life. Certainly, the availability of such information can be adapted by small-scale farmers and incorporated into their traditional farming methods, thereby increasing their resilience to the changing climate especially as local knowledge farming has developed in harmony with the local environment for decades (Stigter et al., 2005; Briggs, 2005; Beckford and Barker, 2007).

Some of the local environmental farming techniques, traditionally implemented by local farmers, are also concerned with the increasing concentration of carbon dioxide emissions in the atmosphere from the anthropogenic activities. Such strategies include planting of trees to prevent soil erosion that enhances the role of forests in carbon sequestration and storage. For example, local farmers in the Sahel practising zero tillage during farm preparation which conserves and retains carbon dioxide stored in the soil, reduces the loss of soil moisture, and uses organic manure as opposed to chemical fertilisers and practice (Nyong et al., 2007). Farm fallowing also allows natural regaining of nutrients for crop growth in subsequent seasons.

A successful adaptation and mitigation to climate change can be attained through developmental processes that consider people's life, history and the conditions for and of change (Escobar, 1995). This is because by incorporating indigenous skills in the management of resources, or in obtaining a solution to the local problem, this increases the confidence of the local people and level of success to the project because it gives a sense of belonging and ownership, as well as voice in development processes to the local community (Briggs, 2005). Hence indigenous knowledge should be at the centre towards attaining solutions for some of the climate change impacts than just the use of contemporary technology alone (Odero, 2011).

Although indigenous traditional knowledge and contemporary scientific knowledge are two different knowledges that are competing with one another, due to their original epistemological foundations (Briggs, 2005), both can be used to provide solutions in managing the impacts of climate change and resource conflicts and challenges facing rural societies. Indigenous traditional knowledge has much to offer about the specific nature of the local people's life style and history and how they interact with their environment on a daily basis towards earning their living (Briggs, 2005; Beckford and Barker, 2007).

However, there are problems that hinder the synergies of indigenous traditional local knowledge with contemporary science in the management of resources, such as differences in power relations between developed and developing countries, limited integration techniques which are exacerbated by the lack of proper background in local knowledge, lack of realisation that indigenous traditional knowledge has values attached to local content touching the life of the local people and could contribute to the development of sustainable climate change, mitigation and adaptation strategies and lack of proper understanding on how local knowledge could be used in dealing with environmental issues hence solutions to developmental problems (Briggs, 2005; Nyong et al., 2007).

Despite the positive features of indigenous traditional knowledge, there are doubts that question the legitimacy of the knowledge in managing agriculture, while many farmers still suffer from food shortages and increased environmental degradation. As argued by Briggs (2005) and Beckford and

Barker (2007), just because traditional knowledge exists, this does not mean that it is unproblematic. There are other factors that are embedded in food production that farmers encounter such as imported food, abrupt and prolonged occurrence of natural hazards such as floods, drought and windstorms that most rural farmers are not able to cope with (Beckford and Barker, 2007; IPCC, 2007), as well as the misguided notion that all indigenous practices are unproblematic and would be a panacea to all small-scale farming and nature related environmental problems just because they are local in origin (Beckford and Barker, 2007).

However, current development planning strategies based on the contemporary and dominant role of the expert, who may attempt actively to discredit indigenous knowledge to maintain his or her position, with the argument that indigenous farming methods are responsible for environmental degradation (Briggs, 2005). However, not all local knowledge practices cause environmental degradation, although the justification that local knowledge is unscientific in exploiting the natural resource base sustains the expert position in devaluing and discrediting all indigenous methods and hegemony of the contemporary science (Briggs, 2005; Thompson and Scoones, 1994).

2.5 The concept of hazard

Extreme weather events such as floods, droughts and heat waves associated with climate change result in hazards that affect people and resources. According to UNEP (2011) and Armah et al. (2010), the reported occurrence of hazards has increased significantly in the last two decades, affecting more people especially in developing countries. As a result, Yonetani (2011) reported that the number of disasters doubled from 200 to 400 per annum in the past two decades, with over 90% of their occurrence in 2010 being associated to climate related hazards (floods and storms). Globally, agriculture is among the sectors which are more affected by the occurance of hazards that lead to loss of produce.

Hazard refers to a natural condition that acts harmfully in a defined space and time, causing loss of lives, property and destruction of the environment (Alcántara-Ayala, 2002; Smith, 2003: 6). They are often associated with agents such as atmospheric, hydrological, geological, biological and technological conditions. Types of hazards include earthquakes, volcanoes, floods, landslides, storms and droughts. Natural hazards cause deaths, injury, disease and stress to human beings, damage to and loss of property, loss of flora and fauna, pollution and a loss of amenity (Alcántara-Ayala, 2002; White et al., 2001; Smith, 2003; Tano and Paki, 2011). It should also be noted that hazards have greater economic losses beyond devastating damage to structures, as they disrupt industries, putting them out of operation and causing losses in productivity, with the result of a loss of wages for employees, who are left without a place to work (Tano and Paki, 2011). However, it is important to note that when a large number of people are killed, injured or affected in some way, the event is termed as a disaster. Unlike hazards, a disaster is an actual happening, rather, than a potential threat (Keith Smith 2003).

There are different views on the causes of hazards. Some believe that hazads are events of nature and/or human acts on the environment while others belive hazards to be caused by a vengeful or wrathful act of God against sinful man (White et al., 2001). But, more importantly, is the view that there is no such thing as a truly “natural” hazard – the impacts of all hazards are mediated by social, political, cultural and economic factors which lead some people and households to be resilient and others to be vulnerable. Currently, many authors agree that many hazards are associated with human beings’ interaction with the natural environment (White et al., 2001; IPCC, 2011). The variations in understanding of the causes of hazards may affect the implementation and management measures to reduce societal vulnerability to hazardous events.

2.5.1 Management

People view hazards differently and the different perceptions affect their management strategies. Such differences exist among resource users, scientists, technical personnel and professionals (Burton and Kates, 2004). For instance, soil erosion and droughts are viewed as key hazards by highland farmers, while this might not be so among the lowland farmers, who would view floods as a key hazard. On the other hand, it is more likely for some events to be considered a hazard among urban dwellers and not among rural dwellers, also among the rich and not the poor. For instance, the poor are more vulnerable to floods because they live in hazard prone areas; they lack sufficient resources, and are highly dependent on nature especially on climatic sensitive sector (Carter et al., 2007, Eriksen et al., 2007). The literature indicates that in the future developing countries will face more damaging disasters (especially flood-related) as a result of multiple stress and low adaptive capacity of most of the communities (Alam and Rabbani, 2007, Douglas et al, 2008, Boko et al., 2007, O’Brien et al., 2004b). Their vulnerability increases due to increased dependency on agriculture and abject poverty which forces them to live in hazard prone areas such as floodplains (Blaikie et al., 2014).

According to Burton and Kates (2004), the management of disaster is affected by the impact of the calamities and the degree of awareness or perception. However, what is considered to be a natural hazard varies over time and space, depending on the culture of a given society. To cope with natural hazards, people and their societies adjust and adapt (White et al.2001); the actions that are variously termed as human responses, coping actions, mitigating actions, adjustments, and adaptations. Furthermore, some theories suggest generic sets of adjustments that are applicable to all hazards. It is, however, important to note that the capacities of various societies to adopt and implement the adjustments to hazard vary as well. There is a need to localize the adjustments and adoption strategies. Weichselgartner and Obersteiner, 2002 argue that many societies are making efforts in managing the impacts of hazards. However; the efforts do neglect the political, social, economic and cultural aspects. Thus, in order to have management strategies that may help in mitigating hazards and reduce vulnerability, societies in the world should consider the following guideline suggested by Godschalk (1985) and Larsen (2008): i) assessment of the hazards, this provides information on the likelyhood and intensity of effects of natural phenomena and the possibility of them occurring within a specific time and location; ii) Vulnerability assessment, i.e. estimation of the degree of loss or effects that would occur when a hazard strikes; iii) Risk assessment, i.e. the information obtained for the analysis of the hazard and its vulnerability is integrated in an analysis of risk, thus estimate the likelihood of expected loss from a given hazard event.

2.5.2 Vulnerability

Vulnerability refers to a situation of being prone or susceptible to damage or injury from natural hazards and the ability to predict, cope with, resist and recover from the impact of the same (IPCC, 2001). However, some people are more vulnerable than others and suffer more from the damage, loss, suffering and fatalities under the occurrence of natural hazards or events. Although disasters occur all over the world, studies show that their impacts are more devastating in the developing world, where they occur more frequently because of their geographical location in relation to geological settings and the lack of capital and the requisite technology to deal with disaster prediction, preparedness and post disaster adjustment (Alcántara-Ayala, 2002).

Africa in particular has low coping capacity; hence the majority of the populations are affected more due to dependency on hazard sensitive sector such as agriculture. Similarly, Africa is becoming increasingly vulnerable to floods and droughts as a result of poor planning, poverty and socio-economic changes such as the spatial distribution of population. Carter et al. (2007) categorically state that vulnerability exacerbates the impacts of disasters and makes recovery difficult, leading to increased poverty and deprivation. Vulnerability among groups is also supported by Adger (1999) and Khandlhela and May (2006), who suggested that vulnerable groups, such as women, elderly and the poor are the most negatively affected by disasters as a result of their limited access to resources and/or their dependence on the natural environment for subsistence.

2.6 Agriculture in Tanzania

Tanzania has a total land area of 945,000 sq. km of which 44 million hectares are arable land for agriculture, out of which only 10.8 million hectares, equivalent to 24% of the arable land, is being cultivated (Chachage, 2010). However, agriculture in Tanzania accounts for about 95% of country's food demand and employs over 75% of the total labour force (URT, 2012). About 85 % of the country's population living in the rural areas is employed in agriculture and the sector contributes about 26.8% to the country's GDP, and about 30% in foreign exchange earnings (URT, 2007, URT, 2013). The sector also contributes about 65% of the raw materials for domestic agro-based industries (Tumbo et al., 2010). Food crop production accounts for about 65% of the agricultural GDP and about 10% and 25% are from the cash crop and livestock sectors, respectively (Tumbo et al., 2011).

About 70% of the total cultivated land in the country is dug using the hand hoe, 20% by ox plough and 10% by tractor; and the average farm size ranges from 0.9 – 3 hectares (URT, 2013, Tumbo et al., 2010, Chachage, 2010). This means that the country's huge agricultural potential remains underutilised and production remains low. For instance, production of maize which is the main staple food remains at an average of 1.2 to 1.6 tonnes per hectare (Otunge et al., 2010). Major staple food crops are maize, sorghum, millet, rice, wheat, beans cassava, potatoes and banana; and the major cash crops for export include coffee, cotton, cashew nuts, tobacco, sisal, pyrethrum, tea, cloves, horticultural crops, oil seeds, and flowers (URT, 2013). Maize being the main staple food crop accounts for more than 20% of the total GDP (URT, 2012, Tumbo et al., 2011). However, food and cash crop production account for about 70% of the rural incomes (URT, 2012), making the sector a prominent element in the efforts to reduce and, ultimately, eradicate poverty in the country. Thus, agriculture sector plays a unique role for the development and wellbeing of the Tanzanian citizens.

Since the country's independence in 1961, several policies have been enacted to boost agriculture - National Food Strategy of 1982; the National Livestock Policy (NLP) of 1983; the National Agricultural Policy (NAP) of 1983; the National Economic Recovery Programme (ERP) of 1986 to 1990; the Agriculture Sector Development Strategy (ASDS); and the Agriculture Sector Development Programme (ASDP) of 2006; the National Strategy for Growth and Reduction of Poverty (NSGRP/MKUKUTA) and (ZSGRP/MKUZA). There also have been slogans to emphasise the importance and transformation of agriculture – these include *Siasa ni Kilimo* (Politics is Agriculture) of 1972, *Kilimo cha Umwagiliaji* (Irrigated Agriculture) in 1974; *Kilimo cha Kufa na Kupona* (Agriculture for Life and Death) of 1974/1975; and *Mvua za Kwanza ni za kupandia* (First Rains are for Planting) of 1981/82, and recently in 2009 *Kilimo Kwanza* (Agriculture First) (Ngaiza, 2012; Mlozi, n.d.).

All these strategies aimed at transforming the agricultural sector from subsistence to commercial and enable the country attain modernised and improved agriculture with higher productivity. All policies, strategies and slogans that were introduced in the socialism era empowered the public sectors and local communities to participate actively in agricultural production and increasing food security. The latter strategies recognise the role of private sector involvement in the development and improvement of the agricultural sector in the country through improving agricultural production, ensuring availability and distribution of agricultural inputs, crop marketing, and value addition to improve agricultural products. However, there is a very low level of agricultural development that could lead to the attainment of poverty eradication since agriculture in the country has remained predominantly small-holder, characterised by very limited use of modern technology (mechanization), poor techniques of production and vulnerability to erratic weather conditions (Tumbo et al., 2010).

Other challenges facing the agriculture sector include limited application of agricultural sustainable land use and management and improper land husbandry practices which have led to land degradation. Notably, soil erosion leading to adverse changes in soil characteristics and properties (e.g. hydrological, chemical, biological and physical properties) has resulted in the continued depletion of soil nutrients causing low crop productivity (URT, 2013). With the increasing drought conditions, more land becomes unsuitable for farming which explains the recent conflicts in Morogoro Region and southern parts of Tanzania between farmers who clash with pastoralists when they migrate to areas less affected (Benjaminsen et al., 2009; Mbonile et al., 1997).

2.7 Institutional framework governing land administration in Tanzania

In Tanzania, the Ministry of Land, Housing and Human Settlements and Development (MLHHS) is responsible for all land matters. The Ministry develops land policy and strategies for land allocation and use for various purposes. However, the land acquisition process has some irregularities despite the laws and policies that govern proper acquisition and use (Kweka, 2012; LAWYERS, 2011; Broadhurst, 2011; Chachage, 2010). For instance, Chachage (2010) points out that the acquisition of land for bio-fuel plantation in Utunga, Kilwa District was clouded with deceit where the government issued more land to SEKABU Energy Tanzania than the villagers had consented.

According to Broadhurst (2011) and Sulle and Nelson (2009), foreign investment in land in Tanzania does not profit local people since the existing laws deprive them the right to decision making and right to land resource. They show that the large-scale plantations, for instance, give investors the right to own land while local farmers produce and sell their crops to the investor under agreed contracts. The out-growers have a positive impact on improving rural livelihood as it has minimum effects on the environment and creates opportunities for local people to diversify their livelihoods and income, while large scale plantation farming is reported to have adverse effects on land rights, livelihoods of indigenous people, food security and environment as the mode alienates large estates from locals (Smalley, 2014; Broadhurst, 2011; Mwakaje, 2010).

The Tanzania Presidential Commission’s Report of inquiry on land matters known as the Issa Shivji Land Report (1998), aimed at making a detailed research on land matters which could help in solving land problems in the country. The Commission found that the land tenure regime in Tanzania was not fit for purpose. The last major land review had been the East African Royal Commission in 1953-55 where all land was declared ‘Public land’ vested in the Governor. Indigenous land users were largely governed by their customary law so long as it was in the interest of the state. Even after independence the same trend continued. The truth of the matter is the control of land by the executives led to enormous abuses, contrary to the interest of rural land users and the interest of the nation. Major changes in the structure of the government i.e. decentralisation (1972) and later villagization (1972- 74) followed by reintroduction of local governments led to total disruption of land administration.

The Commission came out with several concrete suggestions that would have helped in hamornising land ownership issues and disputes. For instance, one of the recommendations was to make Tanzanian land a constitutional issue. In particular, it stipulated clearly the fundamental principles of land tenure, as well as the responsible organizations mandated with issues of land tenure. This would forestall frequent manipulation and amendments. It is disappointing to mention that despite the efforts used in the development of the above recommendations, the government did not adhere to them and the country continues to experience land conflicts in different sectors.

The importance of land among small holders in the country and in Africa in general is well known. For example, in Tanzania and elsewhere, land is much more than simply a factor in economic production and one would not risk losing land if there was no potential alternative means of livelihood. In the rural areas, loss of land can mean marginalisation and possibly destitution. Thus, lack of land through shortages, limited access or unequal distribution affects socioeconomic development activities among rural farmers which increase the level of poverty in the community; Seventy to eighty percent of the rural dwellers obtain a large part of their income from agriculture (ECA, 2004).

In the view of the entire dynamic socio-economic and political influences on land tenure, ownership and land use among the poor in developing countries; contributed by sectoral and macro economic policies and the increasing changes in climatic and environmental conditions associated with increase in the occurance of hazards, it is evident that poor people in Tanzania and other developing countries will be more and more marginalized. Accoding to Bruce (1989), the sectoral and macroeconomic policies have had adverse effects on agriculture. Furthermore, those adverse effects are compounded by frequent policy shifts and changes in institutional arrangements. Poverty will increase as more areas become unusable for agriculture while the fertile land becomes expropriated by the private investors and the ruling/elite class. As a result, this will increase vunerability and susceptibility to hazards and consequent disasters among the poor.

2.8 Conclusion

This chapter has explored various literatures on the impacts of climate change among agricultural dependent livelihoods, adapation strategies and the role of local indigenous environmental knowledge in farming under changing conditions. It has further explored the concept of hazards, agriculture and institution governing land ownerships in Tanzania. As the literature has shown, it is obvious that changing climatic conditions affect nature dependent livelihoods thus increasing marginalization to the affected population. The poor are much affected due to their limited access to resources, location in a hazard prone environment and limited livelihood diversifications. Similarly, the discussion has revealed that the current changes in the country’s political and economic ideologies especially a change from public to private sector ownership favours the minority while the majority increasingly become poor and marginalized. In addition, literature has shown that poor people depend more on land thus when they are not empowered and their right to land is not protected, their poverty level increases, and so is their vulnerability to hazards and thus are exposed to disaster.

Chapter 3
The Study Area and the Research Methodology

3.1. Introduction

This chapter describes the study area as well as the methodological processes which were employed in the collection, organisation, analysis and presentation of the data. The scope and limitations of this research are also presented. To achieve its objectives, the study employed a mixed method approach in order to gain sufficient insights into the phenomena under study (Creswell, 2009; Rocheleau, 1995). The mixed methods used in this study were both qualitative and quantitative in nature. The chapter begins with the description of Mwanga District and proceeds to discuss the types of the data, research methods of data collection, presentation and methods of data analysis.

3.2. Description of the study area

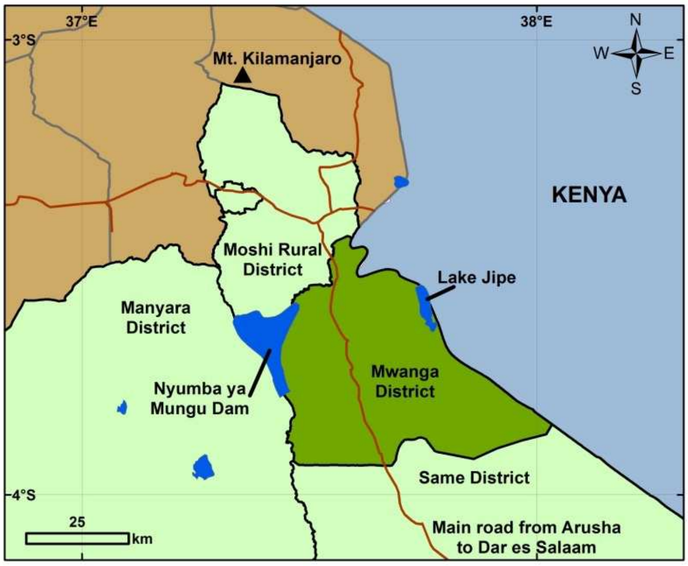
3.2.1 Location

Mwanga District is one of the six districts of the Kilimanjaro Region in Northern Tanzania (Figure 3.1), located 30 km southeast of Mount Kilimanjaro. The District was formed in 1979, after the splitting of Pare District into Same and Mwanga Districts. The district is bordered to the northeast by the Republic of Kenya at Lake Jipe, to the northwest by Moshi Rural District, to the southwest by Manyara Region at Nyumba ya Mungu Dam, and to the south by Same district (Figure 3.2).

Figure 3.1: Location of Mwanga District in Kilimanjaro region

Source: National Bureau of Statistics for Tanzania, districts correct for the 2002 census

Figure 3.2: Map of Mwanga District



The total geographical area of the district, comprising of land and water, is 2 641 km^2; the land and water body areas are 2 558.6 km^2 and 82.4 km^2 respectively. The estimated water body area of 82.4 km^2 consists of 56 km^2 of water from the Nyumba ya Mungu Dam, while the remaining 26.4 km^2 is water from Lake Jipe. However, the Pangani River passes through the District, stretching up to 32 km long. The district is divided into two major agro-ecological zones. These are the highland zone (Usangi, Ugweno, Kindoroko and part of Lembeni division) which covers an area of 810 km^2, and the lowland zone which is divided into the East Plain (Jipendea division) and West Plain (Mwanga, Lembeni division and Nyumba ya Mungu dam) covering an area of 1,230 km^2 and 600 km^2 respectively (see Figure 3.3). The altitudes of the highland areas range from 800 to 3 000 m above sea level while the lowland areas range in altitudes from 500 to 750 m above sea level (Maghimbi, 2007; Ikeno, 2007; Mndeme, 1992) (see Figure 3.4). The district has six divisions, 16 wards and 72 villages (Table 3.1).

Figure 3.3: Map of Mwanga District Divisions

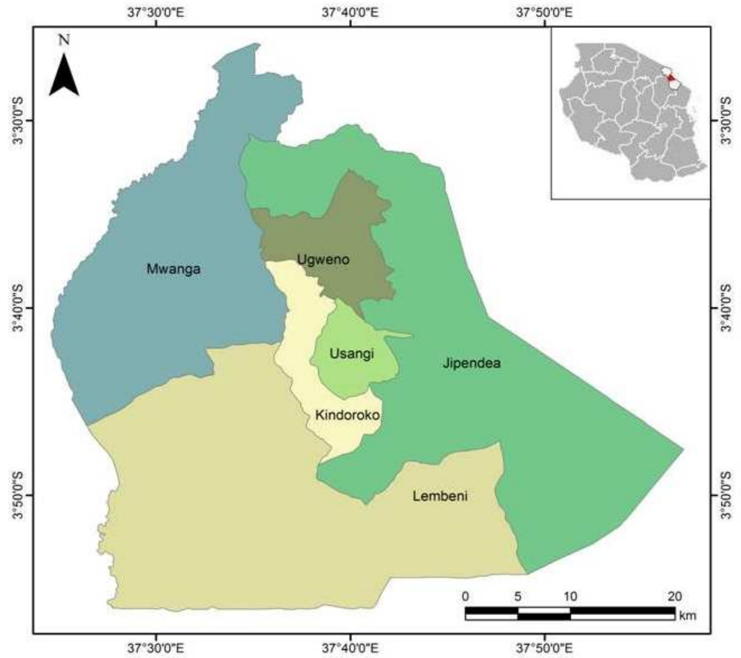


Figure 3.4 Elevation Map for Mwanga District

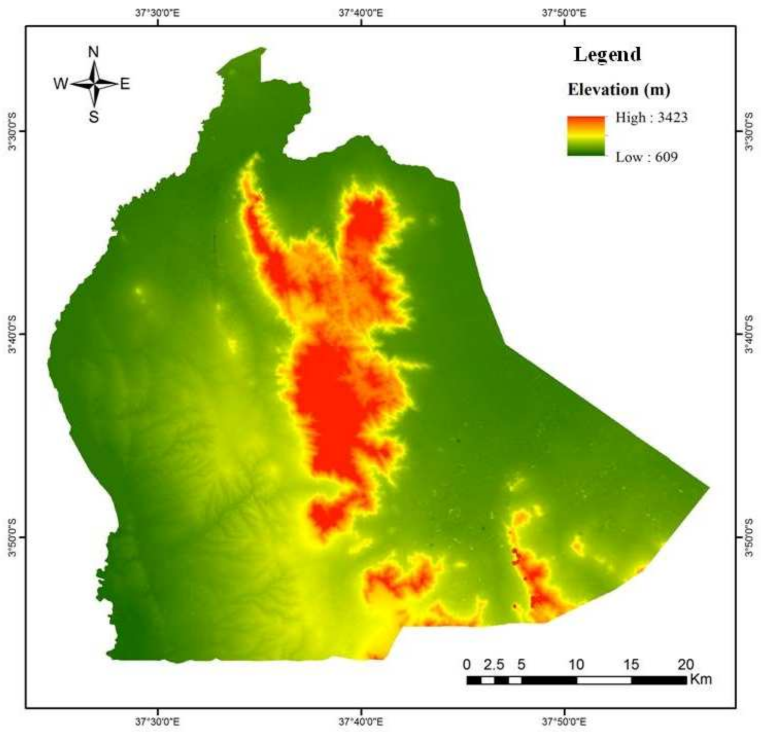


Table 3.1: Mwanga District divisions, wards and villages

Divisions	Wards	Villages
JIPENDEA	Jipe	Jipe and Kambi ya Simba
	Kwakoa	Kwakoa and Ngulu/Mkogea
	Toloha	Gongoni, Kizungo, Karamba, Ndea and Simu
	Kigonigoni	Kigonigoni, Ruru, Kwakihindi and Butu
	Kivisini	Kwanyange “A”, Kwanyange “B”, Kivisini “A” and Kivisini “B”
MWANGA	Lang’ata	Handeni, Kagongo, Lang’ata and Nyabinda
	Kileo	Kileo, Kituri, Kifaru and Kivulini
	Mwanga	Mwanga township ward (Mji mdogo)
LEMBENI	Kirya	Kirya, Kiti cha Mungu and Njia Panda
	Lembeni	Lembeni, Kisangara, Kiruru/Ibweijewa, Mbambua and Mangara
	Mgagao	Mgagao, Kiverenge and Pangaro
USANGI	Kighare	Kighare, Kilaweni, Ndanda and Kirongaya
	Chomvu	Chomvu, Ndorwe, Mbale and Mshewa
	Kirongwe	Vuagha, Lomwe, Kiriche and Mbore
UGWENO	Msangeni	Msangeni, Mamba, Mruma and Simbomu
	Kifula	Kisanjuni, Masumbeni, Raa, Rangaa
	Mwaniko	Mwaniko, Vuchama, Ngofi, Mangio, Mriti
KINDOROKO	Ngujini	Ngujini, Chanjale and Songoa
	Kilomeni	Sofe and Kilomeni
	Shighatini	Shighatini, Mfinga, Vuchama/Ndanbwe, Lambo and Mkuu

3.2.2 Climatic conditions

Mwanga District has a semi-arid climate. The lowland zones receive approximately 400 to 800 mm of annual average rainfall and the highland areas receive approximately 800-1400 mm per year. The highlands are cool and consist of permanent and seasonal small rivers and streams hence forming the major source of water used in the area. Generally, the area has a high potential evaporation with a bimodal rainfall pattern: rainfall occurs from March to May, which is the longer rainfall season locally called *Masika*, followed by a long dry spell that spans from June to October. A short rainfall season, locally called *Vuli*, occurs from mid-October to November and sometimes into December, paving the way for another dry spell from January to March. The highland receives both the *Vuli* and *Masika* rains. Although the rainfall trends in this area were good in the 1960s, recent rainfall patterns across the district are reported to be reduced and more divergent from the seasonal expectations (Ikeno, 2007; Maghimbi, 2007; Mndeme, 1992). The distribution varies across the district leading to decreased and variable rains compared to the past. These variations affect the major economic activities which entirely depend on rainfall to sustain livelihoods in the district. A study by Mndeme (1992) suggested that land use changes associated with deforestation have contributed to the decline in the amount of rainfall received in the district. Low rainfall causes major losses and reductions in agricultural production which compromise food security, employment and income. Also it has reduced water supplies from the mountain reservoir (the main source of water) in the district (Ikeno, 2007). The declining rainfall reduces the agro-economic opportunities for the vulnerable populations in the area, causing food insecurity and reduced opportunities for poverty reduction. Similarly, a decline in water availability affects large- and small-scale irrigation schemes in the area which depends on the water from the highlands (Mndeme, 1992). The average temperature in the district ranges from 12°C in the highland and 14°C in the lowland from June to July, and 28°C to 32°C in the highlands and lowlands respectively usually during the month of January (Ikeno, 2007). However, current changes in climatic conditions temperatures have been reported to rise to 36°C in the hot seasons.

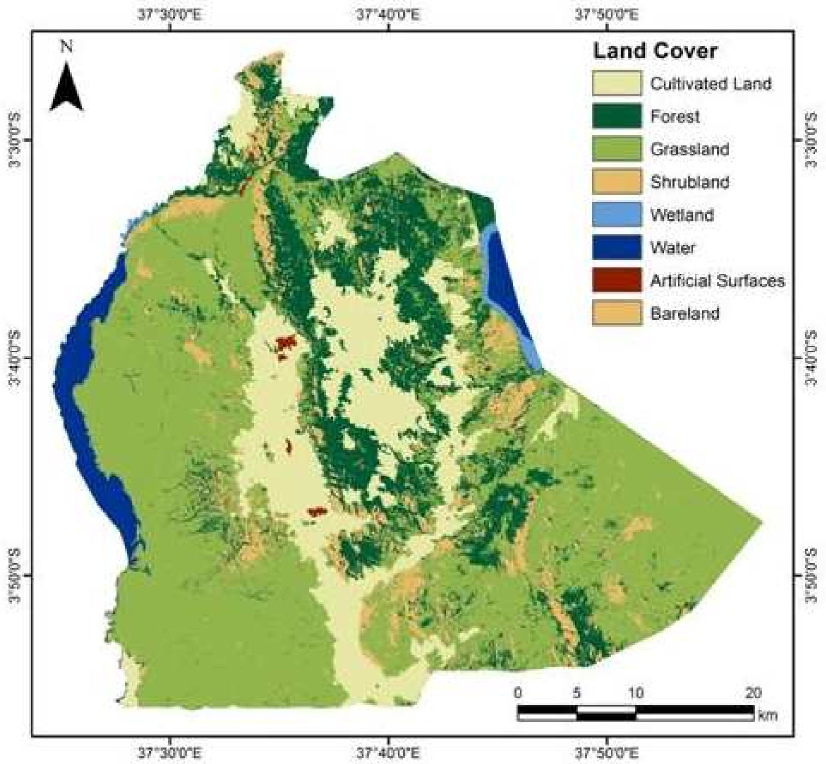
3.2.3 Population

According to the 2002 Tanzania National Census, the population of Mwanga District was 115,145 people, comprising 55,327 males and 59,818 females. The total number of households stood at 24,326. The labour force was 57,807 people, consisting of 27,776 men and 30,031 women; those unable to work, such as the aged and disabled, totalled 8,861, of whom 4,478 were men while 4,383 were women (http://www.tanzania.go.tz/census/census/districts/mwanga.htm; Mwanga District Homepage for the 2002 Tanzania National Census). However, population census data for 1988 and 2002 show that the district has a relatively low population growth rate. The data showed an annual population growth rate of only 1.23%, a rate lower than the average for Kilimanjaro region (1.61%), and much lower than that for Tanzania mainland (currently 2.9%) and from 1978 to 1988 (4.7%) (URT, 2007; Ikeno, 2007). Although the highland areas have a population density of approximately 200 people per km^2 in 1988 (Mndeme, 1992; National Census, 1988), this entire zone has a lower population growth rate compared with the lowland zone which lies along the major road from Dar es Salaam to Arusha (the largest city in northern Tanzania). The population growth rate in the lowland zone is reported to be higher than the district average (Ikeno, 2007; URT, 2007). A number of reports (Maghimbi, 2007; Ikeno, 2007; URT, 2007; Muthoni, 2012) have explained that Mwanga District experiences low population growth due to population pressure and adverse economic and environmental conditions, such as poor performance of agriculture, reductions in farm size, decline of suitable farming areas, and poor cash crop yields (especially coffee). These unfavourable factors have caused more of the youth to emigrate to the urban areas, seeking higher education, employment and other job opportunities. Secondly, Mwanga District serves mainly as a district administrative centre and has only a few job opportunities; commercial activities are also limited in the region, leaving the youth with no other option but to move out of the area in search of jobs elsewhere (Ikeno, 2007; Maghimbi, 2007). Lastly, the implementation of economic policies, such as the Structural Adjustment Programs (SAP), under the supervision of International Monetary Fund (IMF) and World Bank introduced in 1986, contributed to the decline of coffee production in the district and other parts of the Kilimanjaro region. This meant coffee growers in the highland zones faced difficult living conditions, causing some of them to leave the area (Maghimbi, 2007; Ikeno, 2007; Mhando, 2007). In order to support themselves, those remaining in the highland areas must constantly adapt to different economic and agricultural activities which are mostly influenced by globalisation (e.g. market relations), climate (e.g. erratic rainfall) and institutional/power changes (Maghimbi, 2007; Ikeno, 2007; Meena and O'Keefe, 2007).

3.2.4 Land cover and soil types

Much of the land is covered by *Acacia*-type shrubs in the lowland and short grass with interspersed trees with thick forests exists in the highlands. There is also cultivated land, built surfaces, water bodies and bare land (see Figure 3.5). The soils vary depending on the location: in the lowland, the Western plains have very stony and moderately deep soils, the Eastern lowland regions have sandy, clay and loamy soils, while the highland areas have well drained, deep yellowish or reddish clay with moderate organic matter. According to the Geological Survey of Tanzania (1960) and FAO/UNESCO (1977), the highland areas are made of granulites and granulitic rock types, hence forming soils known as Nitosols. However, a survey done in 1992 further suggested that highland areas also have Cambisols and Fluvisols on the pediments of hill slopes and the river valleys. According to Mhando (2007), Nitosols are naturally low to medium in soil fertility and have higher erosion rates, requiring the application of fertilisers to increase production and the use of soil conservation measures to prevent soil erosion. Cambisols are also naturally low in soil fertility but respond well to fertiliser application and require the application of conservation measures because they occur on slopes. Fluvisols are fertile, but flooding and water-logging are a major problem, hence land use systems have to be adapted to floods, inundation and high ground water. However, Nitosols and Cambisols have been used for farming activities in the area for more than 100 years, so currently farming without the application of manure and fertiliser is not possible (Mhando, 2007). Hence the application of manure and industrial fertilisers especially in the highland zone is important for better crop yields.

Figure 3.5: Map for the land cover in Mwanga District



3.2.5 Economic activities

Agriculture, livestock keeping and fishing are the major economic activities performed in the district. Agriculture is predominantly small-scale subsistence farming practised for both cash and food crops. The main crops cultivated include banana, maize, beans, yams, pumpkins, fruits, sweet potato, cardamom and sugarcane as food and cash crops in the highland areas. In the past coffee formed an important cash crop for the highland people but currently is no longer grown. However, plans are underway in revamping the coffee economy in the highlands. In the lowland plains, farmers grow maize, peas, sorghum and millet as the main crops. Also there is a private sisal plantation owned by Mohammed Enterprises Tanzania Ltd. This plantation provides permanent and seasonal employment for people in the area; however, the majority of the permanent employees are non-residents who were brought in the area during colonial labour economy. Livestock keeping is also practised in the study area. In the lowland plains, livestock herding is conducted under free range grazing. The types of livestock raised in the area include cattle, sheep and goats. Non-availability of fields for grazing, caused by increasing drought conditions, has forced many households to opt for zero grazing, which also has led to the reduction of the number of livestock in the lowland zones. On the contrary, in the highland zones, agro-pastoralists practise stall feeding (zero grazing), where livestock such as goats, sheep, cattle, pigs, rabbits and poultry are domesticated. Also, small-scale fishing is conducted at the Nyumba ya Mungu Dam and Lake Jipe. Currently there are 694 fishermen with 600 fishing canoes on the Mwanga District side only.

Fishing at Lake Jipe has almost ceased, as the shores of the lake have become encroached by water reeds and other plants.

The overall land in the district has been allocated to several uses: forests, game reserves, residential areas, cultivated land, and some grazing fields (see Tables 3.2 and 3.3) (Ikeno, 2007).

Table 3.2: Distribution of land use pattern

Land usage	Areal coverage ha.	%
Grazing land	118,115	43
Agriculture	44,300	16
Game reserves	44,500	16
Residential	11,900	4
Forest	8,470	3
Water	8,240	3
Reserved forests	7,806	3
Other land uses	29,090	11
Total	272,421	100

Source: Mwanga District Profile

Table 3.3: Distribution of the cultivated total land area of 44,300 ha

Land cultivation type	Areal coverage in ha.	%
Area under crops cultivation	18,953.6	29
Area under food crop production	16,499.6	26
Area cultivated by hand hoes	14,215.2	22
Area cultivated by animal power/ploughs	3,790.7	6
Potential area for irrigation farming	5,490	9
Area under cash crops production	2,454	4
Area under irrigation farming	1,950	3
Area cultivated by tractors	947.7	1
Total	64,300	100

Source: Mwanga District Profile

3.3. Reasons for field site selection

Like other semi-arid areas, Mwanga District experiences land degradation, unreliable rainfall, repeated water shortage, seasonal famine, overgrazing, dry land cultivation in the marginal areas and heavy competition for the limited biomass between farmers and livestock (Mndeme, 1992). A study conducted by the Tanzania Forestry Action Plan (TFAP) in 1992/93 to assess the socio-economic situation in the Northern Pare Mountains (NPM) in relation to the utilisation of the land resources identified problems such as inadequate food production; low crop productivity; low livestock productivity; shortage of fuel wood, poles and raw materials for cottage industries; low income and labour shortages (Mhando, 2007). Some of the causes of these problems were noted to be due to unreliable rainfall, population pressure, low soil fertility, nutrient losses through erosion and crop harvests, fodder shortages especially during the dry season, poor quality of fodder grasses and youth migration to the cities (Ikeno, 2007; Mndeme, 1992; Maghimbi, 2007). Similarly, the district has suffered from chronic food shortages caused by droughts and floods. Compared with the highland zones, the lowland plains have most commonly suffered from serious crop failures. However, records indicate that between 2001 and 2005, both short and long rains consistently failed, leading to acute food shortages throughout the district (Kilimo, [AGR/C/GEN/VOL.VI]: Doc. No. 147). This is a common situation for Mwanga, which has historically experienced chronic food shortages. For example, in 1984, 1992, and from 2003 to 2005/06, this district recorded the receipt of food aid of maize, maize flour and kidney beans every year except 1996 and 2002/03 (Maghimbi, 2007; Ikeno, 2007). This necessitated food aid and support to the district by organisations such as the Strategic Grain Reserve of the Tanzanian Government, the World Food

Program through Caritas, the Tanzanian Red Cross/Red Crescent and religious institutions such as the Lutheran and Pentecostal churches.

In general, the lowland areas are more vulnerable to drought than the highland areas. However, in recent years crop failures have been experienced in both lowland and highland areas. Similarly, many highland residents depended on coffee in the past as their main cash crop, but in recent years, coffee production has declined either due to the aging of the coffee plants (some of which may be at least 100 years old), changes in highland temperature and/or due to economic liberalisation policies which were introduced in 1986 affecting coffee production in the area (Maghimbi, 2007; Mhando, 2007). Most of the agricultural activities in the district are rain-fed with some irrigated cultivation; any changes in rainfall will therefore have greater impacts on agricultural productivity and the agriculture-dependent livelihoods in the area. The district is highly vulnerable to climate change impacts and, being a semi-arid area, it can be argued that the livelihoods of the people in the area have experienced significant climate variability in the past and are likely to face increased climate changes and variability in the future (Abdallah and Lema, 2010). Hence, this makes this area suitable for undertaking this study in ordered to understand farmers' knowledge and perceptions on climate, climate change and climate variability, and the role of local environmental knowledge in farming activities. It also aims to understand the changing conditions, to assess agricultural coping and adaptation strategies to climate change and climate variability, as perceived and identified by participants in the study areas. Finally the study recommends possible adaptation strategies that can be undertaken by rural farmers in managing their agriculture-dependent livelihoods under climate change scenarios. These are presented and discussed in detail in the findings chapters.

To achieve its goal, the study area was divided into highland and lowland zones in order to capture and compare the views and perceptions of farmers on climate, impacts of climate change and climate variability, adaptation strategies and the associated limitations in agricultural adaptation to climate change. The study aimed for a broadly equal representation of participants from the highland and lowland zones. Hence a total number of 234 participants (117 from each zone) were identified and their opinions and perceptions about the problem under study were captured and compared.

3.4. Research Methodology

The research applied a mixed methods approach (Tashakkori and Teddlie, 2003; Johnson et al., 2007), which is a procedure for collecting and analysing data by mixing both qualitative and quantitative data at different stages of the research process within a single study, to comprehend a research problem more completely (Creswell, 2002). The rationale for mixing both methods is that neither qualitative nor quantitative methods are sufficient by themselves to capture the complex phenomena of climate change and climate variability in agriculture-dependent livelihoods. When both methods are used in combination, they tend to complement each other and hence allow for more complete analysis (Green et al., 1989; Tashakkori and Teddlie, 1998) and provide a more enhanced understanding of the issue at hand. Jick (1979) argued that the combination of qualitative and quantitative methods should be viewed as complementary rather than as competing camps. Similarly, scholars argued that to capture both biophysical realities, as well as the socio-political dimensions of the environment, it is important to utilise hybrid research methods in which a variety of perspectives play a role in dealing with the research problem (Batterbury et al., 1997). In quantitative research, the researcher uses numerical data. The investigator uses positivist claims for developing knowledge, such as cause and effect thinking, reduction to specific variables, hypotheses and questions, use of measurement and observation, and the testing of theories. A researcher isolates variables and causally relates them to determine the magnitude and frequency of relationships. Similarly, the researcher determines which variables to investigate and chooses instruments, which will give reliable and valid scores (Creswell, 2009). In this study, household types of questionnaires formed part of the quantitative approach which made it easier to capture different statistical information used in this study.

Alternatively, qualitative research is "an inquiry process of understanding" where the researcher develops a "complex, holistic picture, analyses words, reports detailed views of informants, and conducts the study in a natural settings" (Creswell, 1998). In this approach, the researcher makes knowledge claims based on constructivist perspectives (Tashakkori and Teddlie, 2003). Through the use of qualitative research, information or data are obtained from those involved in the everyday life of the setting in which the study is framed. Data analysis is based on the values that the participants perceive to represent the real situation. Hence, "it produces an understanding of the problem based on multiple contextual factors" (Miller, 2000).

In a mixed methods approach, the researchers build the knowledge on pragmatic grounds (Creswell, 2003) asserting truth is "what works" (Howe, 1988). They choose approaches, as well as variables and units of analysis, which are most appropriate for finding an answer to their research question (Tashakkori and Teddlie, 1998). A major belief is that qualitative and quantitative methods are not at odds with one another; rather they are compatible and complementary. Thus, both numerical and non-numerical data collected sequentially or concurrently can help better understand the research problem.

The methods employed in this study included questionnaire surveys, semi structured interviews, oral histories, guided transect walk observations, structured observation and focus group discussions. Quantitative methods were used mainly for collecting data on exposure, vulnerability, sensitivity and adaptation strategies, whereas qualitative methods were used to obtain detailed and contextually grounded data (Nightingale, 2003) on farmers' perceptions and understanding on the concept of climate change, local environmental knowledge and farming methods and practices, coping and adaptation strategies, farmers' perceptions, priorities, preferences, attitudes and opinions about climate change and its impacts on agriculture-dependent livelihoods.

3.5. Sources of data

Data for this thesis were mainly collected either from primary or secondary sources. Secondary data were gathered from published scientific papers, journal articles, books, reports, unpublished manuscripts, workshop/conference and symposium papers. References were also made to maps and aerial photographs for Mwanga District in order to obtain secondary data. Similarly, other data and information from Non-Governmental Organisations (NGOs), with regards to improvement of livelihoods in the district and agricultural development activities, were gathered. Primary data were obtained from the field through questionnaire administration, face-to-face interviews, guided transect observations, oral history and structured observation which all aimed at providing an assessment of the vulnerability of agriculture-dependent livelihoods to climate change.

3.6. Sampling methods

Mwanga District has a total of 72 villages (37 lowland and 35 highland), which formed the village sampling frame (see Table 3.4). A simple random sampling method was used in selecting the villages for the study. In total eight villages were selected of which four were from highland and four from lowland areas. The selection of the villages was achieved through the use of table of random numbers. Because the total number of villages was less than 100, each village was assigned with two digit numbers beginning from 01, 02, 03…….35, 36, 37 for the lowland and 01, 02, 03,……..33, 34, 35 for the highland. Random digits from each table were selected to obtain eight sample villages. From the highland areas Sofe, Chanjale, Msangeni and Lomwe villages were identified and in the lowland Kisangara, Mbambua, Kiverenge and Kwakoa villages were selected.

The basic unit of the study was the household, and questionnaire surveys were directed to the head of the households, mostly men, who are usually the main decision makers at the household level. A comprehensive list of the households in each village was obtained from the village household's register to make up the sampling frame. Hence after identifying the population of each village, a sample of about 5% was identified and drawn from the population through the use of a systematic random sampling method. From a list of households in each village, every twelfth house on the household register was selected for interview until the sample size had reached an amount equal to about 5% of the total number of houses. However, to attain an equal number of respondents for both lowland and highland zones (117 each in the highland and lowland respectively) some of the villages provided more than 5% of the respondents depending on the village population (see Table 3.4). Through the help of the Village Executive Officer, Ward or Agricultural Officer the selected households were introduced to the researcher and then interviewed. A sample of 234 respondents was obtained from the eight villages.

It is important to note that some households owned farms in both highland and lowland zones. Clearly, responses from those owning farms in both zones required careful consideration since part of this research investigated major differences between the highland and lowland zones. Following the questionnaire survey, it was apparent only a very small minority of respondents interviewed worked both zones, and their responses were extracted from the main analysis to create a third group of farmers who owned farms in both zones (Table 3.5). However, this group was formed by 14 (about 6%) respondents and their influence in the findings was not significant. This is because the majority reported to have abandoned farming activities in the lowland due to erratic rainfall and repeatedly crop failure which makes them now concentrate more on the highland farms.

Table 3.4: Population and sampled households in each village

Study Site	Name of the village	Total number of households	Number of sampled households
Highland zone	Sofe	1,240	71
	Chanjale	180	10
	Msangeni	345	20
	Lomwe	271	16
Lowland zone	Kisangara	1,389	71
	Mbambua	230	12
	Kiverenge	441	23
	Kwakoa	228	12
Total		4,324	234

Table 3.5: Participants who owned farms in both zones

Study Site	Name of the village	Number of participants interviewed
Highland zone	Sofe	4
	Chanjale	5
	Msangeni	0
	Lomwe	5
Total		14

3.7. Questionnaire survey

A questionnaire survey formed an important source of quantitative data for this study. This was administered to individual heads of the households in the study area. The questions were both open and closed in order to capture facts and opinions of the households on issues related to the impacts of climate change on agriculture (i.e. the respondents' perceptions, priorities, preferences, attitudes and opinions on the problem under study). The technique is favoured because it enables the standardisation of the questions being asked and the answers recorded. This standardisation helps reduce errors that may arise from variations in the questions, thus providing greater accuracy and ease when processing the respondents' answers (Bryman, 2008).

The household questionnaire was divided into five sections (Appendix 1). Section A covered the socio-economic and personal household information especially with regard to age, sex, education, occupation, size and structure of the household and household sources of cash income. Section B of the questionnaire was designed to capture data on farm ownership, size, number of plots owned, main types of crops grown, number of people working on the farm, crops production trends, types and number of livestock owned and problems facing livestock keeping. Section C of the questionnaire covered farmers' knowledge and perceptions on local environmental knowledge experiences and practices in farming activities. In this category, the data collected concentrated on local farming methods, practices and knowledge on local environmental weather forecasts and predictions. Section D of the questionnaire was designed to capture farmers' general knowledge on the concept of climate, climate change and environmental variability. Information on farmers' knowledge on climate, impacts of climate change in agriculture-dependent livelihoods was gathered. Section E of the questionnaire was divided into five sub-sections which aimed at gathering information on farmers' perceptions on climate change, changes in farming practices, adaptation strategies, limitations on adaptation and factors affecting the use and existence of local environmental knowledge experiences and practices in farming activities.

In assessing farmers' perceptions on these issues, participants were presented with a pre-selected list of statements in a random order and asked to indicate how important each statement was. The importance of each statement was determined using a five-point scale, with 5 corresponding to ‘strongly agree’, 4 ‘agree’, 3 ‘not sure’, 2 ‘disagree’ and 1 to ‘strongly disagree’ with statement. The total score for a given statement was obtained by summing up all the corresponding unit scores, where the maximum score on any given factor was 5. With the total of 234 respondents, the maximum possible overall score was 1170 points (i.e. 234 multiplied by 5). Using the overall scores, statements could then be ranked.

3.8. In-depth interviews

In-depth interviews formed the main qualitative method of data collection in this study. This technique uses predetermined questions and topics, but allows new topics to be pursued as the interview progresses since most aspects of the interviews are informal and conversational, but carefully controlled (Grenier and International Development Research Centre, 1998). In-depth interviews were held with purposively selected key informants in the community and with government officials who held different positions from the district to the village level. The method helped in the identification of different impacts of climate change on rural livelihoods, traditional and planned coping and adaptation strategies and community involvement in the implementation of the national adaptation strategies. It further provided an opportunity to identify possible challenges that farmers encounter in coping with and adapting to climate change and variability, as well as the relevance of planned adaptation strategies. The method provided an opportunity to capture information which would be difficult to observe or obtain through the use of other techniques such as a questionnaire survey. Information such as the role of government in the management of farming activities under changing conditions, farmers’ reactions towards the implementation of different adaptation strategies and farmers’ vulnerability to climate change were obtained from the district officials. Hence 20 key informants were interviewed (Table 3.6).

Table 3.6: Interviews conducted with key informants at government, Village and NGOs in the study

Level	Position of the Participant	Number of the Participants
District	District crops officer	1
	District livestock officer	1
	District Natural resources officer	1
	District development and planning officer	1
	District land use and planning officer	1
	District forest official	1
	Kisangara Sisal Estate Manager	1
Ward	Ward Agricultural Extension Officers (WAEO)	4
	Ward Executive Officer (WEO)	4
Village	Village Chair Persons	5
Total		20

Similarly a total of 90 household farmers (45 in the highland and 45 the lowland zone) were interviewed. The in-depth interviews focused on issues such as farming methods, types of seeds used, storage techniques, local methods on weather indicators and predictors, local ways of determining soil fertility, amount of food harvested in different seasons, perceptions of respondents on planned adaptation strategies. As noted earlier, the procedure for recruiting the participants for the interviews was based on purposive sampling in order to capture the most reliable information, given the limited time for the study. Statistical representation of the in-depth interviews was not considered important in the selection of the participants for the interview, instead the study focused on capturing as much as possible, the reliability and depth of the information being provided by the respondents. Hence, in recruiting participants from the communities, contacts were first made with the village leader, Ward or Agricultural Officer through whom the other respondents within the respective communities were then recruited. Those selected were considered by the first contacts to be knowledgeable and experienced in issues concerning farming activities, climatic conditions and local knowledge, experiences and practices in the area. Some other participants were further identified to be suitable for the study by other participants who were already recruited. Finally, others were encountered on-site during field visits to places such the farms, brick manufacturing kilns and fodder collection sites. During some interviews several members of the household (e.g. wife and children) or group were present who also listened and commented during the interview.

The interview process was divided into three stages: pre-interview, interview, and post-interview stage. Identified respondents were notified prior to the interview, a time and place was agreed upon, informed consent was obtained prior to conducting the interview, and the results of each interview were transcribed immediately.

Interview durations varied from one respondent to another. Typically interviews lasted between 45 to 60 minutes, but some lasted as long as two hours. In most of the interviews conducted on-site (such as those on the farms or at the brick manufacturing sites), participants were more relaxed and enthusiastic in expressing themselves, citing evidence from real-life experiences at their workplaces. Some of the interviews conducted at home were interrupted by household activities, visitors and participants' tolerance level to continue with the interview. However, where these interruptions occurred, repeat interview sessions were rescheduled in order to enable such respondents to develop their views further. There were also a few exceptional cases where some participants were only willing to participate in the study if they could be paid or their village could benefit from food aid in exchange for the information they will provide. For example, participant MB17 said:

"…I am only willing to be interviewed if you will pay me or you promise that the study will lead to the village receiving food aid… you interview me and after finishing your studies you live better life from the information which I contribute to your studies while I remain here with my poverty. This is the only time I can benefit from your studies. So you give me money, I participate in the interview; no money, I am not going to participant in the interview…"

Similarly, Village Leader 03 said that:

"…these days, people know that when they participate in research, there are some payments, and considering that agriculture is not performing well, they use these opportunities to at least get some money for their daily needs… so when you call people for meetings like these they expect to be paid…"

This situation was handled by providing detailed explanations and evidence about the research which showed that the aim of the study was only for academic purposes. Thus the researcher stated clearly that no one would receive any benefits contingent by participating to the study. After the clarifications participants were willing to proceed with the interview.

Only four interviews were audio-recorded. A majority of the participants did not want the interview to be audio- recorded claiming that some people (researchers) do audio-recording and share their responses with other people who later mock them. They also claimed that the information gathered is used for making money in a different or the same project, especially among students studying abroad. Even when the researcher explained that the information could only be used for research purposes and would not be shared with anyone else, some participants still were reluctant. Some agreed but their behaviour and freedom in responding to the questions changed; they gave very short answers which implied that they were not comfortable to be audio-recorded. Hence, in such situations, notes from the interviews were taken. Some elders preferred their information to be audio-recorded for they considered everything they said to be relevant. They also valued face-to-face conversation and whenever the researcher was taking notes the interviewee stopped talking which affected the flow of the information and time spent for one interview. In such situations the audio-recorder was used to capture the information.

Table 3.7: List of in-depth Interviews conducted in the study

Study Site	Name of the village	Number of households	Number of participants
Highland zone	Sofe	1240	10
	Chanjale	180	10
	Msangeni	345	12
	Lomwe	271	13
Lowland zone	Kisangara	1389	12
	Mbambua	230	10
	Kiverenge	441	12
	Kwakoa	228	11
Total		4,324	90

3.9. Focus group discussions

This method was used to gather in-depth qualitative data from the farmers. The main advantage of this method is that it facilitates in understanding contentious issues that existed among the respondents during individual interviews, hence it facilitated in meeting consensus. It is recommended that the sample size for a group discussion should not be too big so as to be manageable and allow active participation of all members in the discussion; neither should the sample be too small (≥ five participants is acceptable) (Grenier and International Development Research Centre, 1998).

On the above basis, this study thus organised four focus group discussions (two each in the highland and lowland areas) with a maximum number of twelve participants in each discussion session. Participants were put into different discussion groups basing on the years that they have been involved in farming activities which enable participants to express themselves freely without intimidation due to age/status. The research adopted this type of group formation with the consideration that various sub-groups in the community are likely to have different views on an issue (Cadieux, 2008). This study did not form different groups of men and women as proposed by Oduol (1996) that discussion groups should be selected on the basis of gender, age, education status, and interests in order to increase the level of participation from each individual. For the case of this study, the majority of farmers attained primary education to a level of standard seven and above, and so there was very little difference in the levels of education. Secondly, all participants were farmers. Hence, both men and women formed one focus group discussion where they freely expressed themselves and challenged each other's views where necessary, without being intimidated by the factor of gender. For example, during focus group discussions in the lowland, a woman commented on the views suggested by a male participant who had suggested that people should grow drought resistant crop. The woman said:

"…Which are those drought resist crops that you are suggesting? Go to the farms and you will see cassava is drying, even those who planted sorghum will not harvest this year due to low rainfall received in this season. Let us suggest practical solutions that will benefit us and not just suggest things for the sake of saying so that you can be seen that you have also suggested. We need ideas that will help us survive…"

This method was useful as it gave participants an opportunity to think critically on the practical solutions towards managing farming activities under climate change conditions. It has been suggested that the use of focus group discussions is important for understanding the world as experienced and understood in the everyday lives of people "who live them out" (Crang and Cook, 2007). They allow groups of people to meet and discuss their experiences and thoughts about topics, not only with the researcher but with each other. Focus group discussions also provided an opportunity to develop a seasonal farming calendar, a historical timeline on experienced climatic hazards such as drought, floods and famine, indicators of local environmental weather forecasts and predictions, rainfall trends and variability and problems facing agriculture-dependent livelihoods, as well as identification of opportunities for action.

This gave the researcher the opportunity to experience the reality of life as expressed by participants during focus group discussions. Only members of the community aged 30 years and above were involved in the study with the assumption that younger people would have less experience of climate changes and farming activities, and also less relevant observational knowledge on the issues under study (Gyampoh et al., 2009). Through household surveys, participants who were knowledgeable about farming activities and environmental changes around them were invited to participate in the focus group discussions. They were issued with an official letter of invitation from the Ward office explaining the purpose, place, date and time for the meeting while others were verbally invited by the researcher. Other participants were suggested by the village Chairperson, Ward or Agricultural officer.

3.10. Structured observations

This thesis also employed structured field observations because it is more appropriate for fieldwork that occurs on a short timescale, as opposed to participant observation. This method was used to gather information which was not adequately explained during focus group discussions, household surveys and in oral histories. As argued by Kater (1993), structured observation is useful where interviews may not provide satisfactory results. Structured observation was undertaken through the creation of a pre-determined checklist of physical characteristics that require analysis. The checklist was used to capture on-farm practices on issues such as physical impacts of climate related hazards, agricultural land uses and farming practices, farm sizes, soil fertility level, and soil erosion. The study observed 50 farm plots (25 from each of the highlands and lowlands); 5 farm plots from each village were selected and observed. The criteria used in selecting the farm plots were not similar. For example, in the highland areas, most observations considered changes in the altitude which determined types of crops grown in a given farm plot and also the presence of the farmer on the farm who explained different farming practices. In the lowland areas, however, the case was different because most participants were not met on their farms. In addition to this, most farms were under similar conditions with the same type of crops grown on them. Observations were therefore made on those farms which had been cultivated by using a tractor and compared with those which were cultivated by using a hand hoe. In other areas where it was not possible to locate farms which were cultivated by a tractor, farm plots were then systematically selected in an interval of every 20 metres. Most of the data obtained from these observations were used in developing connections to important environmental conditions and farm management practices that farmers adopted on their farm plots. It also helped to observe the level of vulnerabilities of rural farmers to changing conditions. Frequencies of farming practices were developed and compared between lowland and highland areas. It was through this method that photographs of different physical environmental features, agricultural practices, crop types, land conservation methods and crop conditions were captured. Information gathered through this method reflected the actual prevailing situation in the study areas; such information is not influenced by the behaviour, intentions or attitudes of the respondents. All observations were recorded in detail in a field diary.

However, it was not possible to record the exact farm sizes as most farmers did not know the true size of their farms. In addition to this, since the study was conducted in the rural areas, farmers could not tell the monetary value of their farm lands.

3.11. Guided transect field walk observations

A transect walk is a tool used to obtain the description, location and distribution of resources, features, landscape, and main land uses along a given transect (World Bank, n.d). It involves a systematic walk along a defined path (transect) across the community or area of interest together with the local people to explore the environmental conditions by observing, asking questions, listening and looking at different features in the natural environment (INTERCOOPERATION, 2005: De Zeeuw and Wilbers, 2004). The method allows for discussion among the participants during the walk which helps in clarifying issues that are not clear and familiar to the researcher. The study organised ten systematic transect walks, one in each village and two along the Kindoroko and Kamwala Forest Reserves which helped in the verification of some of the data obtained from oral histories, focus group discussions and household interviews. Through this method, the researcher had an opportunity to explore and become familiar with the community and its inhabitants, and also gained an understanding and experience of the real situation under study (De Zeeuw and Wilbers, 2004; World Bank, n.d). As explained elsewhere (Grenier and International Development Research Centre, 1998), the transect walk method enables the outsider to quickly learn about topography, soils, land use, forests, watersheds and community assets.

In this study, the transect walk helped observe environmental impacts of climate change (dried watercourses, dried wetlands, declining water volume in the streams and rivers, extent of drought conditions revealed by crop failures), community vulnerability to climate change, adaptation strategies, livelihood practices, land-use and conservation practices, soil conditions and traditional farming methods. Meanwhile, the method also provided an opportunity to identify the names of the trees which are used to make weather forecasts and predictions, as well as to determine soil fertility level of farm plots.

The transect walks across a given area were always done with the assistance of either a village leader, ward officer, or a farmer who helped in the identification of the route, with the company of three experienced farmers (or elders) who were familiar and knowledgeable about environmental conditions and farming activities, and were willing to accompany the researcher for the walk during which they had an opportunity to emphasise and support their responses with evidence on the existing environmental conditions. On some occasions, the researcher was accompanied by a botanist who helped provide the scientific names of the trees, grass and shrubs as they were being identified and named by the participants in their native language. In most situations, the district natural resources and forest officer provided their expertise on this.

During the transect walks, the researcher asked questions and paid attention to the explanations given by the participants, observed environmental conditions and made notes in the field note book. The gathered information was used in complementing the data from interviews, focus group discussions and oral histories. Furthermore, during transect walks, the researcher had an opportunity to conduct interviews with the farmers who were met during the walk and provided their views on the problem under study as observed on the spot. Most transect walks lasted for two to three hours on average; however, due to the interviews that were being conducted during the walks, some transect walks lasted for up to six hours.

3.12. Oral histories

This method employed in-depth interviews in which participants were asked to recall events from the past and to reflect on them (Bryman, 2008). The study used open-ended questions, hence giving participants a chance to explain their opinion; this prevented any possibility of participants saying what they thought the researcher wanted them to say. The method provided detailed accounts on how changes in natural environmental conditions and farming activities have occurred over time and how farmers have managed to cope with these changes. Through this method, in-depth information on past and present climatic hazards such as drought and famine incidences, knowledge on local weather forecasts and predictions, types of traditional pesticides and farming knowledge (e.g. types of soil and determinants of soil fertility) were obtained and discussed during the oral histories interview.

The temporal scale of the data collected on climatic trends focused on the last 20 to 30 years (1980/1990-2010) although some participants were able to recall some incidences that occurred earlier than 1980. However, the use of 30 years is recommended (Elliott and Campbell, 2002) because it is the time scale generally considered within the range of human memory. Participants who were chosen to participate in this method were relatively old people, who had ~30 years of involvement in farming activities and could attest to noticeable changes in rainfall, temperature and farming activities. The requirement for inclusion was that during household surveys, elders who were found to be knowledgeable about farming activities and environmental changes and who were cooperative and enthusiastic about the study were chosen to participate in the oral histories interview. Some others were identified by their fellow participants who considered them to be more conversant in the problem understudy.

In qualitative research, a smaller sample size discussion is usually believed to provide in-depth information than a larger sample size (Creswell and Clark, 2007). Therefore, six individual elders from each zone were involved in the oral history interviews. Data from the interviews were coded and compared. The method was preferred as it depends on the ability of the participant to remember events which occurred in the past and are not available in written documentation thus provided a broader view on how farming has changed over time and also provide past climatic hazards which occurred in the area.

3.13. Data analysis

Data analysis started with organisation of the data from transcription of the audio-recorded interviews, field work notes from transects walk, structured observations, oral histories, and focus group discussions. The information was analysed through coding which involved systematic examination of the text in order to identify phrases, sentences and passages that represented different conditions, phenomena and opinions as expressed by different participants during the field work. These descriptive passages and phrases were then used in making comparisons, trends and differences that existed between highland and lowland zones. Hence interpretation was done by relating the information obtained with key themes in the study (Weiss, 1995). The reliability of the qualitative data was checked by using triangulation methods which uses various techniques to check the authenticity of the same information.

Similarly, rainfall and temperature data from the study area were filtered, and outliers and breaks were removed before obtaining total annual averages for both rainfall and temperature. The annual average totals were used to obtain the mean minimum and mean maximum values which were used in presenting rainfall and temperature trends for the study area. The mean value reduces most of the statistical errors that may have occurred in the annual average values for each year.

The household questionnaire with data on age, size and structure of the households, educational level, occupation, sources of income, land ownership, types of crops grown, number of labourers working on the farm, farmer's knowledge on climate change and local environmental knowledge were verified to ensure consistency in the findings. Data were analysed through the use of the Statistical Package for the Social Sciences (SPSS). Data entry was done by using EpiData software which helped in the management of the data gathered. After data cleaning, the data were analysed and summarised into various categories, and relationships were assessed; the data were also presented in frequency tables, charts and graphs. For comparison purposes, percentage scores for different variables were calculated and comparisons made between lowland and highland zones. Using the Likert scoring method, point scores from the respondents were calculated for each statement and ranked to determine the order of importance of the statements between zones. The overall rank score was obtained by adding up all the scores from all participants and the total score expressed as a percentage of the maximum possible score for all the factors. Based on the overall scores, the statements were ranked in order of their importance as determined by the weights of the responses. The formula (1) below was used to calculate the overall Likert scores for the statements:

where S_c is the overall rank score for a given statement, n_i is the number of responses for a statement of weight i (where i = 1, 2, …, 5), 5N is the highest score assuming all respondents strongly agreed with a given statement (where i = 5), and N is the sample size.

3.14. Research and methods limitations

Although the methods used in this study provided a comprehensive overview of the problem under study, however, there is no data collection technique which is error free as each technique has its weakness (Jick, 1979; Thorlakson, 2011). The limitations arise from the nature of field research and limited amount of time to conduct research. A single field visit and in one farming season may sometimes not give a reality of farming conditions as weather changes over seasons and it may be that the time when this study was conducted was the season with bad weather conditions. However, this was managed through consultation of literature on study conducted in the area.

A possible technical limitation from employing focus groups/oral histories was the introduction of biases rising from confident or outspoken individuals within one group. Persons with particularly strong beliefs and attitudes on a number of topics sometimes dominated the conversations and limited the input from other quieter individuals. This could potentially bias the results towards the opinions of an individual rather than representing the larger population. When this situation arose, it was noted and care was taken by limiting the time for the participant, and also during data interpretation the results of such individuals were compared to field observations and secondary data. Similarly, participants may also have over-exaggerated or understated responses with the expectations of benefiting from the study expecting benefits by responding to the research questions. To limit such bias all discussions begun with the clarifications on that the study was aimed which was for academic purposes and not otherwise so no participant would receive any benefits contingent by responding to a given survey questions. Similarly farmers' perceptions on climate change parameters, e.g. rainfall and temperature, and increasing drought conditions were corroborated with rainfall and temperature data obtained from meteorological agency and data from observations.

The research encountered some logistical problems, such as transport. Highland areas are largely accessible, mini buses commute from the highlands to the lowland zone, mostly to Mwanga town very early in the morning and back during the evening. This was the same also to Kwakoa village which is in the lowland, which meant the researcher was undertaking research at times when a proportion of the population has left the highland zones. The only available transport for the researcher was by motorbike, commonly known as *boda-boda* in Swahili. The researcher had to hire a motorbike to and from the highland zones and Kwakoa village, which took a maximum of five hours round trip. This was expensive in terms of both time and money. However, setting of appointments earlier in advance with the Village and Ward Executive Officers or Agricultural Officers helped in organising before the arrival of the researcher. Negotiations and bargaining with motorbike drivers also helped out transportation costs. The rest of the lowland villages are located along the main road from Dar es Salaam to Arusha hence transport was not a problem.

The study allowed the use of both Swahili and vernacular languages which gave participants freedom to express themselves. Most of the elders preferred their mother tongue to Swahili. However, there were several instances when terminologies, names of trees, plants and seasons were difficult to comprehend and had to be translated in other languages particularly Swahili and English. Similarly, during interviews some of the respondents were more elaborative than others, thus the interview process took a longer time which reduced the number of interviews due to limited time period of data collection. This was managed by asking some of the interview questions during focus group discussions.

Another limitation relates to the research data presented in this thesis since these may be constrained due to limited availability and access, as well as time constraints in the field. For instance, some of the information about the study area is not published online which means it could only be accessed while in the study area. Such information includes government and district reports, academic and researchers' work on climate change impacts, agriculture and agricultural climatic adaptation strategies and limitations, indigenous farming knowledge and climate change adaptation policies and mitigation strategies. However, it is important to note that this study aimed at capturing farmers' knowledge and perceptions on climate change impacts, agricultural adaptation strategies, limitations and indigenous farming knowledge; thus the researcher found it to be of greater importance to spend more time with farmers in the field in order to capture this information as it cannot be obtained from the government and district reports. Similarly, some of this information was not available even if the researcher could have spent more time in the field. For instance, rainfall data and temperature were only available for the past 42 and 30 years, respectively; changes in crop prices were only available for the past three years, while crop production trends were not available at all. However, if there were more time and data available and accessible, this study would have benefited from a longer range of data and information for the above mentioned areas.

Chapter 4

Knowledge and perceptions of small-scale farmers on climate change and climate variability

4.1. Introduction

This chapter presents the findings from and discussion of the knowledge and perceptions of the small-scale subsistence farmers on climate change and climate variability and their effect on agriculture-dependent livelihoods. The chapter in particular will analyse households' perceptions of climate change and climate variability, and identify the local indicators of the effects of environmental changes and how these changes affect households' agriculture-dependent livelihoods. Although climate change is a global phenomenon causing serious impacts and threats to development, agricultural systems and food security (Thornton et al., 2010), the impacts are more seriously experienced at the household level (local level) rather than at national or regional levels. Discussing the adaptation strategies by small-scale farmers is the task in Chapter Six.

This chapter begins by presenting the demographic characteristics of the respondents, followed by the knowledge and perceptions of the farmers on the concept of climate change, and perceived courses of climate change. The last section will provided the observed physical impacts of climate change on agriculture-dependent livelihoods.

4.2. Characteristics of the respondents

Important demographic characteristics of the households interviewed in the study include age, sex, education level of the head of household, occupation and the size of the household. The study involved households who had experience in farming activities of not less than fifteen years, hence the minimum age in this study was 30 years. The study assumed that a farmer who has been involved in farming activities for the past 10 years could have gained sufficient knowledge and experiences in farming activities and the environment and thus could demonstrate possible changes that have taken place in the area and in farming activities. Thus, heads of households whose age was below 30 were considered to have less knowledge and experiences in farming activities as well as fewer relevant observations in environmental changes (see also Gyampoh et al., 2009). About 64% of the households interviewed were male and 36% were female (Table 4.1). Gender characteristics was not considered to influence the findings of this study as in most cases during the household interviews several members of the households (e.g. wife and children) were available, hence both contributed their views to the questions asked.

Table 4.1: Characteristics of the respondents

Variable	Highland Zone		Lowland Zone		Total	
Number of	No.	%	No.	%	No.	%
households interviewed	117	50	117	50	234	100
Sex						
Male	77	65.8	73	62.4	150	64.1
Female	40	34.2	44	37.6	84	35.9
Age Group						
30-39	15	12.8	18	15.4	33	14.1
40-49	35	29.9	42	35.9	77	32.9
50-59	24	20.5	31	26.5	55	23.5
60+	43	36.8	26	22.2	69	29.5
Occupations						
Farmer	110	94.0	107	91.5	217	92.7
Business	1	0.9	7	6.0	8	3.4
Employee	6	5.1	3	2.6	8	3.4
Education level						
Adult education	15	12.8	6	5.1	21	9.0
Primary	68	58.1	84	71.8	152	65.0
Secondary	25	21.4	21	17.9	46	19.7
College	6	5.1	4	3.4	10	4.3
University	3	2.6	2	1.7	5	2.1

Of the household heads, about 93% were farmers, 3% were involved in small business activities and about 3% were employees. About 65% of household heads had attained primary level (seven years in schooling) of education. On average, about 20% of household heads had secondary education, 9% had attained adult education, 4% had college education and about 2% of the household heads had attained University education. The findings show that almost all participants had attained some level of education which depicts the real situation of education status in each zone. The level of education shows that the majority of the participants were literate which is also supported by the household population census of 2002, which showed that the Mwanga District literacy rate was 86% for men and 83% for women, and the net enrolment in school was 90% for boys and 91% for girls. Of all the households interviewed, the average family size was five persons in the highlands and six in the lowland zone, with a maximum of six and nine persons in the two zones respectively (Table 4.2).

Table 4.2: Mean family size by zone and sex

Variable	Zone	Mean	95% CI for Mean		Min	Max
			Lower Bound	Upper Bound		
Male	Highland	2.6	2.3	2.8	0	6
	Lowland	2.8	2.6	3.0	0	6
Female	Highland	2.6	2.4	2.8	1	6
	Lowland	3.0	2.7	3.3	1	7
Family size	Highland	5.1	4.8	5.5	1	9
	Lowland	5.8	5.5	6.2	1	9

Moreover, the findings show that at least every household interviewed had a person living away from the village with an average of 4 persons in the highlands and 3 persons in the lowland zones, with a maximum of 7 and 9 persons respectively (Table 4.3).

Table 4.3: Mean number of people living away from the village by zone and sex

Variable	Zone	Mean	95% CI for Mean		Min	Max
			Lower Bound	Upper Bound		
Male	Highland	2.2	1.9	2.5	0	7
	Lowland	1.8	1.5	2.0	0	6
Female	Highland	1.3	1.1	1.6	0	5
	Lowland	1.2	1.0	1.4	0	5
Family size	Highland	3.5	3.1	3.9	0	9
	Lowland	3.0	2.5	3.4	0	9

4.2.1 Land ownership and distribution by zones

Land forms the most important resource for the rural livelihoods since life in the rural areas depends on it for survival and its ownership describes the wealth and status of the family. The findings indicate that all heads of the households who participated in the study owned land with the average of 4.4 farm plots in the highland zones and 3.7 in the lowland zones, with the maximum of 10 plots in both zones (Table 4.4).

Table 4.4: Mean number of farm plots owned by zones

Variable	Sub variable	Mean	95% CI for Mean		Min	Max
			Lower Bound	Upper Bound		
Zone	Highland	4.4	4.1	4.7	2	10
	Lowland	3.7	3.3	4.0	1	10

However, the majority of the participants who owned farm plots with a size less than 2 acres (62%), between 2-3.9 were 29%, between 4-4.9 were 6% and greater than 6 acres were 4% (Table 4.5). The findings show further that most of the farm plots are less than 2 acres which may affect household food production in the study area.

Table 4.5: The size of farm plots by zones

Variable	Land Size in Acres							
	<2		2-3.9		4-4.9		> = 6	
Zone	**No.**	**%age**	**No.**	**%age**	**No.**	**%age**	**No.**	**%age**
Highland	77	65.8	31	26.5	5	4.3	4	3.4
Lowland	67	57.3	37	31.6	8	6.8	5	4.3
Total	144	61.6	68	29.0	13	5.6	9	3.8

4.2.2 Types of food crops grown by farmers

During the interview, 12 crops were reported as being cultivated by farmers in the different zones of the study area (Table 4.6). Maize was cultivated by all participants in both zones, followed by beans (72%). However, bananas (100%) and yams (87%) were grown by highland farmers, while cowpeas (38%) sorghum (32%) and green grams (22%) were grown by significant numbers of lowland farmers. Crops such as cassava, groundnuts, sweet potatoes and sunflowers were reported to be cultivated by less than 10% of the households surveyed.

Table 4.6: Types of crops grown by respondents by zone

Type of crop	Overall	%	Highland		Lowland	
			No.	%	No.	%
Maize	234	100.0	117	100.0	117	100.0
Beans	169	72.2	117	100.0	52	44.4
Banana	120	51.3	117	100.0	3	2.6
Cocoyam	87	37.2	87	74.4	0	0.0
Cowpeas	44	18.8	00	0.0	44	37.6
Sorghum	32	13.7	0	0.0	32	27.4
Green grams	27	11.5	1	0.9	26	22.2
Sugarcanes	24	10.3	16	13.7	6	5.1
Cassava	14	6.0	5	4.3	9	7.7
Groundnuts	16	6.8	2	1.7	14	12.0
Sweet potatoes	12	5.1	12	10.3	0	0.0
Sunflowers	11	4.7	5	4.3	6	5.1

4.2.3 Livestock

Keeping of livestock is one of the important livelihood activities carried out by farmers in Mwanga District. Livestock are mainly kept for farmyard manure (to apply in the homestead farms of banana and coffee), to provide milk for household use and as a source of cash earning from the sale of milk and the animals themselves. Major types of the livestock kept by farmers in the study area are cattle, goats, sheep, pigs and chicken. Cattle were kept by highest number of households (81%), followed by chickens (71%), goats (53%), sheep (38%) and pigs (6%). The percentage of cattle and chicken was higher among the highland than the lowland participants (Table 4.7).

Table 4.7: Distribution of livestock kept by zone

Animal	Overall	%	Highland		Lowland	
			No.	%	No.	%
Cows	189	80.8	112	95.7	77	65.8
Goats	124	53.0	56	47.9	68	58.1
Sheep	89	38.0	43	36.8	46	39.3
Pigs	14	6.0	9	7.7	5	4.3
Chickens	167	71.4	109	93.2	58	49.6

Lowland farmers kept large herds of livestock which grazed freely in the rangelands while in the highland areas farmers kept fewer livestock under zero-grazing system (Table 4.8). The overall average number of cattle was 7, with 4 (2.7-4.5) in the highland and 11 (8.2-13.5) in the lowland areas; goats were 11.9 with 8 (5.3-7.9) and 12.8 (9.6-16) per household, sheep was 8 with 6 (4.8-7.2) and 11 (7.9-13.0) per household, pigs was 5 with 3 (1.8-3.9) and 9 (2.3-21.1) per household and chickens were 11 with 11 per household in both zones respectively. Livestock keeping is discussed in detail in the proceeding sections.

Table 4.8: Distribution of mean of livestock kept by zone

Animal	Overall mean	Highland	Lowland
Cattle	6.6	3.6 (2.7-4.5)	10.9 (8.2-13.5)
Goats	11.9	8.4 (5.3-7.9)	12.8 (9.6-16)
Sheep	8.2	6.0 (4.8-7.2)	10.5 (7.9-13.0)
Pigs	5.2	2.9 (1.8-3.9)	9.4 (2.3-21.1)
Chickens	10.8	11.0 (9.7-12.3)	10.5 (8.7-12.2)

4.3. Knowledge and understanding of climate change

Changes in climatic conditions and environmental variability are of particular concern because they affect food production, water availability and employment opportunities for the agriculture-dependent communities, particularly in developing countries, where farming activities depend on the natural environment (Henson, 2011; Collier et al., 2008; Rosenzweig and Hillel, 1995; IPCC 2001; 2007; Kangalawe, 2012). This section presents the knowledge, perceptions and understanding of the concept of climate change by small-scale farmers in Mwanga District in Kilimanjaro region. The findings reveal that despite changes occurring in the environment the concepts of “climate” and “climate change” are understood but perceived differently by different people at varied levels in the community. The majority of the respondents interviewed in the selected villages in the study area (both lowland and highland zones) demonstrated high degrees of knowledge, awareness and understanding of the concept of climate, climate change and the likely causes of climate change on their local environments. The majority of the participants understood the concept of climate as rainfall (100%), temperature (100%), wind (71.8%), drought (70.5%), cold (54.7) and flood (33.8%). The results show that out of 234 respondents 181 respondents, equivalent to 77.4%, were aware of the factors responsible for climate change where they associated the causes of the changing environmental conditions with increases in environmental degradations, deforestation, forest fires, expansion and intensification of agriculture activities in the highlands and air pollution. The results revealed further that the proportion of the respondents who were aware of climate change was higher in the highland zone than in the lowland zone (Figure 4.1). However, about 22.6% of the surveyed households did not have a clear knowledge and understanding about the causes of climate change, instead they associated climate change with social, religious and cultural factors. Similarly, the level of awareness was higher among respondents within the aged group of 40-49 then followed closely by the 50-59 age group (see Figure 4.2). The higher level of understanding of the knowledge of climate change with the varied reasons responsible for the changes may be attributed to increased levels of literacy among the respondents in the study area, increasing numbers of education activists and NGOs advocating for climate change where the majority of the youth are involved in the education process on adaptation strategies and the role of media (radio, newspapers and television), as almost every family has access to a radio and increased levels of literacy among the youth in the study area. However, the declining level of understanding of the true causes of climate change, especially among the elders age 60 and above, may be attributed by higher levels of illiteracy and too much adherence and attachment to the traditional and cultural values of the society. Some of these traditional and cultural values can act as a barrier to the effective implementation of climate change adaptation strategies and mitigation measures. For instance, the belief that climate change hazards, such as drought and floods, are associated with God (see also White et al., 2001) may limit the effective implementation of agricultural climatic adaptation strategies. As for the study area when flood or drought occur, some people implement the right adaptation strategy while others take it for granted as a punishment from God. This affects its management due to lack of common understanding of the causes of such disasters.

Figure 4.1: Knowledge of the causes of climate change by zones

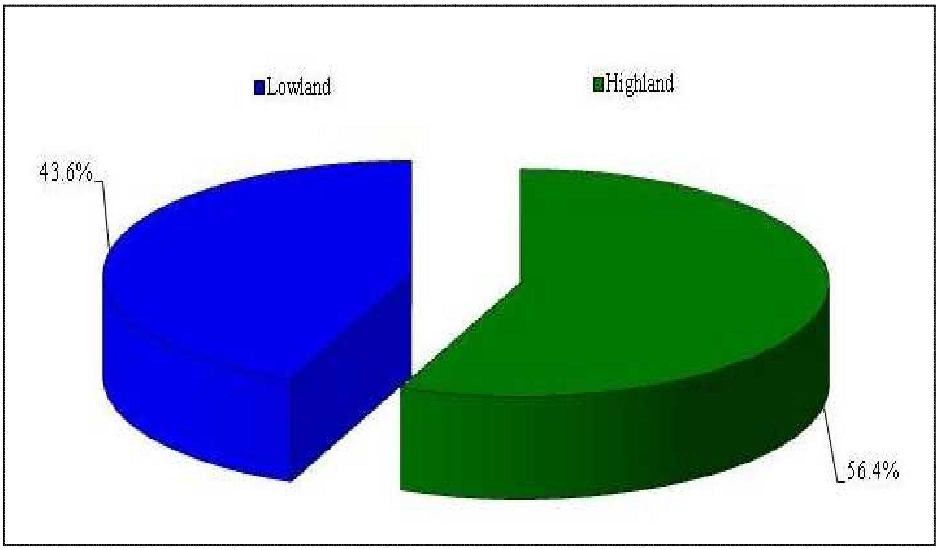
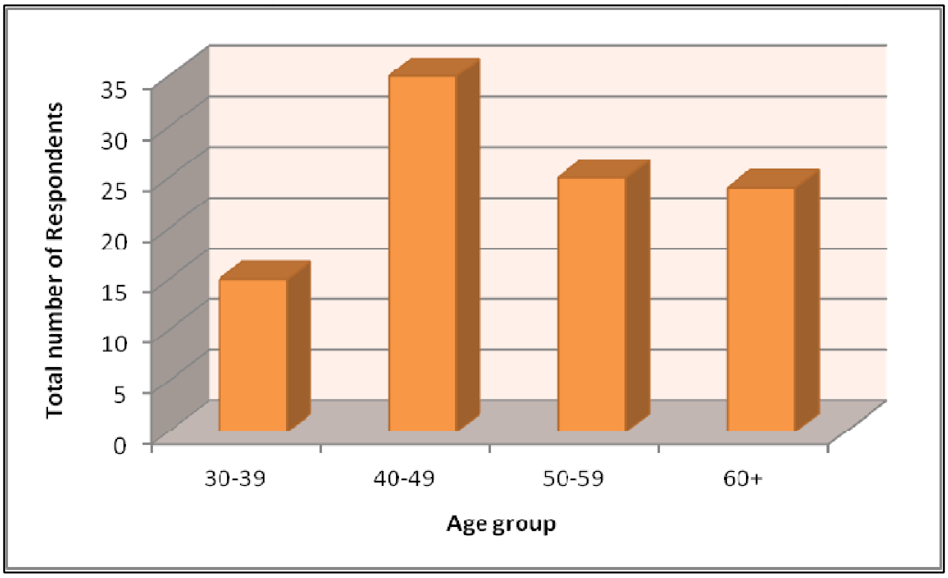


Figure 4.2: Knowledge of the causes of climate change for all percipients by age group



4.3.1. Local perceptions and indicators of climate change

The findings in Tables 4.9, 4.10 and 4.11 suggest that there is a growing understanding among farmers that climate change and climate variability are happening and are continuously affecting their livelihoods which depend on agriculture. The study shows that households understood the indicators of climate changes as increase in drought, increased temperatures, decline in rainfall, decrease in water, increase in pests and shorter planting and growing seasons which had the highest responses from the majority of the respondents; weather variability, increases in wind conditions, animal diseases and the occurrence of floods had the lowest responses (Table 4.9).

Table 4.9: Percentage responses on the local indicators of climate change by zones

Local indicators of climate change	**Overall %**	**Highland (n = 117)**		**Lowland (n = 117)**	
		Number	**%**	**Number**	**%**
Increase in drought	100.0	117	100.0	117	100.0
Increase in temperature	100.0	117	100.0	117	100.0
Food shortage	77.4	91	77.8	90	76.9
Decreases in crop productivity	75.6	96	82.1	81	69.2
Decline in rain fall amount	73.9	91	77.8	82	70.1
Decrease in water	69.7	72	61.5	91	77.8
Increase in pests	67.1	89	76.1	68	58.1
Short planting/growing season	62.8	87	74.4	60	51.3
Weather variability/unpredictability	33.8	53	45.3	26	22.2
Increase in wind conditions	32.5	28	23.9	48	41.0
Increase in animal diseases	19.7	11	9.4	35	29.9
Occurrence of flood	6.8	10	8.5	6	5.1
Others*	33.8	53	45.3	26	22.2

NB: Others*: Seasonal changes, disappearance of morning dew and mountain clouds, and disappearance of bird species

Table 4.10: Perceptions on climate change over the past 20 years by highland farmers

Statement on perception	5	4	3	2	1	Total Score	Score as % of the max
Drought period seems to be longer	550	28	0	0	0	578	98.8
Rainfall seems to be less	525	48	0	0	0	573	97.9
Average temperature seems to be higher	525	48	0	0	0	573	97.9
Rainfall seems to be more variable	540	24	9	0	0	573	97.9
Decrease and drying of water	480	84	0	0	0	564	96.4
Weather seems to be unpredictable	475	88	0	0	0	563	96.2
Loss of crops seem to be higher	460	100	0	0	0	560	95.7
Fodder seems to be less	480	76	0	4	0	560	95.7
Growing season seems to be shorter	440	96	15	0	0	551	94.2
Pests and crop diseases have increased	340	52	108	0	0	500	85.5
Declining and loss of wetlands	90	272	93	0	0	455	77.8
Livestock diseases have increased	0	52	162	66	17	297	50.8
Soil erosion is a bigger problem now	0	12	12	174	23	221	37.8
Death of livestock have increased	0	12	39	90	56	197	33.7
Rainfall seems to have increased	0	0	0	112	61	173	29.6
Floods seems to be more frequent	0	0	0	82	76	158	27.0

Note: Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1

N = 117

Maximum score (117*5) = 585

Table 4.11: Perceptions on climate change over the past 20 years by lowland farmers

Statement on perception	5	4	3	2	1	Total Score	Score as % of the max
Drought period seems to be longer	585	0	0	0	0	585	100.0
Average temperature seems to be higher	585	0	0	0	0	585	100.0
Rainfall seems to be less	585	0	0	0	0	585	100.0
Growing season seems to be shorter	585	0	0	0	0	585	100.0
Decrease and drying of water	575	8	0	0	0	583	99.7
Rainfall seems to be more variable	565	16	0	0	0	581	99.3
Loss of crops seem to be higher	535	40	0	0	0	575	98.3
Declining and loss of wetlands	435	120	0	0	0	555	94.9
Deaths of livestock have increased	435	120	0	0	0	555	94.9
Fodder seems to be less	230	284	0	0	0	514	87.9
Weather is more unpredictable	280	148	6	44	0	478	81.7
Pests and crop diseases have increased	0	64	96	112	13	285	48.7
Livestock diseases have increased	0	0	135	30	57	222	37.9
Soil erosion is a bigger problem now	0	44	0	24	94	162	27.7
Floods seems to be more frequent	0	4	0	50	91	145	24.8
Rainfall seems to have increased	0	0	0	0	117	117	20.0

Note: Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1

N = 117

Maximum score (117*5) = 585

4.3.2 Drought indicator

Virtually all the respondents identified the increase in drought conditions as one of the indicators of climate change and environmental variability (Table 4.9). Drought was also perceived to have increased over the past 20 years and ranked highest in both zones (Table 4.10 and 4.11). Focus group discussions and interviews revealed that in the past drought incidences occurred, but they were rare and their occurrence took a sequential series over time to the extent that farmers were able to predict when another incidence of drought would occur. The drought incidences in the past were reported to occur about every 10 to 15 years (see Table 4.12 where the drought name represents the coping strategy opted for during that particular drought). However, the study revealed that, the majority of the participants perceived that in recent years, drought conditions have become more frequent and intense especially since the 1980s. Discussions with the participants suggested that drought conditions in recent years occur almost in every season, or in consecutive years which result in increased crop failures and food shortages at the household level. The study also observed intense drought conditions, especially in the lowland zones, as shown in Plates 4.1 to 4.4.

Table 4.12: Famine incidences occurred in the study area

Year	Name of the famine	Meaning of the name as a representation for the coping strategy
1920	*Nzota ya Kigogo*	Indigenous people fed on bulb of plantains which are known as *kigogo* (in vernacular)
1930	*Nzota ya Mkebe*	Food was so scarce especially maize grain and or maize meal which is the main staple food and the only amount that one would get was measure by a container known as *Mkebe* (in vernacular) which is equivalent to 1 kg
1944-1949	*Nzota ya Mbiru*	Famine incidence occurred in this time when people were paying tax according to the property owned by the household (wealth possessed), hence famine was named after the local name for the tax known as *mbiru*
1960-1961	*Nzota ya Kilombero*	Drought forced many people to migrate to Kilombero district in Morogoro region to work in sugarcane plantations for wage labour, while others had access to land and cultivated maize which was sent to their families back home
1974/75	*Nzota ya Yanga*	People received yellow corn meal as food aid from America. The colour of the corn meal (yellow) is among the colours of a popular football club in the country (Young African Club) and hence this famine was named after the name of the club
1984	*Nzota ya* Bulgur (Alianza/alianca)	People received bulgur wheat and cooking oil called *alianza* and *alianca* as food aid from America hence the famine was named after the names of the food aid

Plate 4.1 Wilting maize at Kiverenge village in Kisangara Ward

Plate 4.2 Maize failing to germinate at Ibweijewa in Kisangara ward

Plate 4.3 Wilting maize after germination at Kisangara Village in Kisangara ward

Plate 4.4 Dried Sorghum at Mbambua Village in Kisangara ward

The study revealed further that due to the frequent occurrence of drought conditions, some of the highland farmers have abandoned farming activities on their lowland farms and now are concentrating on highland farm plots only. This finding is supported by the findings from other studies, such as Collier et al. (2008) and Rosenzweig et al. (2001), which suggest that drought conditions caused by climate change will make some areas unsuitable for farming activities, resulting in reductions in farming land and also may force out of production some food crops. Farm plots' observations in the lowland revealed that prolonged drought conditions have made many of the perennial crops and non-staple crops such as cassava, sugarcane and banana difficult to grow, leaving most farm plots bare and prone to wind erosion. Similarly, during focus group discussions, it was revealed that prolonged droughts make it is easier for termites to feed on those crops, and also due to shortages of fodder force livestock herders to graze their herds on the farms. Grazing livestock on the farms increases soil compaction which limits the infiltration of water during the rainy season, while the thin fertile surface layer of the soil is loosened by animal hooves and is regularly eroded by wind action. In the highlands, prolonged drought conditions were reported not only to cause crop failure, but they also have resulted in the recurrence of fire events in the forest reserves, causing a reduction in water flow and even the disappearance of vegetation cover and an overall decline in the forest thickness. This finding on the occurrence of drought conditions has been suggested in other studies that climate change will result into increased drought conditions particularly in Africa (Rosenzweig et al., 2001; Collier et al., 2008; Hulme et al., 2001), and the impacts will be severe due to increased reliance on rain-fed agriculture with only a limited capacity to invest in coping and adaptation strategies (IPCC 2007; Stern, 2007). However, the IPCC (2007) reported that warming of global climate will result in a gradual increase in global temperatures which will result in an increased frequency of extreme weather events, including drought.

4.3.3 Temperature indicator

Increase in temperatures is another indicator of climate change and climate variability as reported by the majority of the respondents (100%) and also ranked highest in both zones (Tables 4.10 and 4.11). Many respondents shared the views that in recent years they have noticed an increase in the intensity of sunshine which influences the surface temperature in their localities, in both the lowland and highland zones. Daily temperatures are perceived to have increased which also leads to an increase in the evening to midnight temperatures. Respondent KS01 at Ibweijewa was quoted saying that:

"…nowadays, days and nights are very hot that I even do not bother to use a bed sheet or blanket to cover myself during the night, probably early morning hours is when I bother looking for it…"

Respondent KS02 in the same area said that:

"…nowadays the solar intensity has increased to the extent that at 10 am the sun is strong and 'stings' like that of the afternoon and mid-day…"

Making references from the radio and television, one of the participants during the focus group discussions in the lowlands reported that:

"…it was broadcasted in the radio and television that the temperature in the district had escalated from the normal 20°C and 28°C in March to 36°C…"

While Respondent CH14 reported that:

"…nowadays there is no difference between lowland and highland temperatures, we now all experience almost the same degrees of heat and sunshine…"

However, the majority of the respondents during focus group discussions and household interviews in the highland zone perceived that temperatures have increased almost three times than in the past. Respondents' perceptions on temperature seem to be supported by the meteorological data for Kilimanjaro region (Figures 4.3 and 4.4) which show that both the annual mean minimum and maximum temperatures have been increasing steadily since 1980 to 2012, however with fluctuations. Similar observations have been made elsewhere in Tanzania and East Africa in general (Kangalawe, 2012; Mary and Majule, 2009; Munishi et al., 2010; Jury and Mpeta, 2005), and also different climatic models suggest that climate change will result in increases in temperature in the African continent (Sivakumar et al., 2005; Hulme et al., 2001; IPCC 2001). Temperatures in African continent have increased by approximately 0.7°C in the past 20th century

(Intergovernmental Panel on Climate Change (IPCC), 2007; Sivakumar et al., 2005; Hulme et al., 2001).

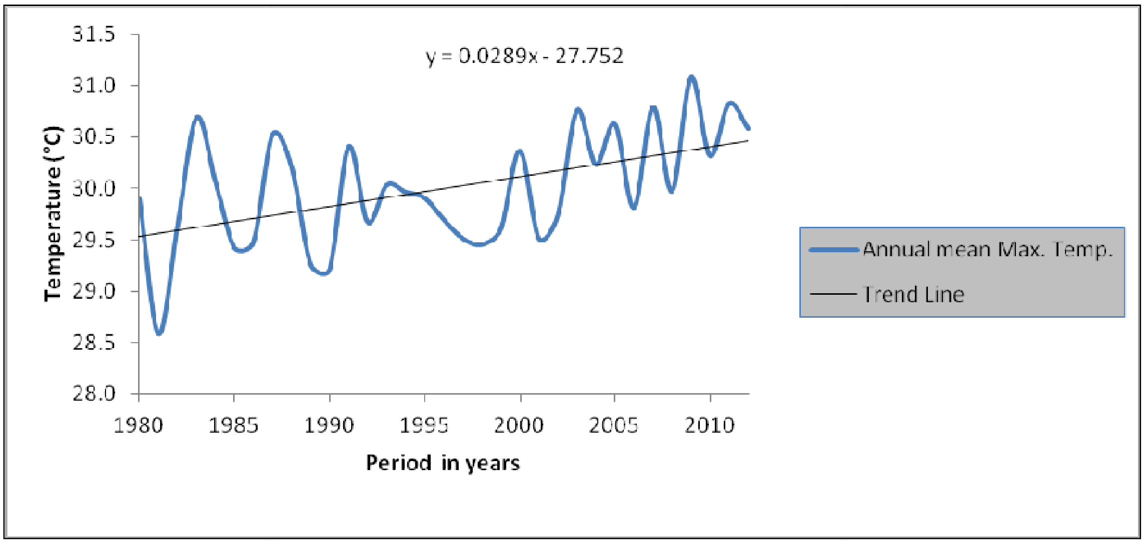


Figure 4.3: Annual mean maximum temperatures for Kilimanjaro region from 1980 to 2012

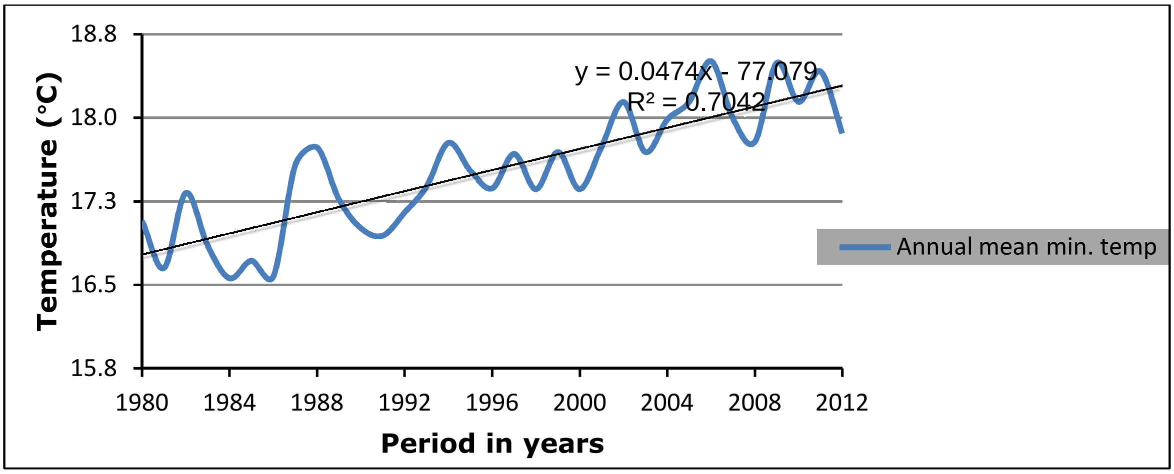


Figure 4.4: Annual mean minimum temperatures for Kilimanjaro region from 1980 to 2012

4.3.4 Rainfall indicator

The majority of the respondents (74%) (Table 4.9) mentioned a decline in rainfall as an indicator of climate change, suggesting that currently they have noticed a bigger decline in rainfall and an increase in rainfall variability, duration and intensity. This was also evident during in-depth interviews, focus group discussions and oral histories where participants agreed that currently rainfall has become highly variable, low in volume and higher in intensity. However, on perceptions, the statement ranked second in the highlands, with 97.9%, and third in the lowlands with 100% in the overall cumulative scores of the responses. During focus group discussions, the study revealed that fluctuations, decline and variability in rainfall started gradually from 1980s, however, from the 1990s to present the conditions have become more marked. Participants were of the view that since 1990, both lowland and highland areas in all seasons have regularly not received sufficient rainfall to support farming activities sufficiently. However, some seasons receive light or heavy rains which are concentrated within a short duration of time which do not adequately support the growth of crops from germination to maturity stage. Using the volume and flow of water in the rivers and streams as the determinant of the volume and intensity of the rainfall, Respondent OH03 said that:

"…currently the amounts of rainfall received do not substantially change the volume of water in the rivers and streams in either the highland or lowland zones..."

While comparing the current situation with the past, respondent further explained that:

"…in the past it used to rain heavily until rivers and streams were overflowing and crossing the river was not possible while in others crossing became difficult….sometimes you could even be washed away if you dared to cross, it was not possible to see the bridge and some of the big stones along the river channels, all were covered with water and the rivers were roaring due to higher water volumes and falls and channels widened. Wetlands, ponds and irrigation dams were filled with water and lowlands river channels were flooded. In recent years the rainfall amount received is low and does not even cover half of the river channel nor stones, sand and mud along the river channel…it rains at night or even during the day, but there is not much run-off and also the water level and volume in the rivers does not significantly change, and where it does, the changes do not last for more than three days to one week…"

An interview with District Official 01, confirmed that the average amount of rainfall received per season in the district over the past 20 years has not been sufficient to support agricultural activities, especially maize production. However, the official made a suggestion that some seasons received sufficient rainfall which could support the production of low moisture and higher heat tolerant crops, such as sorghum and cassava as alternative food crops which could help in adapting to changing conditions. But local people have a specific preference for maize and beans which form their main staple food; hence they are reluctant to cultivate any other types of crops. This threatens district food production and security which has made the district dependent on food aid for many years. Similar findings on changes in the volume of water and decline in rainfall patters have also been reported in studies elsewhere in Tanzania and East Africa (Yanda et al., 2006; Olago et al., 2007).

The respondents' perceptions and observations about rainfall trends in the study area are supported by meteorological data collected from four rainfall collection stations within the district. Highland rainfall station includes Lomwe High School and the lowland rainfall stations include Mwanga District Council Meteorological Station, Kisangara Sisal Meteorological Station and Nyumba ya

Mungu Dam Meteorological Station. Among the four stations, data collected before 1986 were only periodically available and were not consistent between sites and therefore ignored. Hence only data sets between 1986 and 2011 were used in the analysis. Also, it must be noted that one of these four 'useful' data stations (Mwanga) had missing data for the year 2005 and so the year was deleted across the board for consistency (see Figure 4.5). Inconsistency in availability and missing data records was said to be caused by the transfer or retirement of the staff responsible for recording daily rainfall data without immediate staff replacements and/or the misplacement of the month or year rainfall data file. The study also collected rainfall data for Kilimanjaro region from the Tanzania Meteorological Agency (TMA). Data gathered from TMA were only available for the past 40 years (1972 to 2012) (see Figure 4.6). The rainfall data records from both district and region show a decline in variability of annual rainfall as well as a decrease in the total annual rainfall trend in the region and the district under study (see Figures 4.5 and 4.6). It is important to note that the figures only show a change in variability between years and not within seasons.

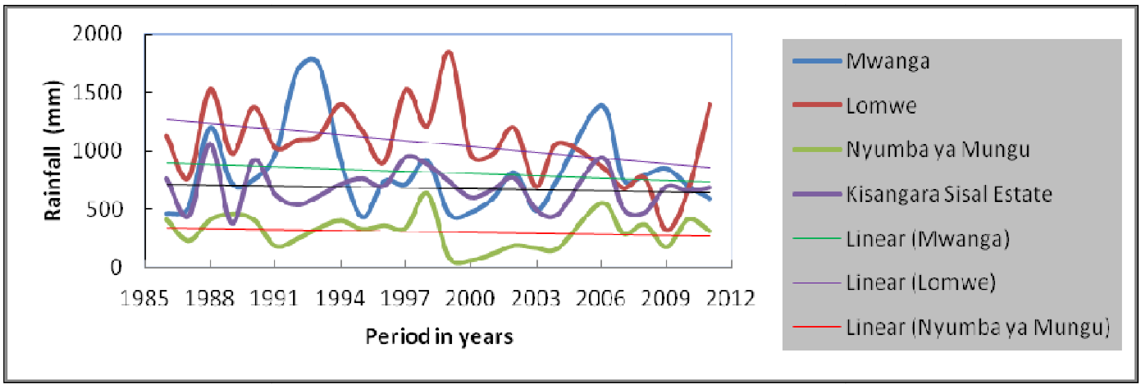


Figure 4.5: Total annual rainfalls for different sites in Mwanga District from 1986 to 2011

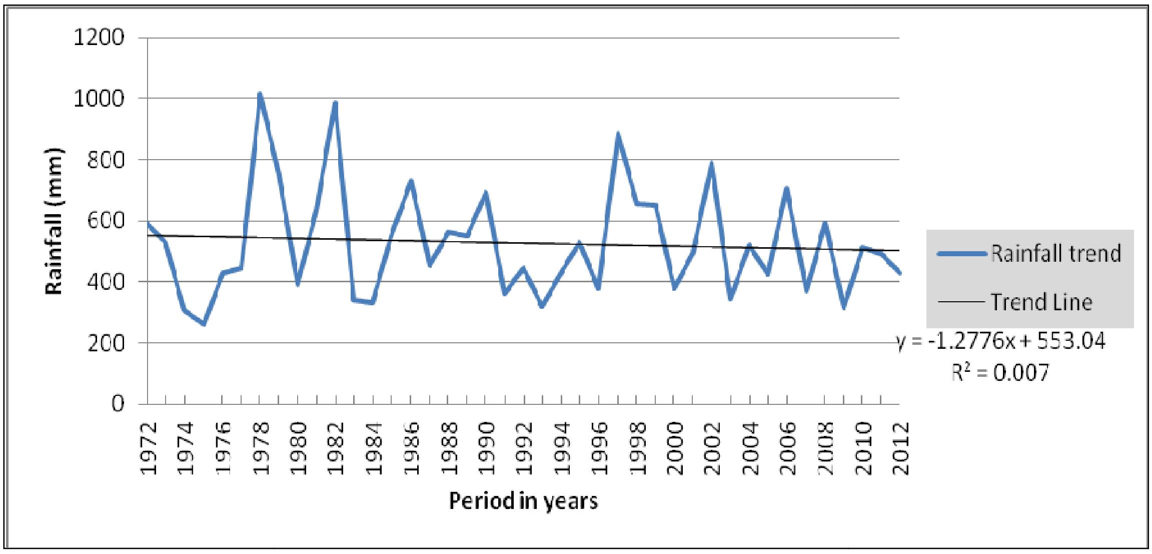


Figure 4.6: Annual rainfall totals for Kilimanjaro region from 1972 to 2012

4.3.5 Shorter rainfall season and growing season

Decline in rainfall and annual rainfall variability were also said to have resulted in a shorter rainfall season and growing season. About 63% of the respondents understood and linked climate change with shorter growing season. The majority of the participants also perceived that the growing season has become shorter when compared to the past 20 years, where the statement ranked ninth in the highland and fourth in the lowlands with 94.2% and 100% of the cumulative scores of the responses respectively (Tables 4.10 and 4.11). Focus group discussions and interviews in both zones revealed that rainfall seasons have changed, where sometimes rainfall starts at the onset or in the middle of the season and ends when crops are still at the growth stage or had just started producing flowers. Citing examples from the farming calendar during a focus group discussion in the highland zones, one of the participants suggested that it was known from the Roman calendar that *vuli* (which is a short and hot rain season with two months of rain) begins on 27th September in each season, at which point everyone started planting and within three to five days it would rain. The rainfall in this season supported farming activities mostly in the highlands, while in the lowlands the rains were sufficient only in supporting the growth and survival of livestock pasture. Over the past 20 years, the season has been commencing late in October or even mid-November, with light or heavy downpours which can last for two or three days, with no more rain for the rest of the season. Focus group discussions in the lowland zones revealed that the trends in rainfall have changed, where now one season can receive sufficient rainfall and the other receives poor rain or a season can receive one year with good rain then followed by three to four, or even five, years with poor rains which are highly variable and do not fully support agriculture activities. One of the participants reported that in the past the season would have four years of good rain then followed by one year of poor rain or drought. Respondent KS09 said that:
"…the situation in rainfall has changed a lot, until now drought and crop failures have become part of our life, and many years have passed now since we had sufficient harvest…we struggle working to earn money for the purchase of seeds and pay for tractors for farm preparations and as soon as it rains we plant, and do weeding early enough but to our surprise there is no further rain after planting and weeding…crops survive under limited moisture conditions while others wilt and die due to prolonged variations in rain days and increase in drought…"

Respondent SF06 said that:

"…nowadays agriculture is no longer a certain activity that one can depend on for food and livelihood as it was in the past years…"

Drawing an example from the masika season, the respondent said that, the normal long rainy season (*masika*) that used to start in early March and last to May now typically produces light to moderate rainfall with increased variability, resulting in increased crop failure. The respondent said that the *masika* season in 2012 had only three days of rain (i.e. two days in March and one day in late April). This argument was shared by the majority of the participants in the study area. Similarly, from field observations it was evident that few crops survived under such dry and heat stress conditions and as soon as it rained, they all produced flowers at a height of a metre or less, resulting in a low or failed harvest (Plates 4.5, 4.6 and 4.7). Similarly, it was ascertained by Respondent CH12 (retired agricultural officer) that moisture stress and rainfall variability force crops to grow to maturity before their real time which results in poor and low crop yields. This finding is supported by a study by Kangalawe (2009), conducted in the southern part of Tanzania, which suggested that changing climatic conditions have resulted in delays and fluctuations in rainfall onset. According to URT (2003), Tanzania has being facing famine incidences caused by either floods or drought since the mid-1990s which undermine food security in the country. However, FAO (2008) suggested a tripling of the food crisis per year in Africa between 1980s to 2000s due to the impacts of climate change. Chandrappa et al. (2011) made an argument that climate change and variability threaten agricultural livelihoods and food security of the people in Africa whose lives depend on agriculture. Hence, this finding agrees with most of the literature that changing climatic conditions, especially decline in rainfall and increases in variability, affect the livelihoods of the agriculturally dependent farmers.

Plate 4.5 Crops forced to grow to maturity due to drought conditions in Kisangara ward

Plate 4.6 Beans forced to grow to maturity due to drought in Ngujini ward

Plate 4.7 Maize forced to grow to maturity due to drought in Ngujini ward

The decline in rainfall and increase in annual rainfall variability have resulted in fewer planting days. Focus group discussions in both highlands and lowlands revealed that planting days in both seasons (*vuli* and *masika*) have become very short due to declining rainfall duration associated with prolonged rainfall variability and increases in temperature. Most of the participants reported that most rainy seasons no longer follow known trends from the past, hence affecting the normal routine of the planting seasons, making crops both in lowland and highland zones survive under limited soil moisture and heat stress conditions leading to poor harvests. Citing examples from their farming calendar, the planting season in *vuli* normally started on 27th September and the whole month of October was considered as a planting month for maize, and legumes were planted in late October to mid-November. In late November to early December, most crops begin flowering while those planted early are getting ready for early harvest. Also planting in some areas in the highlands in Ngujini, Usangi and Kilomeni wards started much earlier in August and also along the wetlands (popularly known as *chambombe*) due to the presence of cool and moist weather conditions, with the support of light hand/bucket irrigation. Changing climatic conditions associated with increases in temperature have resulted in the drying of wetlands and the disappearance of cool wet conditions making early planting and *chambombe* farming no longer practicable. *Masika* which is a longer rain season started in March to May and May 2nd marked the end of the sowing date for beans while maize sowing ended much earlier. However, the whole season would have enough rainfall, with farmers able to stagger planting dates to avoid crop failure, diseases and pest attack. These trends in rainfall were reported to have changed over the past 20 years, and there has been no consistency with regard to the beginning of the rainy season. Most rain commenced late and sometimes a month later after the normal dates for the start of the season, and the seasons received light rainfall or heavy short-lived rainfall which could not support crop growth to the full maturity stage. This finding is supported by the other researchers. For instance, Collier et al. (2008) suggest a similar view that climate change will result in the reduced length of the growing season. The increased variability and unpredictability of rainfall within the season was also seen to be responsible for crop failure and poor yields, because in most cases increased variability in rain days stressed crops through the prolonged duration of drought and heat. However, those crops which survived under such heat stress conditions flowered early before growing to full maturity leading to low yields. A similar argument on the impacts of increased heat and drought conditions on crops was made by Collier et al. (2008) and Rosenzweig et al. (2001). From the observations and discussions with farmers it was evident that, despite the variability and unpredictability of rainfall, farmers did not hesitate to plant, and indeed they kept on planting so long as it had rained, even though through their experience they knew that it would be a short season, probably with not enough rain resulting in poor harvests.

4.3.6 Weather variability and unpredictability

A few of the respondents (34%) mentioned weather changes, variability and unpredictability as an indicator of climate change and climate variability with the argument that weather conditions were no longer as predictable as they used to be in the past 20 years. Thus the past experience has ceased to be a good guide for both present and future conditions. The statement on weather unpredictability was ranked sixth in the highlands and eleventh in the lowlands with 96.2 and 81.7% of the cumulative responses respectively (Table 4.10 and 4.11). The study revealed further that participants depend on both modern scientific weather forecast information received via radio and television as well as on traditional weather predictions and indicators. However, most of the participants reported that neither of the techniques on weather predictions was helpful. For instance, it was revealed that reliance on forecasts of medium to high rainfall led farmers to invest in agriculture by cultivating larger areas, but the season ended by receiving below average rainfall, causing wide-spread crop failures. The same situation was experienced with the use of local weather forecasts, using indicators such as tree sprouting, bird chirping and changes in animal and insect behaviours. Discussions revealed that most of the local environmental weather indicators tended to occur at their normal time, but the rain would not commence, or would commence with heavy, normal to very little rain and disappear. However, those with such knowledge reported that by seeing those indicators they would nonetheless prepare their farms despite the risks. Due to weather unpredictability and uncertainties about the commencement and ending of rain in different seasons, some farmers now avoid preparing their farms in advance, but wait and immediately it rains they plant on uncultivated farm plots, the technique popularly known as *kitang'ang'a*. As reported by Respondent KV38 that:

"…nowadays each season begins at a different time and farmers have to adapt. No one can predict, or expect what happened in the previous years, to occur in the following season…"

The changes in weather conditions limit the knowledge and ability of the farmers in understanding their local environmental behaviour, and instead they depend on natural conditions to control their farm management. For example, farmers now just stay and wait until it rains and then they start planting, while in the past they planted some few days before the commencement of the rain.

It is a common view that weather variability and unpredictability have resulted in changes in normal seasonal characteristics. For example, the characteristics of the cold season have changed and the changes have been said to have a link with the conditions of the *masika* season. One of the participants during focus group discussions in the highlands reported that when the *masika* season had less rainfall that ended early, it was followed by a very cold, dry season which commenced earlier than normal. Participants in both zones reported the disappearance of short rains that occurred in the cold season and now the season has become dry without wet conditions, such seasons' conditions are referred to as *kiho cha kiume*, (in the local language), literally meaning a dry and cold season without rain. Making reference to the 2010 to 2012 cold seasons, respondents reported that the seasons were very cold and were associated with dry weather conditions. However, on some occasion, the season experienced fluctuating conditions of cold days and hot days, which is contrary to the past experience when the season used to be cold and wet. The cool and wet conditions in the past supported the growth of crops to maturity after the end of the rainy season in mid-May and also ensured the continued availability of fodder and water flow in the area. The changes have resulted in increased food shortages caused by crop failures of staple and non-staple crops, as well as cash crops such as coffee and cardamom. Similar cases of changes in seasonal behaviour have been observed in other studies conducted in the southern part of Tanzania (see Kangalawe, 2009; Kangalawe, 2012).

4.3.7 Changes in seasonal characteristics

Participants also reported noticing changes in the characteristics of the *vuli* and *masika* seasons. Normally, the *vuli* is characteristically hot with short rains associated with windy conditions towards the end of the season in December, and *masika* has calm weather conditions with warm and moderate temperatures associated with longer rains. However, over the past 20 years the characteristics of these two seasons are no longer as stable and consistent as they were. The temperatures for both seasons are now believed by many farmers to have increased to the extent that they perceive that all seasons now experience higher and almost similar heat conditions associated with the decrease in rainfall amounts. However, in some seasons, *vuli* was said to receive more rainfall than *masika* which has made farming activities possible in the lowland zone during *vuli,* although only on a very small scale. In addition, some farmers observed that both seasons now have strong winds and sometimes the winds are associated with rainfall. Increased wind intensity affect crops' productivity, because wind blew away crop flowers and leaves, increased the rate of transpiration and accelerated the rate of soil moisture loses.

There is a further perception that there has been a decline in morning condensation (dew). Focus group discussions suggested that in the past these conditions were common, sometimes with mountains covered by clouds for the whole day or half a day from morning to afternoon, perhaps disappearing during the afternoon hours and appeared again during the evening. The mountain clouds and short rains that occurred in the highland zone during the cold season kept the highlands cool, green and supported the growth of both annual and staple crops. Crops such as sugarcane, banana, yams, sweet potatoes, Irish potatoes, cassava, beans, coffee and cardamom did well in these cool weather conditions and provided highland dwellers with higher crop yields. However, participants reported that over the past 20 years, these conditions have become increasingly rare which has resulted in increased crop failures, lower yields and even water shortages, all making life in the highlands increasingly difficult. The change in these conditions, along with increases in temperatures, has created conducive conditions for the survival of mosquitoes in these cool highland zones which were previously mosquito free. This finding agrees with several other studies which suggest that climate change will expand the geographical range of diseases carrying insects from the plains ecosystem to the highland and other areas where these diseases were not experienced exposing many people to new diseases with no knowledge on how to treat them (Henson, 2011; Kangalawe et al., 2011; Yanda et al., 2006; Githeko et al., 2000).

4.3.8 Flood incidence indicator

About 7% of the respondents associated the occurrence of floods as an indicator of climate change and climate variability and the majority were from the highlands (Table 4.9). However, perceptions about the frequency of floods showed that the majority of the participants in both zones saw floods to be less frequent in recent years. Hence the statement was ranked fifteenth in the lowlands and sixteenth in the highlands with 20% and 27% of the cumulative scores respectively. Although the literature predicts an increase in the incidences of floods, wind storms, heat waves and other extreme weather events as the result of climate change, associated with increase in temperature (Collier et al., 2008; Nordhaus, 2007; IPCC, 2007), the occurrence of heavy floods in the area is now seen to be a rare event. Most of the participants reported that for over 10 years now they have not experienced serious flood events but the conditions are getting drier and warmer. However, the study reveals that there have been a few cases of heavy, but short-lived, rains which resulted in landslides, rock and tree falls, some of which blocked roads and caused the destruction of houses, bridges and crops. Landslides along the roads in the highlands were reported to occur more regularly causing communication problems within the highland zones. In addition, some of the lowland areas especially in Kwakoa division were said to be flooded especially when there is heavy rain in the highland zone in Kilomeni ward. Respondent KW24 reported that farmers benefit from this flood because their area receives moderate to low rainfall, hence run-off from the highlands increased soil moisture and increased soil fertility from the deposition of alluvial materials carried by the storm water from the highlands. However, the case of storm water flowing from the highlands was reported to have become rarer due to the low amount of rainfall received in the highlands leading to limited or low run-off. Similarly, from the observations and responses from the highland dwellers, it was evident that there was limited occurrence of run-off due to the low volume and intensity of rainfall received in recent years. Also the use of soil erosion control measure (contour and terrace farming and agro-farming) has reduced run-off especially in those areas prone to soil erosion.

Nevertheless, occurrence of crop destruction from the short heavy rains was evident from the report issued by the District Agricultural Office on food condition and crop progress in the field on 20th January 2012. The heavy and short rains of *vuli* season in October 2011 caused the destruction of 882.5 hectares of planted crops (527 hectares of maize, 41 hectares of sunflower, 10 hectares of sorghum, 140 hectares of beans, seven hectares of cassava, 14 hectares of yams, five hectares of sugar cane, 126.5 hectares of banana and two hectares of varieties of vegetables). The destruction affected a total number of 642 households with a population of 2,588 people. However, the report showed further that after this heavy rain event the area did not receive any further rainfall that season, resulting in crop failures, especially in the lowland zone. The report argued further that similar weather conditions of insufficient rainfall and drought were also happening in the highland zones, but the situation in the highlands was not as bad as in the lowland and hence highland dwellers might gain some reduced harvest at the end of the season.

4.3.9 Decline in water level and drying of surface streams flow indicator

Climate change was also associated with the increased decline in the amount of water in the rivers and streams. About 70% of the participants from the lowlands associated climate change with decreases in water volume and the drying of rivers and streams. However, perceptions from most of the participants suggested that the area has experienced a steadily decline in the amount of water in the local rivers and streams over the past 20 years. They attribute this to rises in temperature and declines in rainfall, and increased rainfall variability. Some of the perennial rivers and streams have become seasonal, and others have dried out altogether. In the lowlands, participants reported that most of the rivers flowing from the highlands have become seasonal, as they now only flow during and shortly after the rainy season. From observations, most rivers and streams in the highlands had low volumes of water and some had dried, while in the lowland many river channels had dried (Plate 4.8). The photo was taken in the month of April which is in between the *masika* and *vuli* rainfall seasons.

Plate 4.8 Low water volume in Ngujini/Changalavo river flowing from the highlands to the lowlands

It was observed further that water in many of the lowland river channels no longer flows on the surface, but only underground, so as a solution to water shortages dwellers excavated ditches along the river channels to extract water for irrigating vegetables, feeding livestock and for brick making (Plates 4.9 and 4.10). The depths of such ditches increased as drought conditions became prolonged, as well as in response to increases in demand for water. Under prolonged drought conditions, these ditches are abandoned and dwellers search for new locations. This finding is supported by several studies which suggest that climate change will affect the future discharge and flow of many rivers and streams in Africa leading to unprecedented water shortages (Collier et al., 2008; Orindi and Murray, 2005; Adger et al., 2003; United Republic of Tanzania (URT), 2003), many of which are ephemeral, flowing during and shortly after rainy season (Nyong et al., 2007).

Plate 4.9 Dried river channel in the lowland in Kisangara ward

Plate 4.10 Excavated water ditch along the river channel in Kisangara ward

However, the decline of the surface water flow is not only associated with the increase in drought conditions, but also with improved water distribution to households through the use of hosepipes, as opposed to open stream, rivers and channel water collection which allowed water to keep on flowing along the river channel after collection. Focus group discussions revealed that the majority of the highland dwellers now use tap water which was not the case even 10 years ago. However, in the highlands the discussions suggested that even water collected in wells was not enough to satisfy domestic uses. This has triggered village water committees to instigate a water distribution schedule, where households get water only at specific hours of the day. During the night and for few hours in the day, water is collected in the well to make sure that everyone gets enough during the time of distribution.

4.3.10 Incidence of the occurrence of forest fires

The drying of streams and rivers was also associated with the increase in the incidence of fires in the forest reserves within the district. Participants in the study area reported to have witnessed an increased occurrence of fires in the forest reserves in almost every season for the past 20 years (Table 4.12). The fire incidences were said to have consumed significant parts of the forest reserves burning those areas which had never previously been burnt since the forest grew. Field observations captured some of the pictures of part of the areas which were destroyed by fires (Plates 4.11 and 4.12). The decline in the thickness of the forest reserves, caused by increased drought and fire incidences have reduced the rate of surface cover, hence exposing land and water catchments to the direct sun rays which increases the rate of evaporation and evapotranspiration. Furthermore, from oral history interviews with participant OHH04, it seems that water catchment sources had dried because of the removal of the surface cover and disturbances from human activities. For instance, the participant reported that traditionally it is believed that catchment points, which he referred to as *eyes of the water,* are said to be "shy", that is whenever the eye is exposed to the direct sunlight or touched by human beings with the aim of improving it, the water source disappears underground and surface flow ceases. Thus increasing temperature affects water volume which makes water users to encroach water catchments which sometimes leads to the disappearance of the surface stream flow.

Table 4.13: Fire incidences that occurred in different forest reserves within the district 1993-2012

Year	Forest reserve	Area destroyed
September 1993	Kiverenge	1.5 ha
September 1993	Kindoroko	10.5 ha
February 1994	Kindoroko	4.0 ha
March 1995	Mramba	15 ha
November 1995	Mramba	18 ha
December 1995	Mramba	1 ha
October 1996	Kileo	4 ha
January 1997	Kamwala	170 ha
February - March 1997	Minja	200 ha
February- March 1997	Kindoroko	260 ha
September 1999	Kiverenge	1 ha
September 2001	Kindoroko	2.5 ha
February 2003	Minja	3 ha
January 2008	Mramba	3.5 ha
October 2008	Mramba	2 ha
October 2008	Minja	2.5 ha
February 2011	Mramba	2 ha
September 2011	Kamwala	6 ha
February 2012	Kamwala	1.4 ha
March 2012	Minja	6.5 ha

Source: Field data 2012, compiled from the District Natural Resources Office reports on fire incidences

Plate 4.11 Burnt area in Kindoroko forest reserve in Ngujini ward

Plate 4.12 Burnt area in Kindoroko forest reserve

4.3.11 Effect of eucalyptus trees

Participants also associated the substantial decline of surface water flow and the drying of water sources originating from the Kindoroko Forest Reserve (KFR) with the expanding population of the eucalyptus trees. This was reported during focus group discussions, where one of the participants mentioned that eucalyptus trees have increased and are contributing to the declining and drying up of water courses especially in the highland zone. The study revealed that, after the gazetting of KFR in the 1960s, eucalyptus trees, which are an alien species in the area, were planted to mark the border of the forest reserve. However, participants perceived that the eucalyptus species are much more competitive in terms of drawing water from the soil than the native species. Hence this is attributed to the lowering of the water table causing a decline in surface water volumes as well as drying of some of the springs, streams and rivers in the area. In addition, it was ascertained that the species is more tolerant to periodic fires that are experienced in the reserve than the native species. The fire tolerance nature of this species has led to their proliferation resulting in the increase of tree population growth that suppresses native species (Photo 4.13). Participants proposed the uprooting of the species and replacing it with the native species which it is supposed would not only improve water availability but also enhance forest biodiversity. Farmers' perceptions of the effect of eucalyptus trees on the forest ecosystem and water is supported by studies conducted elsewhere. For instance, a study conducted in Ethiopia by Jagger and Pender (2003) suggested that eucalyptus trees are the fastest growing and most resilient tree species which perform better than most of indigenous tree species. However, the government in Ethiopia banned the growing of eucalyptus on farmland due to negative environment externalities associated with the eucalyptus. One of the most common problems associated with growing of the eucalyptus trees is soil nutrient depletion. In contrast to other commonly used agroforestry species, such as *Leucaena* and *Acacia*, eucalyptus tree are non-leguminous, thus they do not fix nitrogen, an essential element for soil health nutrients and sustainability.

Plate 4.13 Part of Kindoroko Forest Reserve colonised by eucalyptus at Sofe Village in Kilomeni ward

The declining water levels in the highland rivers and streams have affected all irrigation activities, both in the highland and lowland zones. The demand for water for domestic use by both highland and lowland dwellers and for the sisal decorticating plant create increased demands and priorities where food crop irrigation is considered to be of a lesser priority. This has resulted in pressure on both traditional and modern irrigations systems, with those few still operating will be closed down if drought conditions persist (Plate 4.14). The finding on the decline in water availability is supported by the literature in climate change. Studies by Mwandosya, (2006) and Rosenzweig and Hillel (1995) suggest that climate change is predicted to reduce water availability which will in turn affect irrigation activities due to increased demand and competition between agriculture, urban demands and hydroelectric power production as well as industrial users.

Plate 4.14 Abandoned water reservoir at Kwalutu hamlet in Kisangara ward

4.3.12 Pests and crop diseases indicators

About 67% of the participants associated climate change with the increase of pests, crop diseases and insects as an indicator of climate change (Table 4.19). This indicator had a higher proportion of responses from the highland than the lowland zones. However, in perceptions, the statement was ranked tenth in the highlands and twelfth in the lowlands, but with 85.5% and 48.7% of the overall cumulative scores. Highland focus group discussions revealed that there has been an increase in the population of pests, crop diseases and insects, compared to the past 20 years. They also associate the increase with the declining amount of rainfall, as higher rainfall was believed to cause more deaths of the pest and insect populations, while moderate rainfall and warm conditions encouraged the survival and proliferation of insects. Also, the limited availability of varieties of grasses for insects to feed on confined them to agricultural crops only. In addition, reliable rainfall speeds up the growth of crops making them less vulnerable to pest damage. One of the participants in the focus group discussions in the highland zone reported that due to an increase in droughts and continued crop failures in the lowlands, many pests and insects have migrated to the highland zones, although there was no direct evidence to support this perception. Highland farm observations and guided transect walks revealed that many of the crops in the highlands had been attacked by insects and diseases (Plates 4.15, 4.16 and 4.17). However, a few farmers who were met in the fields applying insecticides (Plate 4.18), said that the majority of farmers did not apply agrochemicals because they were expensive and shops were located far away from the village which required one to travel. The high price of pesticides and travelling cost increases the cost of apply agrochemical and hence was avoided by the majority of farmers who resorted to the use of traditional pesticides which did not always prove to be very successful. In addition, participants confirmed that weather conditions were not predictable as the application of agrochemicals could only be effective when applied under moderate rainfall and moisture or the presence of dew conditions. This finding agrees with other research findings such as Collier et al. (2008), Rosenzweig et al. (2001), Boko et al. (2007) and Githeko et al. (2000), which suggest that warm and humid conditions associated with climate change will provide favourable conditions for the survival and proliferation of agricultural pests, insects, weed, fungi and pathogens which will cause more damage to agricultural crops causing food insecurity. However, weather conditions are dry and hot with little hope of rain, incurring costs on agrochemicals which were considered to be a waste of money. From the focus group discussions, it emerged that in the past farmers applied coffee pesticides to the crops, as these were provided under subsidised price conditions. But after the failure of coffee economy in the area, caused by with withdrawal of the subsidies and dissolution of the farmers' cooperative unions (Maghimbi, 2007; Mhando, 2007), farmers no longer received these pesticides reducing pesticide use on crops. The study revealed further that although farmers applied traditional pesticides, insecticides and fungicides (see Plates 4.15 to 4.19), most of these pests, fungus and insects have now become resistant to these traditional chemicals and hence are now largely ineffective.

Plate 4.15 Maize attacked by maize stock borer in Ngujini ward

Plate 4.16 Bean attacked by aphids at Ngujini ward

Plate 4.17 Bean weevils (Nasheve) attack bean leaves and yellow and black beetles feed on bean flowers in Kilomeni ward

Plate 4.18 Applications of agrochemicals in Kilomeni ward

Plate 4.19 Maize applied with a traditional pesticide in Ngujini ward

As a partial solution, farmers replant crop filling up the gaps created by destroyed crops immediately as soon as it rains again (Plate 4.20). However, this was reported to have mixed success due to the shorter growing season and increased rainfall variability. It was further argued that the two seasons (*masika* and *vuli*) normally had differences in the population of pests, diseases and fungi; *masika* has more pests, diseases and fungi than *vuli*. The common types of pests that were seen in the farm plots include bean weevils (*Laprosema indica),* known as *Nasheve* in the local language, grasshoppers, blister beetles (*Cerotis capensis* and *Mylabris)* (which feed on leaves of the freshly germinating beans leaves and flowers), white flies and aphids which attack the leaves of beans, greengram, cowpeas and lablab. Maize stalk borer (*Buseola fusca)* was also considered to be a problem in recent years and attacked maize stalks, leaves and corn. Farm plot observations showed that maize stalk borer was a problem in the highlands, as most of the farm plots observed showed maize attacked by stalk borer. In the lowlands, participants reported crop failure in many seasons, and hence they could not determine whether there was an increase in the population of pests, insects and diseases or not. However, they reported the presence of common insects, such as grasshoppers, blister beetles, aphids, spider and white flies.

Plate 4.20 Replanting of beans after damage by insects in Kilomeni ward

4.3.13 Disappearance of bird species

Participants in the focus group discussions in both zones reported the disappearance of an important bird species known as the *ground hornbill* (*Mumbi* in Swahili) which used to be very common in the area (Plate 4.21). The respondents said that the last time the bird was seen in the area was between 1980 and 1990, since when this bird has not been seen. Some participants said that the bird had disappeared due to the increased clearing of bushes and logging which deprived the bird of a favoured habitat for living and ample breeding sites, while others linked its disappearance with food shortages caused by the increased application of chemicals on the farms resulting in increased deaths of snakes and grasshoppers which were the bird’s favourite meal.

Source: (Darcey, 2006)

Plate 4.21 The Ground hornbill

4.4 Non-climatic factors associated with climate change and environmental variability

About 22% of the respondents associated climate change with other non-climatic factors, such as religious, social and cultural aspects. This group of participants suggested that the current changes were occurring due to non-adherence to the cultural norms and customs of the society, as inherited and passed down from generation to generation. It was argued by some participants that many people are perceived to have abandoned their cultural ways of worshipping and respecting their forefathers. They argued that, if the changes were natural, then why now and not in the past when people were religious and respected their cultures and values? They further argued that the similar conditions of drought occurred in the past, but their parents managed them through their unique traditional ways which involved praying and offering sacrifices to the dead and other spirits. Recently these values are no longer observed. Respondent CH13 was quoted saying that:

"…today all these are happening because people have exceeded the values and limits of the normal expectation of the society (*Vandu vacha mpaka vakatoveja ahothi,* in the local language which literally means that people are doing unspeakable things)..."

Participants further associated the changes with the introduction and acceptance of outside religions (Christianity and Islam), which consider traditional ways of worship to be uncultured (belonging to black ages) and forbad people from following them. It was argued that in the past each clan had a traditional forest called *Mbungi* in the local language which was protected and used as a worshiping place; a meeting place for elders to discuss matters pertaining to the safety of the local community and their economy; for initiation ceremonies and the teaching of traditions and folklore; research and inventions etc. These roles made *Mbungi* sacred and nobody would collect fire-wood from the forest or practise farming activities on them. Because *Mbungi* played such unique cultural roles in the community, they were important also in the protection of important ecological species, resources and niches. The *Mbungi* also modified the local climatic conditions of the area around the forest, conserved water catchment sources, attracted rainfall, played the role of carbon sequestration and provided aesthetic value in the surrounding environment. The introduction of foreign religions treated traditional cultural beliefs as ungodly and disrespected those areas that were used for worship by building schools, dispensaries and churches, while in other areas they opened up institutional owned farms such as coffee and banana farms (Table 4.14). It was argued that this marked the end of many traditional and so called “sacred” forests by opening them up for logging and farming activities which exposed some of the water catchments in some of the reserves to direct sun light and human disturbance. It also removed the role played by trees as a local climatic modifier and carbon sink, and endangered flora and fauna located in those reserves and the surrounding ecosystem. The changes in the use of *Mbungi* may have also contributed to some of the environmental problems in the area such are decreases in surface water flow, drying of some of the water catchments and increases of temperature, decline in the amount of rainfall and hence accelerated changes in climatic conditions and weather variability. The respondents added further that in the past each clan worshipped its own gods of different seasons and events (gods of rain, gods of harvest, gods of diseases etc.) and honoured the dead. They said during the time of a bad event in the society, they prayed and they were granted their wishes accordingly. For example, incidences of human or animal diseases, drought and hunger were managed through special worship and sacrifices. But after the introduction of new religions, people from different clans and traditions gathering together under one roof and worshiping one universal ‘God’ and abandoning their own ‘gods’ and their ancestors, as well as the good values taught to them on how to relate with their local environment, this has made their ancestors angry and now is the time for punishment. Similar perceptions in associating the causative of natural hazards with non-human factors as observed in this study have also been discussed in the literature (White et al., 2001; Smith, 2013).

Table 4.14: Encroached traditional forest reserves

Name of the forest (*Mbungi)*	Owners of the forest (*Mbungi)*	Location		New activity introduced
		Village	Ward	
Kitivoni	Wasofe	Chanjale	Ngujini	Kitivoni Primary school
Dindimo (Kwa mathanga)	Wasofe	Chanjale	Ngujini	Coffee and banana farm
Mwetambaha	Wasofe	Ngujini	Ngujini	Primary school, dispensary and a Church
Kwakitanga	Wasofe	Ngujini	Ngujini	Changalavo Primary school and Kindoroko Secondary school
Kiindi	Washana	Kilomeni	Kilomeni	Kilomeni primary and Secondary school, Church and a dispensary

However, an interview with District Official 03 revealed that lack of understanding of the role of protected and conserved traditional forests (*Mbungi*) contributed to the clearing of traditional forests, resulting in the disappearance of the important ecological hot spots and other important roles that these forests played. However, the official explained further that there is now a growing recognition of the traditional forest reserves by the government and these forests are now under the district forest protection by-law and the rights of protection have been reserved to the clan elders to whom the forest belongs. Due to this recognition of traditional forest reserves, the district has now an estimated area of about 207 km^2 of traditional forest reserves. However, from the above discussion on farmers' knowledge and perceptions of the causes of climate change and environmental variability, respondents also mentioned some of the experienced impacts of climate change and environmental variability; that are discussed in the proceeding section.

4.5 Experienced impacts of climate change

Dwellers in the study area recognised the relationship that exists between climate and agriculture activities as they were able to mention some of the impacts which they have experienced over time and associated them with climate change and climate variability. Table 4.15 presents the experienced impacts of climatic change as perceived by different participants. The respondents reported a number of impacts as such as an increase in drought, food shortage, decreases in crop productivity, buying food, decrease in water, increase in poverty, increase in crop failure and unemployment. Drought, food shortages, decrease in crop productivity and buying food had high responses from both lowland and highland zones. However increase in drought, food shortage, decrease in crop productivity, decrease in water and pests were mentioned as both indicators of climate change and impacts of climate change by all participants in all zones. This is because livelihoods of rural farmers depend on agriculture and changes in any of these factors touches the lives of everyone in the community.

4.5.1 Drought and food shortage effect

Drought and food shortage were mentioned by almost all participants (100%) in both zones. The lowland area was mostly affected, however, as most crops had dried out during the field-work period. However, the study revealed that drought conditions and rising temperatures have resulted in highland farmers now experiencing food shortage, just like their fellow farmers in the lowlands due to crop failure and low crop productivity. Food shortage implied by the majority of the respondents meant a shortage of the main staple from their own farms and not necessarily unavailability in the market. Decreases in crop productivity were also mentioned by 96% of the respondents with the majority of the response (93%) from the lowlands. During focus group discussions in the highland zones, one of the participants reported that the amount of crops harvested was low, making highland areas experience food shortages. Focus group discussions revealed that the increase in drought conditions in the highlands did not only affect the productivity of annual crops (maize and beans) but also was said to have affected the productivity of other staple crops such as banana, sugarcane, sweet potatoes, pumpkins and yams, which are the major food crops that supplement food shortages when there is a poor maize harvest. These crops are also sold direct to the market to earn money for household use. The productivity of these crops was reported to be very low and mostly of poor quality. Most interviews revealed that in the past, when conditions did not favour the growth of maize, the highland zones still remained free from hunger and food shortages, as households depended on the less preferred food crops (see also Kangalawe, 2012). However, current droughts and rainfall variability were reported to affect even the productivity of these less preferred food crops. The majority of the participants, about 82%, reported insufficient food harvests for the past 10 years (Figure 4.7). However, observations revealed that not only drought conditions affected crop productivity in the area, but poor soil fertility, use of poor seeds, limited application of agrochemicals and the effect of vermin.

Table 4.15: Percentage responses on the experienced impacts of climate change and climate variability by zones

Impact of climate change	Overall	%	Highland (n = 117)		Lowland (n = 117)	
			Number	%	Number	%
Increase in drought	234	100.0	117	100.0	117	100.0
Food shortage	234	100.0	117	100.0	117	100.0
Decrease in crop productivity	225	96.1	116	99.1	109	93.1
Buying food	201	85.8	89	76.4	112	95.7
Decrease in water	176	75.2	87	74.4	89	76.1
Increase in poverty	167	71.4	90	76.9	77	65.8
Increased crops failure	166	70.9	94	80.3	72	61.5
Unemployment	161	68.8	90	76.9	71	60.7
Deaths of the livestock	131	56.0	20	17.1	107	91.5
Decrease in the number of livestock	113	48.3	15	12.8	98	83.8
Increase in temperature	97	41.5	39	33.3	58	49.6
Increase in pests and diseases	88	37.6	88	75.2	00	00.0
Increase in human diseases	36	15.4	8	6.8	28	24.0
Increase in vermin	34	14.5	29	24.7	5	4.2

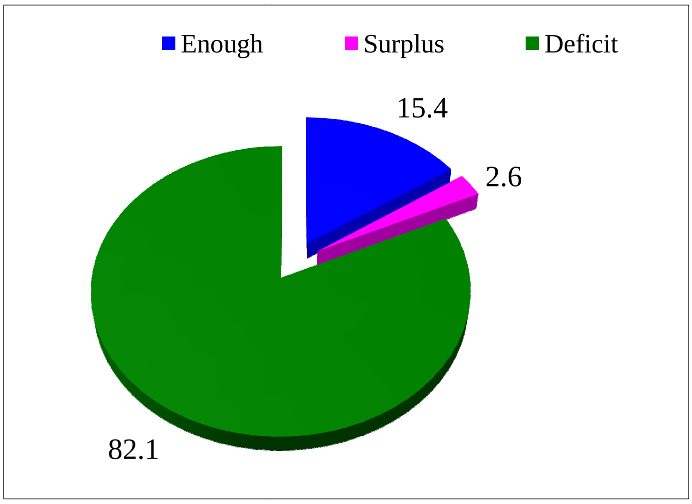


Figure 4.7: Responses on the perceived amount of crops harvested the past ten years (2002 to 2012)

The majority of the respondents, about 86%, reported that currently they make a living through working to earn money for the purchase of food. However, they claimed that the prices of food in the market keep on increasing in every season. Respondent KS08 said that:

“…sometimes I spent money for the purchase of food to the extent that it is beyond my means of survival…”

This view was shared by the majority of the participants in the study. However, the study searched for the prices of main staples in the market and with the support of evidence from the district agricultural office, it was evident that the prices of main staple food crops had increased when compared with the previous years. As Table 4.16 indicates, the price for maize and beans which are the main staples increased four and twenty times respectively within a period of nine years. This is a burden to households as the majority of them cannot afford such prices.

Table 4.16: Crops prices in 2003, 2011 and 2012

Crop type	Years	2003	2011	2012
	Unit of measure (kg)	Price (Tsh)		
Maize	1 kg	138	450	600
Rice	1 kg	400	1 800	2 000
Maize flour	1 kg	150	500	1 200
Beans	5 kg	70	1 600	1 600
Banana	15 kg (per bunch)	1 000	8 000	10 000
Sweet potatoes	1 kg	200	8 000	2 000
Irish potatoes	1 kg	100	700	100
Cassava	1 kg	200	1 000	2 000
Yam	1 kg	200	2 000	2 000
Fish	1 kg	1 000	1 800	2 500
Tomatoes	1 kg	150	800	1 500
Vegetable	1 kg	200	500	600
Beef	1 kg	1 200	1 200	5 000

Source: District reports on for the food conditions in, May 2003, November 2011 and January 2012

During the interview, District Official 03 also reported that “…it is now over 10 to 15 years that the harvests in the district have been below the average target, making the district depend mostly on food aid from the national food reserve and other international organisation such as CARITAS, UNDP, WFP and RED CROSS/RED CRESCENT…”

According to the official, the food received is sold at subsidised prices to ensure food access to everyone and is also provided for free to those families with elderly persons and families with persons who have prolonged sickness or chronic diseases. In some instances, food is provided in the form of "food for work", especially food aid from WFP where healthy members of households volunteer for public work, such as contributing labour in the road maintenance, building school or a hospital, and after work they receive food (Plate 4.22).

Plate 4.22 Villagers working on road construction to link Ngujini and Kilomeni wards

4.5.2 Poverty and unemployment

Poverty and unemployment were also mentioned as experienced impacts of climate change by 71% and 69% of the respondents respectively who argued that changing climatic conditions have increased the level of poverty and unemployment in the community. This was due to the fact that the majority depend on agriculture as their major source of livelihoods, and now due to changes in climatic conditions many now have to depend on casual labour to earn money for the purchase of food. One of the participants in the focus group discussions reported that the living standards in the village were declining because much money is spent on the purchase of food rather than on other activities such as education and building better houses. The study revealed that participants depended on the sale of labour to earn money to both agriculture and non-agriculture sectors; however, the study showed that increasing drought conditions causing failure in agriculture have resulted in fewer agricultural labour opportunities hence making the majority depend on non-agricultural labour which are also few and seasonal. Respondent SF08 said that:

"…it is a shame to a father as a head of the family to live in a house without food reserve in the granary and depend on working to earn money for the purchase of food and sometimes not knowing whether you will get something to do to help you earn money…in the past when conditions were favourable one would harvest crops, store them and use for almost three seasons and was also able to sell the surplus and earn money for the purchase of clothes, pay for medical facilities, education and also change diet... today the granary is empty, the amount harvested is not sufficient and does not last longer… no one today has food in the granary harvested in the previous season, we all buy…".

This view shows that changing climatic conditions make agriculture-dependent farmers live a life full of uncertainties. However, due to poor harvests coupled with limited income sources as well as low purchasing power, poorer households have to adopt food coping strategies such as skipping the number of meals consumed per day, reduce the amount of food consumed per meal, eat unusual and less preferred food types and sell livestock and household belongs in order to survive. Such strategies are not sustainable and impoverish the household financially and health wise.

Other non-agricultural activities include logging (for timber, furniture and fire-wood for sale) and stone quarrying. Some of these activities, e.g. logging cause deforestation, expose soil to erosion and may accelerate the increase of greenhouse gases in the atmosphere which are contributing to climate change. During focus group discussions, participants reported that the forest reserves were becoming very thin with open patches compared with 20 years ago. Sand and stone quarrying is done along the river and stream channels which result in deepening of river channels which accelerate river bed erosion and contribute to landslides, as well as soil erosion along the river banks which may lead to flooding.

4.5.3 Decline and drying of water sources

About 75% of the respondents mentioned a decline in water as one among of the experienced impacts of climate change and climate variability. Focus group discussions revealed that some of the lowland dwellers now walked for more than 10 km or more to collect water while others bought water from vendors. The situation in the highlands was not good either, as the majority of participants (74%) who mentioned a decline in water reported that many of the water sources have dried up while other sources experienced a decline in the volume. The participants reported that although the majority are now using tap water, the amount is not enough which has resulted in water use rescheduling where households receive water on specific hours of the day.

4.5.4 Livestock deaths and diseases

About 56% of the respondents, the majority from the lowlands, mentioned livestock deaths as an experienced impact of climate change and climate variability. During focus group discussions it was revealed that the frequent occurrence of drought conditions in recent years has being causing more livestock deaths in the lowlands than in the highlands, due to the insufficient and low quality of fodder, making livestock highly vulnerable to diseases which accelerate more livestock deaths. Such conditions have resulted in the majority of the livestock keepers in the lowland zones reducing their stocks to a manageable size, while others have reallocated their herds to other areas outside the district. However, keeping fewer livestock is considered to be uneconomical because one could not earn sufficient money from the sale of both livestock and livestock products. The majority of the farmers focused more on quantity than quality. One of the participants in the focus group discussions reported that by keeping less livestock means increasing the price of the livestock products as well as the selling price of the livestock, which the majority of the consumers in the area cannot afford. Another participant added that although some farmers have resorted to zero grazing, it is expensive especially during drought conditions where farmers have to purchase fodder or walk longer distances in searches for fodder. Similarly, during focus group discussions it was reported that despite the occurrence of livestock deaths within the drought season, more cases of deaths occurred at the beginning of the rain season which was said to be caused by sudden changes from dry to fresh fodder. Although cases of livestock deaths associated with droughts were less reported to occur in the highland zones, the zone was nonetheless reported to be experiencing fodder shortages due to an increase in drought conditions. Households, however, reported trying to manage fodder shortages by growing pasture on their farms and also by collecting fodder from the forest reserves. However, the study revealed that not only prolonged drought conditions and rainfall variability caused fodder shortages in the highlands, but also increases in the number of livestock, as livestock keeping has become a very important economic activity, thus intensifying competition for fodder among highland farmers as well as lowland dwellers who also collect fodder from the highlands. Fodder shortages have has made farmers in the highlands avoid keeping pure breeds of Friesian and Jersey types which were introduced in the highlands in 1987/88 by Same Catholic Dioceses under the HIFER project with the aim at improving livestock productivity. Focus group discussions and interviews revealed that pure dairy breeds are labour intensive due to high demands for fodder, are fodder selective (especially Jersey cattle) and prone to diseases and ticks hence demanding higher care and treatment.

Livestock diseases were also mentioned as impacts of climate change. About 48% of the participants, the majority from the lowlands, reported an increase of livestock diseases such as East Coast Fever (*theileriosis*), lung diseases and cattle miscarriage than in the past. Although there was no statistical evidence to prove such claims, an interview with Ward Officers suggested that such cases have been reported to occur in the area but there was no direct link to climate change. However, according to Ward Office 03, many of the livestock diseases are curable when the cases are reported and treated in a timely fashion. However, many of the agro-pastoralists cannot afford veterinary services due to limited funds, and also some of the cases were not reported early enough. The officer added further that the cases of miscarriage are due to many factors including the lack of minerals in the fodder and limited use of supplement feeds. This finding on the shortage of pasture and reallocation of livestock as the result of frequent occurrence of drought conditions has also been echoed in the literature on the impacts of climate change in Tanzania. For instance, research by Mbonile et al. (1997) and Kangalawe et al. (2007) showed that frequent drought conditions, which cause shortages in pasture and water, has led to long distance migrations of pastoralists to the southern highlands in search of pasture and water.

4.6 Conclusion

The findings suggest that climate change is happening in Tanzania and is affecting agriculture activities and the lives of the agriculture-dependent communities. However, agriculture-dependent societies have been surviving within these changing environmental conditions over generations and have gained a considerable knowledge and understanding of their local environment. The study reveals that the level of understanding about climate change varies from one geographical location to another and is also influenced by other factors among which are age and place of residence. As evidenced from the study, both lowland and highland dwellers are aware of climate change. The large portion of the participants interviewed were knowledgeable about climate change and were able to link the perceived environmental changes with the scientific understanding of climate change. However, amongst those participants who did not have clear understanding of the knowledge of climate change they linked the causes of climate change with social, cultural and religious factors. Generally, respondents considered and perceived climate as an increase in drought, increase in temperature, decline in rainfall, water shortage, increase in pests, shortened growing period, weather variability increase, windy conditions, and increase in animal diseases and floods. Nevertheless, small-scale subsistence farmers have being adapting to these changes in environmental conditions over generations, thus increasing their resilience to the changes through coping and adapting. Understanding different local environmental knowledges and practices on how helped farmers manage to cope with the impacts of the changing environmental conditions is the task for the next chapter.

Chapter 5
Local environmental knowledge on farming

5.1. Introduction

This chapter examines the role of local environmental knowledge, experiences and practices (LEKEP) in the local community's understanding of the concept of climate change. As noted in Chapter Four, rural farmers are aware of the concept of climate change and variability as they observe and experience changes such as variations in seasonal rainfall patterns, drought conditions, sunshine intensity and air temperature. Invariably, changes in these environmental factors influence agricultural production, about which farmers are very conscious. Despite the challenges of these environmental changes, the farmers consistently make efforts to cope and adapt to the changes using their LEKEP. The concept of LEKEP, otherwise known as wisdom knowledge, has been developed through the continuous observation and experience of weather patterns and farming activities over time, and passed down generations by word of mouth. Using this knowledge, small-scale rural farmers have devised local solutions to the problems affecting farming activities among which include unpredictable climate changes and environmental variability.

Local knowledge and practices have proven to be successful to some extent because the farmers' livelihoods depend directly on the natural environment, and so they pay close attention to any changes, in order to find appropriate coping and adaptation strategies to such challenges. Even though such strategies may be developed to target environmental changes, they are not able to mitigate or manage all effects arising from these changes, especially when changes occur at a faster rate than they can adapt to.

However, rural farmers have always been able to use their LEKEPs to plan their farming activities with regard to their knowledge of the duration of rainfall seasons, expected amount of rainfall, soil fertility management practices, pest control, treatment of crop diseases, and the prediction of the occurrences of natural calamities such as drought and floods. Most of these environmental factors have been successfully managed over the years through the LEKEP concept, and so some of these local strategies will likely be used by the practising communities for years to come. This means that wisdom knowledge has a role to play in contributing to the development and implementation of climate change adaptation strategies for the future.

This chapter examines the usefulness of LEKEP in farming activities and how the knowledge has been successful in managing farming activities under changing environmental conditions. It examines the extent to which LEKEP can contribute to the understanding of changing environmental conditions and hence guides the development of management strategies for future climatic and weather conditions. The chapter also analyses the major bottlenecks that limit the effectiveness of LEKEP in farming activities and its contribution to climate change and adaptation strategies. The chapter is divided into four main sections. The first section looks at farmers' awareness and use of different LEKEPs in farming activities. The second part of the chapter looks at the use of LEKEP in determining seasons and weather predictions. The third section assesses the effectiveness and reliability of LEKEP. In the last section, the chapter examines the major limitations of LEKEP in farming activities as perceived by local farmers in the study area.

5.2. Awareness and use of LEKEP in farming activities

Small-scale farmers in Mwanga District use LEKEP in planning and managing agriculturally dependent livelihoods. The results (Table 5.1) show that all participants, both in the lowland and highland areas, are aware of LEKEP used in farming activities. About 64% of the participants admitted practising more local farming methods and the majority (72%) were from the highland areas (Table 5.2). Approximately 30% of the respondents (38% of whom were lowland farmers) reported that other than the use of a hand hoe, they also use modern farming techniques (e.g. tractors and ox ploughs in land preparation, use of improved seeds, application of industrial fertilisers and pesticides) more now than in the past. As explained by respondent CH13:

"…I cannot consider my farming techniques to be pure traditional because traditional farming methods involved the use rudimentary farming tools such as the use of sticks and metal hoes made by local iron smiths which are currently not in use... however, I neither considered it to be modern because I do not use tractors at the sometime I grow indigenous crops, and in other occasions I resort to improved seeds and apply both modern and local pesticides…"

Table 5.1: Local farming methods and practices known to farmers in the study area

Method	Overall		Highland		Lowland	
	Frequency	%	Frequency	%	Frequency	%
Hand hoe	234	100	117	100	117	100
Mixed cropping	234	100	117	100	117	100
Random planting	222	94.8	115	98.3	107	91.5
Traditional seeds	219	93.6	105	89.7	114	97.4
Traditional pesticides	199	85.0	101	83.7	98	86.3
Zero tillage (kitang'ang'a)	123	52.6	58	49.6	65	55.6
Farm fallowing	32	13.6	19	16.2	13	11.1
Crop rotation	25	10.7	13	11.1	12	10.2
Traditional crop storage	18	7.9	12	10.2	6	5.1
Use of animal manure	4	1.7	1	0.85	3	2.5

Table 5.2: Responses to the use of local farming methods and practices

Responses	Overall		Highland		Lowland	
	Frequency	%	Frequency	%	Frequency	%
Agree	150	64.1	84	72	66	56.4
Disagree	71	30.3	26	22	45	38.4
Not sure	13	5.5	7	6	6	5.1

5.2.1 Hand hoe

Among the traditional farming methods and practices used by the small-scale rural farmers (Table 5.1), the hand hoe was the most popular being practised by all participants in their farm operations. Supported with the evidence from observations, the hand hoe formed the predominant means of farm operations (farm preparation (tillage), planting and weeding). In the lowland areas, only about 20% of the respondents acknowledged using tractors in farm preparation; however, during focus group discussions in the lowland zone one of the participants said that:

"…in recent years the use of tractors in farm preparations has declined due to increased hiring costs which range between Tsh 30, 000 to 40,000 (~USD 20) per hectare…"

In addition, some farmers fear persistent drought conditions and rainfall uncertainties, thinking that they might end up in getting losses if the crops fail and they do not recover the resources spent on the use of tractors. The testimony by the Ward Leader 04 justifies these views:

"…I cultivate some of my farm plots by using a tractor and others with hand hoe so that in case of poor rain I do not incur big loss. Currently I prepared two plots with a tractor, one for maize and another for sorghum but drought conditions are giving me pressure…"

Similar testimony was made by respondent MB08 who said that:

"…Today, using a tractor during farm preparation is like throwing money on the ground… you cultivate by using a tractor and harvest very little or nothing completely, crops fail due to drought... most people now just use hand hoe to avoid losses…"

These views show that changing environmental conditions and poverty limit the enhancement of rural agriculture especially for the resource poor. Weather variability and uncertainties limit the use of tractors due to limited funds and this makes farmers nervous to invest in agriculture, and hence maintains the hand hoe as the dominant means of farm operations, very much as a way to mitigate climatic conditions uncertainties, even though the use of tractor would increase the rate of infiltration, improve soil aeration and easy plant root penetration which could improve crop yields.

5.2.3 Mixed crop farming method

Another traditional farming practice is the use of the mixed crop farming technique. This is a popular farming method which was mentioned by 100% of the participants in the study and practised by 98% of the highland farmers, compared to only 80% of the lowland farmers (Table 5.3). Farmers are aware of the specific crop types which can be cultivated simultaneously on the same farm plot to ensure that competition for soil nutrients, soil moisture and sunlight is minimised. Some of these crops provide shade for the undergrowth, shield crops against wind effects and rainfall damage, and improve soil nutrients/fertility (through compost mulches from foliage and nitrogen fixation plants) (Snelder et al., 2007; Smith, 2010). This is supported by the explanation by Ward Officer 01:

"…Crop mixing helps in the management of insect pests because as insects target specific crops' leaves and/or flowers, the presence of many other crops confuses them, which make it difficult for the insects to identify the preferred crop. This allows crop to grow to maturity with minimum damage from insect pests…"

A study by Finch and Collier (2000) shows that insects settle on plants only when various host plant factors such as visual stimuli, taste and smell are satisfied, hence the chance of insects encountering 'bad' stimuli is higher for polycultures than in monocultures. Examples of intercropping that effectively prevent pests are the use of clover undersowing to deter cabbage root fly (Finch and Edmonds, 1994) and *Medicago litoralis* to deter carrot root fly (Ramert, 1993; Ramerti and Ekbom, 1996).

A similar view was expressed by District Official 01:

"…the growing of maize and beans together [which is common for the majority of the farmers in the study area] helps to increase soil nutrients…"

This finding is similar to other studies which suggest that the growing of leguminous plants together with maize helps to mitigate soil degradation (Sileshi et al., 2011), as they add organic matter and nitrogen to the soil (Akinnifesi et al., 2007; Beedy et al., 2010; Mafongoya et al., 2006; Snapp et al., 1998).

Table 5.3: Responses on the use of mixed crop farming method

Responses	Overall		Highland		Lowland	
	Frequency	Percentage	Frequency	Percent	Frequency	Percent
Agree	208	88.9	115	98.3	93	79.5
Disagree	26	11.1	2	1.7	24	20.5

Farmers also practise this method to ensure they can harvest some crops when others fail and because they do not have sufficient area of land to practise monoculture, as reported by District Official 03. Through farm observations, it was evident that all farm plots in the study area were planted with two or more crops depending on the preference of the farmer and location of the farm. However, lowland areas had fewer crop options compared with the highland areas, because other than maize (the main crop), most of the crops grown in the lowland areas are drought tolerant. For instance, in the highland areas, besides maize, beans and bananas which were the major crops grown in all farm plots, farmers also grew together other crops such as sugarcane, cocoyam, sweet potatoes, pumpkins, groundnuts and sunflower. Similarly, in most of the plots observed, farmers planted exotic trees and also retained selected natural types of trees, such as *Grevillea robusta*, *Cordia africana*, *Acrocarpus fraxinifolius*, ficus species and *Albizia gummifera*. From the interview with Ward Officer 01, it was apparent that some of the trees also improve soil nutrients from their foliage and nitrogen fixation from root nodules. Farmers also planted fruit trees such as avocado (*Persea americana*), jackfruit (*Artocarpus genus*), mango (*Magifera indica*), pawpaw (*Carica papaya*) and guava (*Psidium guajava*). Studies conducted in South Africa on agroforestry show that organic matter added to the soil by trees increases the structural stability of the soil, resistance to rainfall impact, infiltration rate, and faunal and microbial activities (Beedy et al., 2010) (Mafongoya et al., 2006; Sileshi and Mafongoya, 2006). Similarly, according to a study by Ulsrud et al. (2008), growing trees on the farm has the benefit of reducing risk of losses during extreme weather events such as floods, landslides and drought because trees are more resilient to such weather events than other plants (Ulsrud et al., 2008).

In the lowland areas, farmers grew together maize, greengram, cowpeas, groundnuts, cassava, lablab and sunflowers in varying proportions. Beans, sugarcane and plantain were grown on plots found in moist areas besides river channels and swamps, commonly known as *kitivo* in the local language. There were fewer trees grown on lowland farms, many of which grew naturally and are left on the farm because they do not affect crop growth and development. Such trees include mango (*Mangifera indica*), baobab (*Adansonia digitata*) and Ficus species (mostly along the water channels). Mixed cropping is considered to be beneficial as it is seen to balance the input and output of soil nutrients, reduce weed growth and insects, resist climate extremes and suppress crop diseases. The findings in the study match with the findings from other studies that suggest mixed cropping contributes positively to surrounding ecological processes due to its functional diversity which promotes sustainable agriculture (e.g. Altieri, 1999; Ramert et al., 2002). Similarly, as argued by Olukosi (1976) and Belshaw (1979, in Briggs, 1985), intercropping (which was long discouraged and considered as wasteful and inefficient) has been shown to be the most economically and ecologically efficient method of cultivation under certain environmental conditions, both reducing risk and aiding the maintenance of soil fertility. Also, cultivating tree crops together with food crops is practised elsewhere in the world, such as Indonesia, where farmers have introduced tree crops, such as rubber, into the Swiddens farming system (Gouyon et al., 1993). In West Africa, farmers maintain valuable trees which resist periodic fires in and around their crop fields, giving a park-like landscape (Boffa, 1999; Aruleba and Ajayi, 2012); while planters of tree crops such as cocoa, coffee and tea provide shade trees to reduce pest and disease pressure and nutrient requirements of their crops and protect them from climatic extremes (Beer et al., 1998). This shows the value and usefulness of some of the local traditional farming methods among the rural farmers in managing their farming activities. Although in the study area farmers enjoy these benefits and use them in mitigating the effect of climate changes, however, limiting access to sufficient farmland may have also contributed on the use of mixed cropping. On the other hand, changes in climatic conditions threaten the benefits accrued from agroforestry because more trees are now cut and sold to earn money for living.

Field observations showed that the rate of intercropping is higher in the highland areas than in the lowland areas as a result of increasing drought conditions with limited drought-resilient crop options, as increasing drought conditions favour fewer crops than in the highland areas, as well as increasing involvement of lowland dwellers in non-agricultural activities. This is supported by the remarks made by the Ward Leader 04:

“…despite the increasing drought conditions, the lowland areas are becoming more urbanised due to the increase in business activities and interaction with other near and distant urban centres within the district and outside. The growing urbanisation tend pushes the majority of the dwellers to engage in small-business and service activities more than agriculture which is affected by increasing drought conditions. Hence, a few who are engaged in agriculture focus more on increasing production per unit area with a greater focus on increasing production with minimum losses…”

5.2.4 Random crop planting method

Another popular traditional farming method practice is the use of a random planting technique which is known to 95% of the respondents. This was also evident from farm observations where all 50 farm plots observed had crops planted randomly without a defined pattern or spacing between neighbouring crops. However, the study revealed that due to continued involvement in farming activities, farmers have gained knowledge and skills where they grow different types of crops haphazardly and maintain a reasonable distance from one crop to another which enables crops to grow to maturity without affecting each other and also allow other farm operations e.g. weeding and application of pesticides. During interviews respondents had different views with regard to the method. For instance,

Respondent SF07 said that: “…planting by lines wastes much space because distances between crops and lines are too wide that too much space in-between remained unutilised…”

Respondent SF04: “…I determine the space from my mind…”

Respondent CH15: “…I use the handle of my hoe and that distance has always been accurate…”

Respondent CH64: “…the plot is small and if I plant crops on lines, I will have very few planted because growing crops in lines require bigger areas…”

Respondent MB21: “…I plant randomly and make sure that I do not skip those areas which have more fertile soils than others…”

Respondent ML37: “… the presence of permanent crops (e.g. sugarcane and banana), stones and trees in the farm limit the use of lines…”

Respondent KW14: “…the problem is not random planting but insufficient rainfall; I grow my crops randomly but maintain sufficient distance between them and I have always been doing this and harvested enough when there was sufficient and reliable rainfall…”

From the observations, interviews and focus group discussions, it is clear that some of the farmers who practised random planting were more interested with quantity of the crops on the farm rather than their quality, while others practised the strategy as business as usual. The majority of the participants did not consider random planting to be a problem despite the fact that they are able to determine proper spacing without affecting the productivity of the crops in the farm. This technique, although considered useful, may contribute to poor harvests as many of the crops observed were weak and experienced stunted growth due to the limited availability of soil nutrients and lack of sufficient sunlight.

5.2.5 Local and indigenous seeds

About 94% of the respondents mentioned the use of indigenous traditional seeds and locally prepared seeds (maize and beans) as a popular traditional farming practice. However, about 38% of the participants, the majority from the highland areas, used locally prepared seeds. The use of local seeds was explained by farmers during focus group discussions and interviews.

Respondent SF05 said: "…in the past, indigenous local seeds formed the basis for the farming activities... farmers grew local maize varieties commonly known as *Mwasu* in the local language. The species was sweet, tasty and resistant to most of the storage pests, but it required a longer growing season (four to six months) with sufficient rainfall. Hence planting was done early in August which was favoured by cool weather conditions with the support of traditional irrigation methods (use of open water canals and buckets) due to the availability of water along the rivers, streams and in wetlands [popularly known as *champombe* in the local language] where maize survived until the rain began in early or mid – October and in the lowland, planting was done in late February to mid-March…"

Similarly, Respondent CH13 said:

"…in the local language, *mwasu wangu ethekinitagha* means 'whenever I planted local maize species I always harvested'. Currently the varieties fail due to increasing drought conditions which makes me rely on improved seeds which take a shorter time to grow top maturity, tolerate drought conditions and may lead to high yield when compared with *mwasu*…"

However, respondent said CH13 said:

"…currently farmers grow improved seeds which take a shorter time to grow to maturity, tolerate drought conditions when compared with *mwasu...*"

Participant HOH03 suggested that because indigenous local maize varieties require longer growing seasons with sufficient rainfall, they are currently not preferred. A few farmers who still grow local maize varieties do not grow it independently, but mix it with improved varieties. Early planting which was once possible in the highlands, especially *champombe* farming, is no longer practised because most of the rivers, streams and wetlands, which otherwise could support *champombe* farming, have dried, while the remaining few cannot support this type of farming due to insufficient water and increase in sun intensity. In addition, Participant HOH03 explained that *vuli* and *masika* rainfalls have become erratic, which can make early sown maize fail due to increases in drought conditions, temperature, sunshine intensity and erratic rainfall. These views were shared by the majority of participants who also agreed that these changes have resulted in the disappearance of most of the indigenous local maize varieties. However, participants throughout the study admitted the use of improved seeds but explained further that these changes also contribute to crop failure among both local and improved maize varieties. The participants' views suggest that farmers realise that changes in weather conditions, especially rainfall and changes to the normal growing season, do not favour the growing of local maize varieties. Their views also suggest that changing environmental conditions affect some of the local farming methods and crop species. The increasing erratic nature of environmental conditions may potentially influence some farmers to gradually abandon some of these local farming practices and some of the valued indigenous crops.

Despite the increased use of hybrid seeds, farmers still use their local knowledge, skills and practices in the preparation of seeds. Farmers in the study area, especially women, have learnt how to identify and preserve the best seed grains for planting in subsequent seasons. According to Respondent CH11, the sorting of maize grains is done after the maize has been harvested, hence the selected maize cobs are placed or hung in the kitchen or in the loft to dry by smoking them (see Plates 5.1 and 5.2). The smoke from the burning wood forms a coat of soot on the grains which makes the grain taste bitter, which protects it from being attacked by grain borers and rats during storage and after being planted. When the grains have dried and gained a sufficient coat of soot, they can either be removed from the cob and stored in a dry air-tight container, or left hanging in the kitchen until the day of planting. The most popular container in the preservation and storage of seeds is the gourd. This technique of seed storage allows the seeds to be stored longer without being spoiled. A similar traditional maize seed preparation and storage technique was also observed among the Shona farmers in Zimbabwe (see Mapara, 2009).

Plate 5.1 Traditional maize seed storage in Ngujini Ward

Plate 5.2 Traditional sorghum seed storage in Ngujini Ward

The locally prepared and preserved seeds are mixed with improved seeds during planting which reduces the risk and rate of pest, insect and vermin attack before and during seed germination. Respondent CH09 explained that:

"…Improved seeds, although treated, are also vulnerable to pest attack especially small ants and destructive lizards locally known as *ving'ola* and vervet which feed on maize seed grains before or during germination…"

The participants explained further that the rate of attack increased when seeds were planted early with the expectation of the onset of rainfall, or after first rain followed by long period of no rain occurring before the crops have fully germinated.

Mixing the locally prepared seeds with factory seeds was perceived to reduce the rate of pest and vermin attacks on the seeds because locally prepared seeds tasted bitter thus were not favoured by pests and vermin. Similarly, participants reported that by mixing seeds, they reduced the risk of crop failure under poor conditions which did not favour the particular type of maize variety. These views on the use of the seed-mixing technique were shared by both lowland and highland participants during focus group discussions.

In some cases, the planting of locally prepared seeds was necessitated by delays in the delivery of seeds from the District Agricultural Office, as explained by Respondent CH11 that:

"…Locally prepared seeds help especially when the seeds provided through vouchers are delivered after the first rain. As it rains, I begin planting the locally prepared seeds on a few plots while waiting for the improved seeds. This is because I registered for receiving improved seeds so I cannot spend money buying other seeds for I will end up paying twice for seeds…"

Respondent MB10 claimed that most of the factory-made seeds have more yield when recycled compared with the first time harvest. This view also justified why most farmers in the study area preferred to recycle seeds despite the non-availability of improved seeds

5.2.6 Use of local pesticides and herbs

Another local farming method which is practised in the study area is the manufacture and use of local pesticides. Farmers, through the use of their LEKEP, identify certain materials from the natural environment, including plant and animal by-products, and use them in the preparation of local pesticides. The locally made pesticides have been effective in the treatment and control of the damaging effects of the crop diseases and insects among farmers for generations. Knowledge of the use of local pesticides as a local farming method was mentioned by 85% of the respondents, with very little difference between highland and lowland farmers (Table 5.1). However, out of the 234 farmers sampled, only 57% confirmed the actual application of the local pesticides on their farms (27% who only used local pesticides and 30% who used both pesticides), of whom the majority were from the highland areas; 31% reported not using local pesticides and only 12% reported using neither of the two pesticides on their farms (Table 5.4). However, farm observations revealed that most of the crops in the highland farms were applied with local pesticides due to the higher rate of pests and crop diseases compared to the lowland areas and costs involved in the use of pesticides.

Table 5.4: Responses to the application of pesticides

Responses	Overall		Highland		Highland	
	Freq.		Freq.	Percent	Freq.	Percent
Apply only local pesticides	62	26.5	35	29.9	27	23.0
Apply only industrial pesticides	73	31.2	35	29.9	38	32.5
Apply both pesticides	71	30.3	39	33.3	32	27.4
Apply both none of the pesticides	28	12.0	8	6.8	20	17.1

This knowledge and skill on the use of traditional pesticides has been developed over generations through trial and error, and continuous observation of the relationship between plants and insects' behaviour. For instance, participant HOH04 explained how farmers discovered different types of local herbs and pesticides in the past. The interview revealed that farmers were able to identify types of trees and plants with medicinal value by smelling and chewing the plant. If the plant tasted bitter or had a strong odour, they used it in the manufacture of pesticides. They also observed the relationship between insects and plants, in which certain plants were not preferred or eaten by insects; these insect-resistant plants were considered to have some medicinal value, and so were used in the manufacture of pesticides. Some plants are poisonous, others have a strong odour, while others taste bitter; such plant features either repelled or killed insect pests, and so were identified as suitable materials for the production of pesticides. Such plants used include *Tephrosia vogelii*, *Lippia javanica*, *Lobelia hypoleuca* and *Capsium frutescens*.

Observations and experiments were done in the traditional clan forest *Mbungi*. Elders observed these relationships and when they discovered something, they said 'the gods have shown us'. This is the reason why no one was allowed to enter into these forests. People were banned from collecting fire wood, fruits and poles for house construction from the *Mbungi* because they could disturb the ecosystem and affect the observation process. Even entering into the forest without notifying specific elders was prohibited. It was believed further that a person who entered the *Mbungi* without permission and collected fruits, fire wood, or used the forest as a place of convenience, could be transformed from one sex to another. *Mbungi* were considered to be sacred and private places for prayers and meeting places with gods and spirits as discussed in the previous Chapter. The use of *Mbungi* reveals a complex relationship which existed between the indigenous people and their natural environment, and how that enabled them to develop special knowledge and skills which they utilised in managing and solving agricultural related problems, such as pests and crop diseases, without affecting their ecosystem. Focus group discussions and interviews revealed that most of the farmers have abandoned the use of these local herbs as most of them do not prove to be effective.

According to District Official 01, some of the traditional pesticides do not kill the insect pests but others do. Some trees/plants varieties just produce odour which is not preferred by insects. Hence, when applied to the crops, they expel the insects or cause them to lose appetite for the crop, thus allowing those crops to survive to maturity, free from pest attacks. Although farmers still use locally prepared pesticides, some have lost confidence in them, probably because they do not know that they are supposed to use local pesticides/herbs persistently rather than occasionally; otherwise the very first pesticide application loses its potency within which period pests invade the crops again and cause more damage. This makes farmers lose confidence in their local knowledge and practices.

These explanations justify the effectiveness of local pesticides by suggesting that if local pesticides are administered properly, they can prove to be effective. However, the study suggests that the ineffectiveness of the local pesticides may not only be caused by limited knowledge in their applications, but also may be caused by insects becoming immune to some of the locally prepared pesticides and herbs due to continuous applications. Moreover, changes in environmental conditions, such as increases in temperature and drought conditions, may contribute to the changes in insects' behaviour and make them feed on crops which they previously did not prefer, some of which are used in the manufacturing of local pesticides (in this case, those plants which produced unpleasant odours or tasted bitter).

Plants such as *Tephrosia vogelii* species (*Utupa* in Swahili), *Lobelia hypoleuca* species (*Ngonye* in the local language), *Capsium frutescens* (*pilipili kali* in Swahili), *Lippia javanica* (*Mvuti* in the local language), *Carica papaya* or pawpaw and *Azadirachta indica* tree (*Mwarobaini* in Swahili) are commonly used in the manufacturing of local pesticides. The green leaves of these plants are used in the manufacturing of pesticides, except for C*apsium frutescens* where its fruits are used instead. The preparation involves the picking of the green leaves of these trees (the fruits in the case of C*apsium frutescens*) and pounding them to form a soft substance which is either mixed with water and sieved to get the fluid from the leaves, or dried to form a powder which is applied to the affected crops and vegetables. However, from the focus group discussions, it was revealed that farmers prefer to use the pesticides in liquid form to that in the powder form. These pesticides are used in the management of both insect pests and crop diseases, such as aphids, mosaic, bruchids (beans weevil), armyworms, maize stock borer, white flies, locust and mole rats. Similarly, farmers use the leaves of *Lobelia hypoleuca* and *Lippie javanica* in the storage of crops. The leaves of *Lobelia hypoleuca* (Plate 5.3) are picked and put in the loft of the kitchen, and crops (especially maize) are put on top and left to dry which protects the crops from storage pest attack. With *Lippia* *javanica*, the leaves are picked, pounded and dried to form a powder which is then mixed with crops and stored in a dry air-tight container. *Lippia javanica* manages pests by suffocating them due to its strong smell. Farmers also use *Euphorbia tirucali* (*Mnyaa* in Swahili) in the management of mole rats which feed on potato, cassava, sugarcane and banana corm. The *Euphorbia tirucali* is planted in the farm with other crops or inserted in the barrows of mole rats. This attracts mole rats to feed on it, thus poisoning them. Farm observations witnessed the *Euphorbia tirucali* planted with banana plants in the management of mole rats (see Plate 5.4).

Plate 5.3 Lobelia hypoleuca species

Plate 5.4 Banana planted together with Euphorbia tirucali in Kilomeni Ward

Households also collect wood ash from the kitchen and sieve it to form a fine powder which is applied to the affected crops and vegetables. It was revealed during focus group discussions that some households mix ash with a few drops of paraffin (amount not specified) or factory pesticides to increase the efficiency and amount of the pesticide. Even though respondents did not specify suitable trees or plants for the manufacturing of pesticides from ash, according to District Official 01 and Ward Officer 03, the most effective ashes are obtained from maize cobs and wheat husks, due to their high concentrations of silicate which harm the insect when its body comes into contact with the ashes. The use of wood ash is the most common type of traditional pesticide used in most of the highland farms.

In addition, the focus group discussions revealed that some farmers used lime and sodium bicarbonate as pesticides. These are bought from the market, pounded and sieved to form a fine powder which is applied to the affected crops and vegetables. Similarly, both ashes and lime are used in the management of the storage pests. After crops have been harvested and dried, they are mixed with ashes or lime (amount not specified) and packed in dried air-tight containers. According to District Official 01, the use of lime and ashes in crop storage protects crops from being attacked by pests, because lime and ashes have the following effects on the insects: suffocation, dehydration, drying the air they breathe, irritation effects leading to blisters on their bodies ultimately resulting in their death.

Farmers also prepare local pesticides from cow by-products such as urine and dung. This method is popular among the farmers who use biogas as the source of fuel in their homes. As explained by Respondent LM30:

"…the method involves the collection and mixing of cow urine and dung; the mixture is then allowed to decompose for 7 to 14 days. After this period, the mixture is sieved and diluted with clean water hence applied to crops or vegetables…"

While respondent SF 03 mentioned similar preparation procedure but added the use of soapy water rather than the use of clean water.

This type of pesticide is mostly used in the treatment and control of aphids and white flies that cause damage to the vegetables and it is also used in treating banana root/corm rot disease as reported by Ward Officer 01. The effectiveness of this type of pesticide was explained by Respondent LM 30:

"…I find the pesticides to be effective and have excellent results in controlling vegetable pests, hence I do not have to spend money any more in the purchase of factory pesticides… since I started using this type of pesticide I have been free from the effects of factory made chemicals…"

The respondent who used soapy water as a diluent could not explain why it was necessary to include soap in the mixture. However, Cranshaw (1996) explains that the use of soap and detergents disrupts the cell membranes of the insects, and may also remove the protective waxes that cover the insect, causing death through excessive loss of water. The study suggested further that soap can be used to control a wide range of plant pests such as aphids, mealy bugs, psyllids and spider mites.

5.2.7 Manual insect killing

Another traditional method practised in the management of insect pests, as observed in the field and explained by participants during interview and focus group discussions, involved the manual killing of insect pests. Respondents SF07, CH14 and HOH01 had similar views on the use of this method and similar explanations were given during focus group discussions both in the highland and lowland areas. It was argued that farmers kill the insects by cutting off their heads and crushing their bodies by using stones. The crushed insects release a smell which, when sensed by other insects, makes them sense the danger of death, hence they flee for safety. This exercise of killing insects is done early in the morning before the insects become active, at which point it would be more difficult to seize them. Farmers explained that when the insects are killed early before mid-day, the smell becomes stronger at mid-day (when the sun is strong) and spreads to a larger area making insects fly away to a safer place. This method is popularly used in managing insect pests which feed on crop flowers, especially legumes. The common insect pests managed through this method include black blister beetles and yellow and black-coloured beetles (*Mylabris*) called *mbariti* in the local language (see Plates 5.5, 5.6 and 5.7). In addition, farmers bury the insects deep in the ground making sure that there is no possibility of the insect coming out from the ground. This physical killing of the insects reduces the application of chemicals on the crops especially when the crops are at their flowering stage which could affect the quality of crops due to the application of chemicals.

Plate 5.5 Black blister beetles feeding on Sodom leaves

Plate 5.6 Black and yellow-coloured beetle feeding on beans flowers in Ngujini ward

Plate 5.7 Black and yellow-coloured beetle feeding on plant flowers in the lowland

5.2.8 Use of scarecrows, paper and plastic bags

During farm observations, the use of scarecrows to ward off vermin, especially blue monkey (*Cercopithecus mitis*), vervet monkey (*Chlorocebus pygerythrus*) and baboons (*Papio anubis*) and antelope, especially dik-dik, were observed (see Plates 5.8). Respondent SF03 explained:

"…vermin are scared of the scarecrows because they consider them to be human beings and also because they are dressed in human clothes. When the vermin sees and senses the smell they get scared, hence do not come to the farm. The presence of the images also deceives the vermin that the farmer is already on the farm…"

However, although some farmers still use scarecrows to deter and scare vermin, currently the method is reported to be ineffective due to changes in climatic conditions, especially droughts which have resulted in food shortages especially wild fruits and grass, thus encouraging vermin to feed on crops without been scared of scarecrows. This was reported by Respondents KS05, MB16 and OH06, as well as in focus group discussions.

Plate 5.8 Scarecrow in Kilomeni Ward

Farmers also scare birds from feeding on crop grains, such as sorghum and sunflowers, by using flying clothes and papers or by covering the grains using plastic bags to prevent birds from feeding on the grain (Plates 5.9 and 5.10).

Plate 5.9 Sorghum grains covered with plastic bags in the lowland area (Lembeni ward)

Plate 5.10 Sunflower grains covered with plastic bags in the lowland area (Lembeni ward)

The use of scarecrows, papers and plastic bags in managing vermin (black monkey, vervet and baboon) and birds, although may be thought to be ecologically friendly, is said to be limited and ineffective by the majority of the respondents in the study area. Limited availability of wild fruits, caused by increasing drought conditions, makes this technique rudimentary and ineffective because black monkeys, vervet monkeys, baboons and birds are not scared of these tricks. For instance, birds were reported to tear-up the plastic bags covering the grains and feed on the grains. The vervet monkey and black monkey tease the scarecrow until they recognise that it is not a true human being, hence they start feeding on the crops. Respondent SF03 explained that:

"…baboon and vervet monkey are sometimes not scared of human beings, especially women and children, their presence in the farm does not prevent them from feeding on crops. The only thing which can keep them away from the farm is the use of gun fire or shooting to kill some of them which scares them so they go into hiding in the bush for a short while allowing crops to grow to maturity without being damaged…"

However, the use of gun is considered to be expensive because farmers have to pay for the bullets. Similarly, the method is not ecologically friendly because it affects the population of these animals and increased killing may threaten their existence.

5.2.9 Use of trench method

Another traditional method for the management of vermin is through the excavation of a narrow channel known as *mkuva* or *mtaro* in the local language. The study observed that farmers in Ngujini ward have excavated a deep trench along the forest reserve border which deters vermin such as wild pigs (which feed on sugarcane, yams, maize, pumpkins and banana stem), impala and dik-dik (which feed on bean leaves) and porcupines (which feed on yams) to cross from the forest reserve to the farms (Plate 5.11). The trench is half a metre wide and one and half metre deep, however, the depth in some areas was reported to have increased due rainwater erosion.
According to the Village Leader 02:

"…before getting this idea of excavating a deep trench along the fringe of the forest reserve most of the maize, banana, yams, beans, pumpkins and sugarcane were destroyed by wild pigs, impala, dik-dik and porcupines. But since we finished this task, these animals no longer come to our farms, enabling our food crops to stay safe. The channel was excavated from 1987 to 1988…"

The trench is cleaned and maintained once in a year by the community through a collective participation technique known as *msaragambo,* where one member from every household in the village participates in the cleaning and maintenance of the trench. The study considers this method to be ecologically friendly as it does not cause damage to the existence of the wild life, but keeps them at a distance from the farms and naturally maintains their existence in the forest. According to the oral histories and focus group discussions, dwellers in the past excavated deep pits (~3 metres deep) in the forest, put long pieces of wood across them and then covered them with grass. A bait of banana and/or sugarcane was placed on top of these covered pits to attract the vermin, which, when in an attempt to feed on bait, fell into the pit; the trapped vermin was usually killed and taken out from the pit later by the farmers. However, this method was not very effective as few vermin were trapped. Snares were then subsequently used but that method was also found to be ineffective. The third mechanism was the use of poisoned bait which proved to be successful, but posed certain threats to the community: most domestic dogs died after feeding on the carcasses. It was considered to be dangerous because some of the poison could be washed into running water in the rivers and streams and contaminate drinking water, consequently affecting people's health, while others said it could affect their animals as they collected fodder from the forest to feed their livestock during the time of fodder shortages. Hence, the use of ditch has proven to be successful and effective in the control of vermin especially wild pigs, porcupines and impala and dik-dik.

Plate 5.11 Trench for preventing vermin crossing from the forest reserve to farms

5.2.10 Zero-tillage method

Another traditional farming method practised is the use of zero tillage, popularly known as *kitang'ang'a* in the local language a practice of sowing seeds on an uncleared farm plot. The zero-tillage technique was mentioned by 53% of the participants (Table 5.4). From farm observations, it was evident that the technique was practised by farmers in both zones. Farmers grow crops on uncleared farm plots immediately after the first rain and weeding begins early before the seeds have fully germinated. The technique is said to reduce the costs of weed, vermin and pest management because farm clearing is done during weed germination which keeps the farm clean while germination takes place on a clean farm plot. This was explained by Respondent CH12 in Ngujini ward:

"…By practising *kitang'ang'a*, I only have to weed my plot twice and there are less weeds during crop harvest with fewer rats attacking my crops…"

The technique is also effective in reducing the rate of surface soil erosion from run-off because soil particles remain undisturbed during heavy rain, and the presence of grass on the top soil provides a shield against surface run-off. However, during focus group discussions, both in the lowland and highland areas, participants gave reasons why some farmers practised *kitang'ang'a*. It was evident that in the past farmers practised *kitang'ang'a*, because they had many farm plots to cultivate before planting and they could not clear all of them on time before the growing season started. However, in recent years farmers have been forced to practise *kitang'ang'a* due to the erratic nature of rainfall; that is, sometimes it rained before farmers had finished or even started, preparing their farms for planting. In some seasons, rainfall came late or signs indicated a low rainfall, but to their surprise it rained a lot, hence they were forced to practise *kitang'ang'a*. It was further explained that some farmers had spent money on farm preparation using a tractor in the previous season, but, due to drought conditions, crops failed and farms remained bare, so they planted immediately as it began raining in the following season. Some considered the technique to be economical due to the shortage of labour at the household level and the limited funds available for hiring labourers for farm preparation, planting and weeding. In spite of the benefits accrued from the use of the *kitang'ang'a* method, current changes in climatic conditions limit the applicability of this method.

According to Respondent CH09*:*

"…in the past, *kitang'ang'a* was successful because of reliable, sufficient and continuous rainfall. However, current changing environmental conditions coupled with low, variable and insufficient rainfall, concentrated within a few days the technique has become unsuccessful, hence less practical and is highly opposed by the majority of the households and agricultural extension officers…"

Similarly, Respondent LM24 said:

"…currently if you do not want to harvest completely, practise *kitang'ang'a*… in the past, we practised *kitang'ang'a* because it could begin raining even before we had finished removing crops in the farm. But today, there is not sufficient rainfall, so I do prepare fewer farm plots which I make sure that they are prepared early before rain begins…"

District Official 01 and Ward Officer 01 had similar views that farmers practised *kitang'ang'a* due to poverty and lack of funds to pay for the costs of farm preparations. However, under current changes, the method may not be preferred because it reduces the rate of water infiltration which results in increased surface run-off. This is caused by the fact that compact soils inhibit the rate of infiltration during heavy rains, and also prolonged drought conditions keep surface soils bare which accelerates the rate of surface run-off during period of heavy rainfall. In addition, according to

Respondent ML24, when weeding is not done or finished in time, most of the fresh germinating crops compete for sunlight, soil nutrients and soil moisture with growing weeds, and also are exposed to insect pests, diseases and vermin attack. Similarly, compact soil deters the growth of the roots of crops to deeper soil layers which makes the germinating crops vulnerable to sunshine intensity. More importantly, the technique is attributed to poor crop yields. Evidence from farm observations showed that most of the crops which were planted on uncultivated farm plots in the lowland areas withered quickly after a long period of rain break and intensive sunshine than those which were grown on a cultivated farm using a tractor. These crops tolerated a prolonged period of sunshine and survived until it rained again, but they ended producing flowers due to prolonged period of heat stress.

Crop rotation was mentioned by 11% of the participants who practised this method. Respondent MS20 said:

"…these farms have been cultivated for over 80 years and most of them are tired because farming is done without any additional manure or fertilisers which affects crop productivity. I try to grow crops interchangeably, that is when I grow maize on one farm, I grow beans on the other and alternate these crops in the following season. This helps to improve my production although not much, still there is a need to apply manure…"

Respondent CH13 said:

"…I used to grow maize in *vuli* and beans in *masika* seasons, but in recent years, due to crop failure caused by increase in droughts and insufficient rainfall, I grow all crops in all seasons to try my luck; i.e. if maize fails then I will harvest beans, so that I will not have laboured in vain…"

These sentiments suggest that uncertainties in weather conditions also limit crop rotation techniques which could help in the improvement of crop productivity by limiting the number of crops grown on a given plot. Fewer crops could reduce competition for the limited soil nutrients on the farms and crop rotation could improve soil fertility hence increase crop productivity. However, maize forms the main staple crop cultivated in the study area, hence most farms are cultivated with maize throughout the year without practising crop rotation. This may be contributing to the depletion of soil nutrients in many farms in the study area.

5.2.11 Farm fallowing

Farm fallowing is another traditional farming method mentioned by 14% of the respondents. However, during oral histories and focus group discussions, participants reported that traditionally Farmers did not apply manure to their farms (especially on distant farms), but cultivated the land and when they realised that the soil nutrients had declined (by using local indicators which are discussed in the next section) they abandoned the farm and opened a new one in another area. Nevertheless, they returned to the abandoned plot after they observed that the farm had naturally regained sufficient soil nutrients. Currently, almost all of the appropriate and fertile agricultural areas have been cultivated which limits the creation of new farms. Thus, most of the farms are continually cultivated without fallowing, and even where fallowing is practised it is only done so for a short duration. Cultivating farms without additional nutrients has resulted in increasingly poor soils, especially in the highland areas. During focus group discussions in the highlands, one of the participants commented that currently farm fallowing is not primarily aimed at regaining soil nutrients, but is driven by an increase in drought conditions and a shortage of labour at the household level which force farmers to cultivate fewer plots. However, farmers return to the previous fallowed farm within a very short period before the farm regains sufficient nutrients.

5.2.12 Farm-fertility indicators

Farmers use their LEKEP to determine the level of soil nutrients in a given farm plot. This knowledge helps to recognise the nutrient level of the soil in a given farm plot which enables farmers to take appropriate measures to either replace declining soil nutrients by adding manure, fertilisers, or adopting fallowing to allow natural soil nutrient regeneration and/or change types of crops grown in the farm. As mentioned by Respondent MS17:

"…when yields decline, I know that soil nutrients on the farm have declined, so I grow beans repeatedly in few seasons or stop cultivating the farm plot for a short while…"

The knowledge and skills gained by the above respondent, is also supported by other studies which suggest that the growing of legumes on the farm increases the amount of organic matter and nitrogen to the soil (Snapp et al., 1998; Mafongoya et al., 2006; Beedy et al., 2010; Akinnifesi et al., 2007).

Among the indicators mentioned, crop health (100%) and crop yields (100%) were the most common indicators (Table 5.5). Participants associated good crop health and high crop yields with fertile soil, and poor crop health and yields with infertile soils. This knowledge by the farmers is supported by Schroth and Sinclair (2003), who point out that fertile soils facilitate root development, supply water, air and nutrients to plants and are free from pests and diseases which can result in catastrophic impacts on cultivated plants. Similarly, Smaling et al. (1997) and Ajayi et al. (2007) explain that soil nutrients are considered by many tropical farmers to be the major biophysical constraint to increasing agricultural production. About 89% of the participant the majority from the highland (95%), said they determined the level of soil fertility in a given farm plot by associating it with types of grass and shrubs growing in a given area. Participants explained that by looking at the presence of grass and shrubs in a given farm plot they can tell whether the soil is fertile or infertile. As mentioned by Respondent SF01:

"…When you see grass such as black jack [*Bidens pilosa*], Macdonald's eye [*Galinsoga parviflora*] and wandering Jew [*Commelina benghalensis*] growing on a given plot is an indication that the plot has fertile soil but the presence of ferns [*Pteris tremula*] in a plot means the area has poor soil…"

According to Respondent CH13, the presence of grass such as black jack [*Bidens pilosa*], Macdonald's eye [*Galinsoga parviflora*], *itughutu* in the local language [*Vernonia subligera*] and wandering Jew [*Commelina benghalensis*], and trees such as *Albizia* and *Ficus congesta*, are used to determine the choice of an area to be used as a farmland.

Table 5.5: Indicators used to determine soil fertility in the farm

Soil fertility indicator	Overall	Highland	Lowland
	Percent		
Crop health	100	100	100
Crop yield	100	100	100
Grass and shrubs	88.5	94.9	82.1
Soil colour	67.5	86.3	48.7
Soil texture/particles	66.2	91.5	41.0
Presence of organisms	39.3	47.9	30.8
Type of trees	38.9	58.1	19.7

Approximately 68% of the participants mentioned the use of soil colour in determining soil nutrient levels in a given farm plot. Respondents associated black and brown soils to be fertile and red coloured soils to be infertile. About 66% of the respondents associated soil fertility with a soil texture and particles. They considered fine soils with small percentage of sand to be fertile and white sandy soils, stony/rocky soils and poorly drained soils to be infertile, while 39% considered soils with the presence of soil organisms, such as earthworms and dung beetles, to be highly fertile, and 39% mentioned the presence of specific tree species growing in a given area to be associated with fertile or infertile soils. Trees such as *Albizia species*, *Ficus species*, *Albizia maranguensis*, *Cordia affricana*, *Rauvolfia caffra* and *Bridelia micrantha* are considered to grow on fertile soils (Table 5.6 and Table 5.8); while *Cactus species*, *Brachylaena*, *Senna siamea*, *Dodonaea viscose*, *Columnar cactus pachycereus*, castor plant and *Dalbergia melanoxylon* are considered to grow on infertile soils or normally where they grow soil nutrients are low or wastelands. It is important to note that castor oil plant was reported to grow in areas with moderate soil fertility and on wastelands in the highlands but lowland farmers consider it to grow on the fertile soils especially in alluvial deposits (Table 5.7 and Table 5.9).

According to Ward Official 04:

"…some trees use all the soil nutrients and do not allow undergrowth which makes soils very poor, while others allow undergrowth and attract organisms which increase soil nutrients through decomposition… the presence of a given type of trees can indicate the level of soil nutrient of the plot…"

Indeed, some farmers mentioned *Azabirachta indica* and *Eucalyptus* (which are exotic species) as draining all soil nutrients, limiting undergrowth and hardening soils in the places where they have been planted. As explained by Schroth and Sinclair (2003), most trees take up some of their nutrients from the subsoil and deposit them in the surface soil through leaf litter and root decay, and thus can act as nutrient pump. Farmers' knowledge in determining soil fertility, using different soil characteristics, is supported by the study by MacEwan (2007), which suggests similar soil characteristics in determining soil fertility. The study suggests that soil colour indicates the composition of the soil and gives clues to the conditions that the soil is subjected to, hence providing a valuable insight into the soil environment which is very important in soil assessment and classification. However, soil colour is influenced by the amount of proteins present in the soil, where yellow or red soil indicates the presence or accumulation of iron oxides. Black and dark brown colours represent soils with higher levels of organic matter content, and white indicates the predominance of silica (quartz) or the presence of salts. Wet soils, or soils with a higher water content, have less air, especially oxygen. Similarly, the study suggests further that the presence of specific minerals in the soil also affects soil colour. For example, the presence of manganese oxide causes a black colour soil, glauconite makes the soil green and calcite can make soil appear white.

Evidence from this study shows that both lowland and highland farmers use similar indicators to determine soil fertility levels on a given farm plot which is of paramount importance in agricultural productivity. The best known and widespread soil fertility determinants are crop health and crop yield which were mentioned by 100% of the participants, both in the lowland and highland areas. Farmers also mentioned the use of grass, shrubs and trees growing in a given area to determine the fertility level of the soil. For instance, grass such as black jack (*Bidens pilos*), wandering Jew (*Commelina benghalensis*), Bermuda grass (*Cynodon dactylon*), coach grass (*Elymus repens*) and fig tree (*Ficus species*) are used both in the lowland and highland areas to represent fertile soils (Table 5.6 and 5.8). However, other grass, shrubs and trees are different because their growth and survival is influenced by different climatic conditions (rainfall, temperature and wind) and topography which are different in both zones. Similarly, both lowland and highland farmers use similar soil colours and texture to determine the level of soil fertility. Farmers relate soil colour particularly to the presence of organic matter with black and brown colours, while reddish and whitish (sandy) soils are considered to contain low to moderate organic matter and thought to be infertile. Also, farmers in both lowland and highland areas consider soils with large particles to be low in organic matter and hence infertile.

Table 5.6: Indicators of fertile soil in the Highland zone

Indicator	Local /Swahili name	Common /English name	Scientific/botanical name
Grass and shrubs	Vimbara*	Black jack	*Bidens pilosa*
	Ikwengwe*	Wandering Jew	*Commelina benghalensis*
	Kivughai*	Macdonald's eye/ gallant soldier	*Galinsoga parviflora*
	Ibangi*	Mexican marigold	*Tagetes minula*
	Itunguja*	Ground cherry/ Chinese lantern	*Physalis peruviana*
	Sangari** (soil with lime)	Coach grass	*Elymus repens*
	Ukoka**	Bermuda grass	*Cynodon dactylon*
	Mnafu/mnavu*	Black nightshade	*Solanum nigrum*
	Mifundo fundo**	Tick-trefoil/tick clover	*Desmodium species*
	Ndago**	Nut grass	*Cyperus rotundus*
		Vetiva-Vetiver grass	*Zizanoides*
	Itughutu*		*Vernonia subligera*
	Mvuti**		*Lippia javanica*
Trees	Nyasutu*		*Albizia species*
	Mvuno*		*Ficus species*
	Ihuu*		*Albizia maranguensis*
	Mringaringa**		*Cordia affricana*
	Mberebere (Msesewe)*		*Rauvolfia caffra*
	Mkuu*	Fig tree	*Ficus congesta*
	Mwira*		*Bridelia micrantha*
	Mbono*	Castor oil plant	*Ricinus communis*
Soil colour and particles	• Black soils • Brown soils with small percentage of sandy particles		

Note
*local name and **Swahili name

Table 5.7: Indicators of infertile soil in the Highland zone

Indicator	Local/Swahili name	Common/English name	Scientific/botanical name
Grass and shrubs NB: short and weak grass	Mathiu* Kifutafuta* Kinguji*	Ferns	*Pteris tremula/*tender brake
Trees	Njitwe* Kitakua* Iririko*		*Dodonaea viscosa*
Soil colour and particles	• Red soil • Soils found in soft rocks • Poorly drained soils (called *ipughe* in Pare language) • Stony soils		

Note
*local name
**Swahili name

Table 5.8: Indicators of fertile soil in the Lowland zone

Indicator	Local/Swahili name	Common/English name	Scientific /botanical name
Grass and shrubs	Ndago**	Nut grass	*Cyperus rotundus*
	Vimbara*	Black jack	*Bidens pilosa*
	Ikwengwe*	Wandering Jew	*Commelina benghalensis*
	Sangari**	Coach grass	*Elymus repens*
	Ukoka**	Bermuda grass	*Cynodon dactylon*
	Mdudu*	Tuber root sp.	
	Idungusi*		*Cactus opuntia*
	Imondo*		*Bidens ferulifolia*
Trees	Mwerera*		*Acacia xanthophloea*
	Mgunga*		*Acacia tortilis*
	Mkoro maji**	Natal mahogany	*Trichilia emetica*
	Mbuyu**	Baobab	*Adansonia digitata*
	Mkababu**		*Faidherbia albida*
	Mkuu	Fig tree	*Ficus* spp. (e.g. *Ficus sycomorous)*
	Mthameli*	Scented thorn	*Acacia nilotica*
	Sosongo*		*Euphorbia* species
	Mgunga maji**		*Acacia xanthophloea*
	Mbono	Castor oil plant	*Ricinus communis*
		Thorn apple	*Datura stramonium* *Ficus* spp. *(Ficus sycomorou)*
Soil colour and particles	• Black soil with compact particles • Dump sandy soil • Brown soil		

<u>Note</u>
*local name
**Swahili name

Table 5.9: Indicators of infertile soil in the Lowland zone

Indicator	Local/Swahili name	Common/English name	Scientific/botanical name
Grass and shrubs	Mgiriti*	African ebony	*Diospyros mespiliformis*
	Mdangu (ndulele)*	Sodom apple	*Solanum incanum*
	Kithapa*	Aloe	
Trees	Irumere*	Cactus	*Columnar cactus pachycereus*
	Kikwata*		*Brachylaena*
	Mjohoro**	Cassod tree	*Senna siamea*
	Mpingo**	African black wood	*Dalbergia melanoxylon*
Soil colour and particles	• Red soil with loose or dust particles • White sandy soils • Stony soils		

Note
*local name
**Swahili name

5.2.13 Crop storage methods

Another traditional method mentioned by farmers relates to crop storage which is very important in the management of food in the community. During focus group discussions, the study established that in the highland areas, after maize has been harvested, it is stored in the loft of the kitchen and left to dry by heat and smoke from the kitchen. However, the maize is not removed from the husk, as this protects the grain from contacting soot which could make it taste bitter, and the grain survives longer whilst protected. Thus, any kitchen used as a storage facility has a well maintained loft. However, discussions revealed that most of the local maize had hard kernels, hence it was not easily attacked by storage pests, especially the maize weevil, popularly nicknamed as *skani* by the local farmers. But improved seeds are reported to be highly vulnerable to storage pests hence crops are not stored longer than two months in the loft because they are attacked quickly. One participant in the discussions said that:

"…if you put the current maize in the loft for more than two months you will be left with flour and cobs…"

In the lowland areas, farmers harvest maize, remove it from the husk and dry it in the direct sun. After the grains have dried is removed from the maize cob and stored in air-tight containers or in jute sacks. However, both lowland and highland farmers shared similar views that current climate changes have caused low maize harvests thus there is very little for storage; all that is harvested is dried in the sun and consumed (Plate 5.12). As reported by one of the participants that in the highland zone:

"…in recent years there is nothing to keep in the loft because the harvest is very little. Whatever is harvested is dried in the direct sun and consumed before buying from the market…"

Plate 5.12 Drying of the maize in the lowland zone

However, the study revealed that the drying of crops by direct heat from the sun, which was not traditionally applicable in the highlands, has now been adopted there in response to increases in temperature and decline in precipitation.

According to Village Leader 01:

"…the drying of the crops (maize) through direct sun was rare or not popular in the highland areas in the past due to wet and moist weather conditions associated with occasional and unexpected rain showers during the day or heavy early morning dew which could spoil the crop. But in recent years people dry their crops on the roof tops and leave them over night without the fear that if it rains crops could be spoiled…"

The use of this method in the highland areas provides evidence that changing climatic conditions associated with increase in temperature and declining precipitation allow some of the practices which were previously not applicable in the highland areas now to be effectively adopted due to climate change (Plate 5.13).

Plate 5.13 Drying of maize on roof tops in the highland zone

5.2.14 Early crop growing with the anticipation of onset rainfall

Another local farming technique which was mentioned during oral histories and focus group discussions is early planting with the anticipation of the onset of rainfall. This technique is popularly known as *kutupia* (in the local language), and is favoured by the early onset of rainfall. Through the use of local knowledge and experience in weather forecasting, farmers predict imminent rainfall and plant their crops earlier, so that as soon as it starts raining, crops can immediately germinate. This method assures farmers of an early harvest which helps in the management of food security in the household. According to the highland participants, the normal early planting in *vuli* season was done by the majority of the farmers in the last week of September, with the anticipation of the onset of rain in early October. Similarly, in the lowland areas, early planting was done in the last week of February to the first week in March, with the anticipation of the onset of rainfall in early to mid-March. Some farmers planted during farm preparation by using a tractor where seeds were scattered and covered by the soil tilled by the tractor. Participants added further that early planting was successful because early rain was an indication that the season had started and heavy rain could follow thereafter. Hence, most of the early planted crops grew and survived with the support of wet conditions brought about by the early rain. However, changes in climatic conditions, coupled with less rainfall and increases in temperatures, have made this strategy less practical as most of the early sown seeds dry due to the effect of heat.

The study also observed that the burning of grass and trees remains as a farm practice during farm preparation. This was mostly observed in the highland areas and is rare in the lowland areas. According to Respondent SF04:

"…I burn the grass in the farm so as to increase the area for growing crops, eradicate the hiding places for rats which can hide and feed on the crops as they start germinating. Burning also makes planting and weeding easier…"

Respondent SF01 said that: "…burning ensures the growing of crops on a clean farm…."

However, during focus group discussions, participants mentioned that burning is mostly practised on newly opened farm plots or on farms which were previously fallowed. According to District Official 01:

"…burning is preferred because scientifically it helps in the eradication of pests and crop diseases, especially on the newly opened farm plots. It also increases soil nutrients from ashes gained after burnt grasses because ashes contain potassium and calcium minerals good for crop growth…"

Although burning is considered by some farmers to be beneficial, the amount of nutrient released after burning is very little and much of it leaches very quickly during rain or is blown by wind leading to soil nutrient depletion. Similarly, burning kills soil organisms and bacteria which are important for soil development. When residuals are left on the farm to decompose, they can release beneficial nutrients which last longer than nutrients produced through burning.

Through the use of these traditional farming methods and practices, farmers in the study area have managed and sustained their agriculture-dependent livelihoods over generations. However, their knowledge goes beyond farm operations, as many farmers are also able to determine the beginning of the growing season, predicting the onset and expected amount of rainfall in the season. The predictions are made through the use of local environmental and space indicators, as well as insect and animal behaviours. This knowledge and these skills guide rural farmers in making appropriate farm decisions in relation to the expected weather conditions, and in understanding these local environmental weather indicators and insect behaviours.

5.3. The use of local environmental knowledge to determine seasons and weather predictions

Local environmental weather predictions involve the use of observations of the natural environmental and space indicators, supported by experience of the past to foretell the start of the rainfall in the following season in order to plan farming activities in advance (Mapara, 2009). A successful weather prediction can lead to increased food production because farmers are able to implement informed decisions on when, where and what to plant, and hence ensure quality food production. Wrong predictions, on the other hand, may result in an inappropriate implementation of agronomic practices and adaptation strategies (Hansen, 2005) which may lead to poor quality of agricultural produce. Current observed climate changes and variability pose challenges in the provision of accurate and reliable weather predictions and forecast information. However, effective coping and adaptation strategies for the management of the impacts of climate change and variability can be attained through accurate weather and climate predictions which will help farmers in making informed decisions on their farming activities leading to increased food productivity (Kijazi et al., 2012). Hence, accurate weather forecast information can be achieved through incorporating scientific forecast with local knowledge forecast systems.

Small-scale rural farmers in Mwanga District use a combination of local environmental weather indicators and predictions (LEWIPs), such as plants, animals, insects, birds, astronomical objects and meteorological information (issued by Tanzania Meteorological Agency – TMA) to predict the start of the growing season. The literature shows that rural farmers in different parts of the world have developed a vast body of knowledge, based on their local environment, which they use in making seasonal weather predictions to determine the commencement of rainfall (Ajibade and Shokemi, 2003; Makwara, 2013; Mhita, 2006; Chang'a, Matari et al., 2008; Anandaraja et al., 2008; Svotwa et al., 2007; Haile, 2005; Krishna, 2011). The results from the study show that out of 234 respondents, only 130 (51 lowland zone and 79 highland), which is equivalent to 56%, were aware of LEWIPs below (Figure 5.1 and Table 5.10).

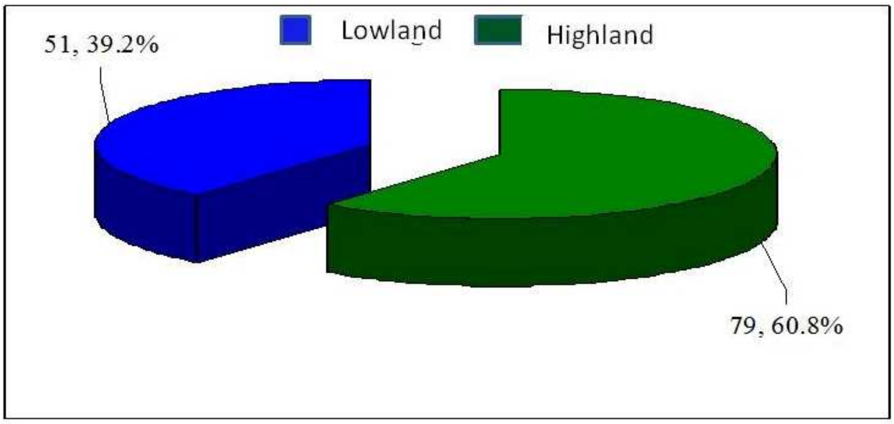


Figure 5.1: Awareness on LEWIPs by zones

Table 5.10: Local environmental weather indicators by zones

Indicator	Overall	Highland (n = 117)		Lowland (n = 117)	
	Percent	Freq.	Percent	Freq.	Percent
Tree flowering	44.4	60	51.3	44	37.6
Tree leaves sprout	43.2	67	57.3	34	29.1
Bird chirping	32.1	45	38.5	30	25.6
Astronomical bodies	20.1	30	25.6	17	14.5
Clouds and weather conditions	21.8	31	26.5	20	17.1
Insects and animal behaviour	19.6	28	24.0	18	15.4

The study also reveals that the level of awareness on LEWIPs was higher among the age group ranging from 60 years and above, followed by age group 40-49, and there was a very low level of awareness on LEWIPs among the age group ranging from 30-39 (Figure 5.2 and Table 5.11).

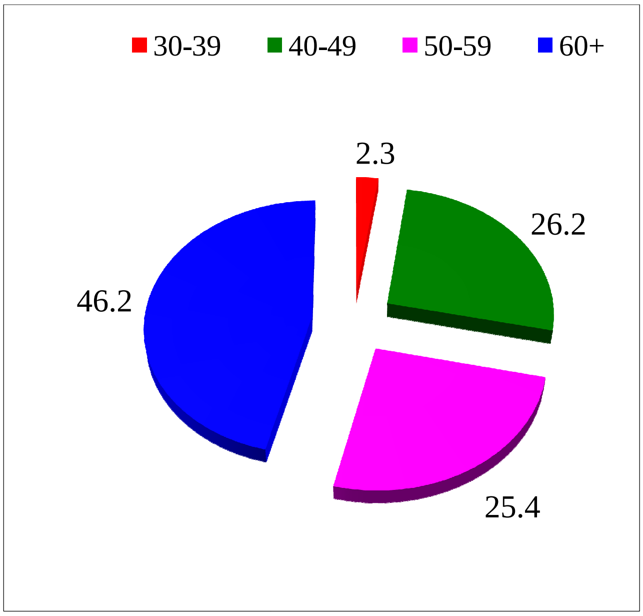


Figure 5.2: LEWIPs by age groups

Table 5.11: Local environmental weather indicators by age groups

Indicator	**Overall**	**Age group**			
	Percent	**30-39**	**40-49**	**50-59**	**60+**
Tree flowering	44.4	2.9	21.2	23.1	52.9
Tree leaves sprout	43.2	3.0	18.8	23.8	54.5
Bird chirping	32.1	2.7	20.0	25.3	52.0
Astronomical bodies	20.1	0.0	14.9	12.8	56.7
Clouds and weather conditions	21.8	2.0	27.5	23.5	47.7
Insects and animal behaviour	19.6	0.0	8.7	26.1	65.2

The findings indicate that among the weather forecasts and indicators, tree flowering (44%) and tree leaves sprout (43%) are the best known weather forecast indicators for the majority of the respondents, followed by bird chirping (32%), astronomical objects (20%), clouds (22%) and insect and animal behaviour (20%). As shown in Table 5.10, the majority of the respondents who mentioned tree leaves sprout as the sign for local weather prediction were from the highland zone. The results also shows further that the majority of respondents aged 60 years and above who mentioned tree flowering, tree leaves sprout and astronomy as the local weather indicators was higher than any of the other age groups (Table 5.11). During oral histories, interviews and focus group discussions, the majority of the participants in both zones shared the view that most of the trees which are used in the predictions for the imminent rainfall, and especially in the lowland areas, have been cut for making charcoal, burning bricks, firewood and building poles. Such trees include *Acacia xanthophloea* and *Acacia tortilis*. In addition, it was noted further that increasing drought conditions affected birds' and insects' habitats and populations, also made them migrate to other areas in search of food and suitable habitats and breeding sites. For instance, participants mentioned that the disappearance of the *African ground hornbill birds* which had predicted imminent rainfall through chirping. Also, it was noted during oral histories and focus group discussions that some of these environmental songs may appear as usual, indicating the imminence of rainfall, but it does not rain. These may be among the factors which contribute to the decline of awareness of local environmental weather indicators and predictions among the participants in the study area hence leaving this precious knowledge among the elders and a few youths who take a personal initiative to learn it. Similarly, an increase in drought conditions, which affect agriculture activities, results in less involvement of people (especially youth) in farming activities which is the only way of passing over the knowledge through observing and sharing of the past experiences on the farm. Also, increasing levels of literacy and heterogeneity in the community make people less dependent depend on their local knowledge. The following section discusses each weather prediction indicators as used in weather predictions.

5.3.1. Predictions from plant phenology

The study revealed that the flowering of plants/trees, such as coffee, peach and *Eriobotrya japonica* (*mstafeli* in the local language), and leaves sprouting of *Albizia gummifera* (known with many names in the local language as *nyasutu, msanga, mriribwi* or *mfuruanje*) are among of the trees used to predict the commencement of *vuli* season in the highland areas. The participants in the focus group discussions and oral histories commented that leaves sprouting from the *Albizia gummifera* trees are an indication that the growing season has started, and when the leaves reach the level of hiding a bird of the size of *barn swallow* (*mbayuwayu* in Swahili) this indicates that rainfall could begin at any moment. Many of the *Albizia gummifera* trees are grown in the coffee farms to provide shade for the coffee plants. On the other hand, the flowering of *Acacia tortilis*, *acacia xanthophloea* (*mgunga* maji in Swahili or *mughaa* in the local language), leaves sprouting and flowering of *Brachlaena* (Kikwata in the local language), fig tree (*Ficus sycomorous*) and baobab trees (*Adansonia digitata*) indicate the beginning of *masika* season and imminent rainfall in the lowland zone. The release of seeds from the shells of the fruit of *Columnar cacti pachycereus*, a cactus species (called *Mrangare* or *Irumere* in the local language) is considered to be a sign for the starting of *masika* season. By seeing these signs, farmers began preparing their farms and seeds ready for planting. On the other hand, the flowering of *Bidens ferulifolia* and *Ipomoea species* (popularly known as *imondo* in the local language) mark the end of *masika* rainfall season in the lowlands, and the flowering of *Cordia Africana* tree (*mringaringa* in the local language) mark the end of *masika* rainfall season in the highland zones.

Farmers determine a season with good or poor rainfall by observing the flowering rates of domestic and wild fruit trees. Higher rates of flowering and yielding of fruit trees, such as *Eriobotrya japonica* (*mstafeli* in the local language*)*, avocado (*Persea americana*), peach (*Prunus persica*), *Syzygium guineense* (*mlama* in the local language), a wild fruit tree, coffee in the highland areas; mango (*Mangifera indica*) and Ximenia species (*mtundutwa* in the local language) in the lowland areas, indicate that the season will have low rainfall which may lead to poor crop yields resulting in famine. The evidence of high fruit yields was given during focus group discussion in the lowlands where one of the participants reported that during the drought of 1996/1997 many people ate mango fruits as their main food which made some people experience stomach problems and generally a higher level of acidity in the stomach. In addition, the participant explained that many of the flowers or fruits may, or may not, grow to maturity, depending on how severe drought conditions will be which may cause many of the fruits to fall before they mature. During interviews with District Official 01 and Ward Officer 01, it was ascertained that high coffee yield are favoured by warm temperatures associated with low to moderate rainfall. However, there is only a limited understanding among participants on what they determine or consider to be normal and above normal rates of flowering of the fruit trees to ascertain that a season will experience normal or low amounts of rainfall leading to good or poor harvests. Similar studies conducted elsewhere in the world show that rural farmers determine the expected amount of rainfall for the coming season by observing the flowering behaviour of fruit trees and abundance of fruits (Makwara, 2013; Muguti and Maposa, 2012; Chagonda et al., 2013; Svotwa et al., 2007). For instance, according to Stigter et al. (2005), farmers in Gujarat in India predict the beginning of the monsoon rain by looking at the flowering peak of the cassia fistula tree.

5.3.2. Predictions from insects, birds and animals

Farmers also use insects, birds and animal behaviour to predict the beginning of rainfall and growing season. Participant HOH04 suggested that the appearance of many red ants (tropical fire ants) and termites on the earth's surface from their hiding holes in the ground is an indication that the growing season has begun and rainfall is imminent. The interviewee said that:

"…ants come out of their holes because after the cold season the ground becomes very hot, a condition which makes them uncomfortable to stay underground, hence they come to the surface for cool temperatures, which indicates that the growing season has started and rainfall is imminent…"

Respondent MS16 said that:

"…when ants appear on the surface looking for food, it is an indication that the food which they had stored and used during the cold season is finished, and because the cold season has ended, they come to the surface to look for food. They also clean their nest which is revealed by heaps of soil which are collected at the entrance to their nest…"

Respondents CH08, MS07 and KW13 shared similar views that when large numbers of ants come to the house (especially to the kitchen), this is an indication of the beginning of the growing season and the imminent onset of rainfall.

Similar observations of ants' behaviour were shared by both lowland and highland participants. However, lowland participants also observe the behaviour and activities of termites. As noted by LOH01: "…when farmers observed large numbers of termites (called *mikoke* in the local language) gathering grasses and tree leaves, this is an indication of imminent rainfall and it will rain within three days". The observation of insects' behaviour (especially ants) has long been considered as a potent signal for the imminent onset of rainfall among the people of Australia, Zimbabwe and Tanzania (Chagonda et al., 2013; Makwara, 2013; Svotwa et al., 2007). Farmers also observe the behaviour of frogs, as was stated by HOH05 that when frogs move from the water courses and ponds to the dry land, and/or enter into the houses, it is an indication that rainfall is imminent and the season is most likely to experience heavy rainfall which may result in floods. Hence, the frogs are scared of being washed away by heavy storm water. Also they observe the behaviour of honey bees that when they remain in the hive signified cold weather and when they are found outside the hive roaming about signified warm weather conditions.

Farmers also determine the imminence of rainfall and commencement of the growing season by observing the behaviour of small spitting bugs called *viriribwi* or *viririgwi* in the local language. It was explained by LOH02, and also shared during focus group discussions, that when *viriribwi* move from the ground to the tree branches, gather together in groups and release droplets of water from the secreted white foam of spittle which cover their bodies and drops little by little like rain drops, this is regarded as a sign that the growing season has started and rainfall is imminent. These insects are said to prefer specific trees such as C*roton macrostachyus* (*Mfurifuri* in the local language), *Albizia gummifera* species and *Gravellier robusta*.

Equally, the appearance of large stocks of Trumpeter Hornbill birds (*Bycanistes bucinator*), called *Hondo hondo* in Swahili, in the highland areas is regarded as a potent indicator of the start of the growing season and onset of imminent rainfall. This was explained by Respondent HOH06 that:

"…in the past the trumpeter hornbill birds used to migrate from the highlands to other areas during the cold season and their reappearance again in the highlands was an indication that the cold season is over and growing season has started…"

The appearance of these birds is used as a common indicator to predict the commencement of *vuli* season in the highland areas. However, it was argued that the rate of migration of these birds has declined in recent years and the majority of birds are now seen in the area throughout the year, and if they migrate it is only a few that leave. The reduction of bird migration may be caused by food shortages or the lack of habitat at the places where they used to migrate to, or it may be due to the increase in temperature which makes the highland areas warmer, hence providing favourable conditions for their survival in all seasons. Similar trends in the migration and appearance of birds such as the Woodland Kingfisher, the swallow, white and black stock and swallow tailed bee eater have also been observed as an indicator for the approaching summer season and imminent of rainfall onset (Chang'a, Svotwa et al., 2007; Makwara, 2013; Risiro et al., 2012).

The chirping of the African ground hornbill (*mumbi* in Swahili and *Mdidi* in the local language) and White-browed coucal (*Dudumizi* in Swahili and *Ishundi* in the local language) is used as an indicator of imminent rainfall. The chirping of these birds is said to be the most accurate indicator, because when their calling sounds are heard it must rain within twenty four hours. However, participants both in the highland and lowland areas argued that currently African ground hornbill birds have disappeared in the district. However, this was explained in detail by Respondent HOH 04:

"…in the past when you heard African ground hornbill birds singing between 11 am and 2 pm it was an indication that rainfall is imminent. These birds were singing from the highland areas and those which were in the lowland areas responded back, and they did it interchangeably forming a rhythm. They followed behind farmers during farm preparation and weeding, eating lizards, grasshoppers, earthworms, snakes and termites. They were not scared of farmers, and because they are not edible, farmers enjoyed their presence. But all of them have disappeared in the district; we neither see them nor hear their singing…"

Local farmers also observe the breeding behaviour of animals and birds in predicting the commencement of the growing season and imminent rainfall. They observe the mating behaviour of goats which was explained by Respondent LOH03 that when a large number of goats enter in heat, which is signified by the snorting and hoarse sounds produced by billy goats, and when birds such as quelea quelea start building their nests in larger quantities ready for breeding, this is an indicator that the growing season has started. This is a popular indicator used in the lowland areas, but less popular in the highland areas. This may be due to the fact that the majority of the lowland dwellers keep large herds of goats compared to the highland dwellers, hence they have a chance to observe their behaviour, thus linking it with the farming seasons. A similar study by Svotwa et al. (2007) shows that breeding patterns of game animals, like impala, kudu, birds and bushbuck, is frequently used in seasonal forecasts and disaster predictions, and when game animals give birth in large numbers, this signifies a normal to above-normal season. A study by Risiro et al. (2012), showed that when guinea fowls start building nests and laying eggs, this is an indication of the onset of the summer season.

An outbreak of fall armyworms [*Spodoptera exempta*] known as *ngweghu* in the local language immediately after the first rain is considered to be a strong indicator of a good rainy season, which will result in a good harvest. Although the armyworms cause considerable damage to crops, especially to early grown maize, it was explained that farmers required the application of pesticides in managing armyworms invasions so as to reap sufficient harvests. However, a good harvest is a function of many factors, of which rainfall and good weather conditions are just one among many. Farmers' observations and experiences on the occurrence of armyworms is corroborated by scientific evidence which suggests that severe African armyworm outbreaks have historically been reported to occur when rainstorms follow droughts (Holt et al., 2000) The timing and distribution of rainstorms is considered to be of fundamental importance in governing armyworm population processes, and hence where rain has not fallen, the risk of an armyworms outbreak is low (Tucker et al., 1999).

5.3.3 Predictions from the observation of the celestial objects

Farmers look at the movement and position of astronomical objects in relation to land features. This was revealed during oral history discussions in Ngullu ward where participant LOH05 said that when the sun reached the centre of the saddle of two hills called *Mbenge ya Pangaru,* this marked the imminent onset of rainfall and it could rain at any time afterwards. This shows how farmers have long since discovered the mysteries of nature to determine seasons. Farmers also look at the appearance and position of specific stars in the sky to predict the expected amount of rainfall and the likelihood of good crop yields in the forthcoming season. There is a shared understanding of the use of this indicator, as it was mentioned by most of the participants during oral histories, interviews and focus group discussions. It was explained that when a big and shining star called *ngalakeri* in the local language appears in the east, it indicates that the season will have sufficient amount of rainfall and crop yields will be good. Such an appearance results in the season being referred to as *Kiluva cha mvono* in the local language, which means a season of abundance or plenty of harvest. However, when the star appears in the west, this indicates that the season will have low amount of rainfall which may result in poor crop yields, and the season is referred to as *kiluva cha nzota* in the local language which means a season of famine. Both lowland and highland participants shared similar explanations about the name, appearance, position and the meaning attached to the star as it appears in the sky. However, personal discussions with an astronomical expert Mr Noorali T. Jiwaji working for the Open University of Tanzania, revealed that the star referred to is the planet Venus. Rural farmers also use the appearance and size of the moon to determine the expected amount of rainfall in the season. This was revealed during oral histories, with Respondent HOH05 and also during focus group discussions. It was ascertained that in every season when the new moon appears it is associated with rainfall and it could either rain during or before the moon appears or is visible in the sky. When the appearance of the new moon coincides with rainfall, it is an indication that the season will have sufficient rainfall, but when the new moon emerges in the sky without rain it implies that the season will have poor rainfall. During focus group discussions in the highland areas, it was explained by one of the participants that when the moon appears in full size, this marks the end of *vuli* rainfall or indicates that there will be no more heavy rainfall in that season. The moon is said to appear at about half size between October and November, and in full size in December. A study by Kijazi et al. (2012) shows that the appearance of a dark moon in July, accompanied by cold, ice and snow-fall, signifies a good rainy season, while the disposition of the new moon (slanted position) indicates more diseases and erratic rainfall. According to King (2005), changes in the moon's movement can trigger changes in weather. This is explained in terms of the four interfacing tides caused by lunar gravitation. If the moon has an influence on the sea tides, then it should control the distribution of water. The effect spreads into the atmosphere and weather through the distribution of clouds (Svotwa et al., 2007).

5.3.4 Predictions from the observation of clouds, wind and temperature

Farmers observe the types of clouds appearing in the sky and the direction of their movement (shaped by the wind direction) to determine the imminent onset of rainfall. Participants, during oral histories and focus group discussions, mentioned the appearance of dark, heavy clouds in the sky and thunderstorms to be an indicator of the imminence of rainfall, while white scattered clouds were associated with the absence of rainfall. However, Respondent LM27 explained that: "…when rainfall is associated with lighting and thunders this is a sign of low rainfall…". Participants' ways of interpreting clouds is the same as the interpretation made by the current meteorological science. For example, according to Barry and Chorley (1998), cumulonimbus cloud (storm cloud) is associated with a heavy rain accompanied with lightning and thunder. Similarly, during focus group discussions in the lowlands and highlands, one of the participants explained that after the growing season has begun and patches of scattered black clouds appeared in the sky moving from northwest to southeast direction, they normally result in the formation of rainfall. Formation of low clouds with drizzle or light rain and moderately warm conditions during the cold season between June and August in the highland areas is considered as a good sign that the cold season will not be dry. Such conditions usually promote a sufficient water supply, growth to maturity of late-grown crops (e.g. maize and beans), and ensure sufficient availability of animal fodder. Extremely cold, dry and windy weather conditions on the other hand negatively affect the growth of late-grown crops, increase the occurrence of aphids, affect water discharge, and cause scarcity of animal fodder.

Similarly, farmers predict the onset of rainfall when warm and calm winds (non-destructive wind) blow during the middle of the day after the growing season has started. Farmers call this calm wind the “rain whistle”. Participants during oral histories said this kind of wind normally precedes the occurrence of rainfall. Farmers also determine the length of the growing season by looking at the season’s temperature. This was explained by participant HOH04, and also shared by participants during focus group discussions in both lowland and highland areas, that when the cold season extends into October this is an indication that *vuli* season will be short and when the growing season has low temperatures is a sign that the season will probably have insufficient rainfall. Equally, an increase in day and night temperatures is considered as a good indicator for the beginning of the growing season and imminent rainfall onset. Participants both from the highland and lowland areas shared the views that an increase of day and night temperatures is a good sign which indicates that the season has started and such conditions normally result in night and early morning rains. Participants explained that when the season has started and the days become very hot (where they say *the sun is very hot and stings*) it is a good sign that such rainfall is imminent.

Highland farmers also determine the amount and distribution of rainfall in the season by looking at the origin and the beginning/occurrence of rainfall. As explained by Respondent HOH06, and also shared in the focus group discussions in the highland zones, when rainfall originates from the lowland areas and moves gradually to cover the highland areas, it normally results in sufficient rainfall. When rainfall behaves in this manner, it indicates that the season will have sufficient and well-distributed rainfall, both in the lowland and highland areas. This was said to be the most reliable determinant for sufficient rainfall in *masika* season. This view was also shared by Respondents ML40 and CH12, who owned farms in both lowland and highland areas.

Interestingly, some of the participants claimed that they did not use any of the weather prediction methods but followed their local farming calendar to determine the beginning of the season which is marked by the activity of the time. This was explained by Respondent SM29:

“…after one activity is finished it is followed by another activity which I have been doing routinely and repeatedly throughout the year in all of my life…”

Respondent CH13 said that: “…people think that they are intelligent and can predict when it will rain, but they keep on cheating us. Their predictions never succeed and they are not true. Only God knows when it will rain…”

Respondent KS07 said that: "…we do not know what will happen tomorrow but only God knows so when they broadcast that it will rain tomorrow, I just listen and laugh. I do not follow their predictions, I just wait until when it rains then I go to plant…"

Respondents gave an example of how they planned and managed their activities by following a farming calendar that, after finishing working in the maize and bean farms (March to May), is followed by weeding and removing suckers in the coffee, banana and sugarcane farms. They also harvest and store crops between June and July. This is followed by the preparation of farms for growing crops in *vuli* season (August to September) which is then followed by planting and weeding from October to December. January to February is crop harvesting and farm preparation for *masika* season.

However, with regard to the dependence on local environmental weather indicators and predictions (LEWIPs) against conventional weather forecast information (CWFI) in planning and managing agricultural activities, the results show that out of 234 participants (Table 5.12), only about 21% admitted to using LEWIPs and about 69% of the respondents acknowledged using CWFI broadcasts, via television and radio stations, in planning agricultural activities, while 3.4% of the participants admitted not using either of the methods but followed their own farming calendar.

Table 5.12: Dependence on weather forecast information (LEWIPs and CWFI) in planning farming activities

Response	Overall		Highland		Lowland	
	Frequency	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
LEWIPs	48	20.5	30	25.6	18	15.4
CWFI	161	68.8	71	60.7	90	76.9
Use both	17	7.3	8	6.8	9	7.7
None	8	3.4	8	6.8	0	0.0

Although the literature suggests that rural farmers rely much on the use of local environmental knowledge in making predictions of weather conditions (Gyampoh et al., 2009; Svotwa et al., 2007; Nyota and Mapara, 2008; Chang'a, 2010; Kijazi et al., 2012; Chagonda et al., 2013; Makwara, 2013), the results of this study suggest that there is an increasing move from the use of LEWIPs to a greater reliance on CWFI. Participants during focus group discussions and oral histories explained that most of the LEWIPs pointed towards the imminent onset of rainfall. This provided the majority of the farmers to prepare their farms and even to plant their crops with the anticipation of onset of rainfall. But late rainfall results in early planted crops failing. Thus, this makes it difficult for farmers to plan their farming activities in advance by using LEWIPs. This finding is similar to a study by Krishna (2011) and Gyampohet al. (2009), which suggested that indigenous traditional weather prediction knowledge is becoming less reliable because, in some instances, these events may occur earlier than normal, and thus do not coincide with the start of the growing season which may mislead the farmers. Similarly, the increasing heterogeneity in the community, supported by the use of modern technology (radios and televisions), cutting of trees (which are used in indicating the imminence of onset of rainfall) for firewood, manufacturing of charcoal and as building materials, has made most rural farmers depend more on CWFI than LEWIPs. On the other hand, participants mentioned that CWFI was also not reliable because it could be broad-casted that the season will have moderate to higher rainfall but the season may receive low rainfall that does not support crop growth to maturity.

Farmers' views on the unreliability of weather forecasting and predictions are supported by various studies which suggest that in least developing countries modern weather prediction is a problem due to the shortage of weather data caused by fewer weather stations on the ground and upper air stations (Risiro et al., 2012). The problem is made worse by poor telecommunications and the high cost of equipment for weather forecasting (Buckle, 1996). In addition, there is a limited understanding of atmospheric processes such as pressure and wind which are essential elements in weather predictions. As argued by Aguado and Burt (2010), the modern weather forecast may be imperfect due to lack of information about the composition of the atmosphere, unstable atmospheric composition and movement of air in the atmosphere. However, discussion with most of the participants who were aware of the LEWIPs suggested that rural farmers, through the use of local knowledge in weather predictions, are capable of predicting the commencement of rainfall up to three weeks in advance and can foretell the expected amount of rainfall for the whole season. They are also capable of predicting seasons of famine or of good harvest. A study by Mapara (2009) also showed that indigenous farmers in Zimbabwe can predict the commencement of rainfall up to three days in advance. Thus there appears to be a need to incorporate successful elements of local indigenous knowledge with scientific meteorological knowledge in predicting weather, and hence climate change and variability (Beckford and Barker, 2007).

5.4 The use of LEWIPs

As it has been pointed out, rural farmers used both local environmental weather indicators and predictors (LEWIPs) and meteorological weather information from the Tanzania Meteorological Agency in predicting the commencement of the growing season, and the onset and expected amount of rainfall in the seasons. Both methods share key elements used in making weather predictions, that is, while local environmental weather forecasting makes use of local environmental and ecological wisdom gained through experience and observation being passed through generations, the conventional weather forecast uses numerical and dynamic methods (Ziervogel et al., 2010). However, both methods have weakness in producing accurate information about expected weather conditions. For example, studies suggest that conventional weather predictions have about a 75% accuracy, hence it is still not sufficient to provide precise information about expected weather conditions due to the spatial and temporal variability of the nature of rainfall (Ogallo, 1989; Nyenzi, 1999; Zorita and Tilya, 2002' Chang'a, 2010). Evidence from oral histories and focus group discussions revealed that some of the LEWIPs in the study area pointed towards low rainfall for the seasons 2010/2011 and 2011/2012. Participants explained that the *ngalakeri* star had been appearing in the west from 2010 to 2012; also flowering of trees, such as *Syzygium guineense, Eriobotrya japonica, Mangifera indica* and *Ximenia* species, indicated that the season would have low rainfall. Similarly, frequently delayed rainfall indicated that the growing season was going to be short. The predictions by LEWIPs are corroborated with meteorological data from TMA which indicated that rainfall for the seasons 2010/2011 and 2011/2012 was low. Thus local environmental knowledge, if combined with scientific information, can provide effective weather predictions helping farmers make informed decisions and implementing appropriate agronomical strategies.

5.5 Limitations on the use of local farming methods and practices

The study is interested in investigating the perceptions of small-scale farmers about those factors affecting the existence and application of local farming knowledge in providing solutions to the problems facing farming activities. As shown in Table 5.13, the majority of the participants (96.6%) strongly agreed to with statement that the lack of government support threatens the existence and application of local farming methods and practices. This statement ranked highest in the overall cumulative scores (Table 5.13) and also ranked first for both lowland and highland areas (Table 5.17). Participants explained that the government does not seem to have faith in local knowledge because most of the local farming techniques have not been scientifically proven to be reliable and are not consistent with internationally recognised modern techniques. According to District Official 05*:*

"…there are no deliberate efforts made by the government to encourage the use of local farming methods and practices. The government only focuses on the use of scientific methods which have been proven to yield optimum output and drive higher economic growth compared to the local techniques. For example, the use of tractors during farm preparation, factory pesticides in the management of pests and treatment of crop diseases and factory fertilisers have proven to give better yields compared to the use of hand hoe, local seeds and local pesticides…"

These views therefore suggest that there is a need for government to take deliberate actions to do research and identify the strengths and weaknesses of the local farming methods and practices, so that prudent steps can be taken to develop hybrid local-modern scientific farming methods (see also Briggs, 2005). Lack of government support marginalises the role of local farming methods and practices even where they could provide solutions to the management of farming activities. For example, according to the view of Respondent CH09:

"…it appears that the government no longer encourages the use of organic manure but rather insists on the use of fertilisers which are expensive and have long term hazardous effects on farmlands following prolong usage…"

A similar argument was raised during focus group discussions in the highland areas where participants argued that although fertilisers were provided at a subsidised price, farmers generally avoided their usage because the amount provided was not sufficient and they were not assured of a continuous supply. One of the participants argued further that in the event of the discontinued usage of fertiliser, this requires more organic manure to be applied to replenish natural nutrients lost in the soil, caused by the discontinued usage of fertilisers. It is also shown in the literature that the increased usage of inorganic fertilisers increases soil acidity which consequently stagnates crop growth, hence affecting yields (Munthali, 2007). Similarly, encouraging the use of the factory pesticides over local pesticides may affect the health of the farmer, and affect non-targeted species which may be beneficial to the environment. In addition, if large quantities are washed into the rivers, that can affect aquatic ecosystems. Excessive application and exposure to industrial pesticides can affect the health of the operator if safe handling procedures are not followed such as the use of protective gear (clothing, gloves, mask, wellingtons and knapsack). They can also affect the health of the consumer through the consumption of pesticide contaminated farm produce or bio-magnification along the food chain leading to long-term health effects. A study by Miller (2004) argued that the use of factory manufactured chemicals can pose severe health and environmental problems as over 98% of the applied insecticides and 95% of herbicides can reach a species other than the target one. This shows that, even though the uses of scientific methods and technology have proven to yield better output, they can have long-term effects on the ecosystem. Limited resources expose rural farmers to health risks and dangers associated with the use of factory manufactured pesticides. However, projected warming conditions associated with climate change will encourage the survival and multiplication of insect pests and crop diseases which will necessitate the increased use of chemicals leading potentially to more environmental and ecosystem hazards (IPCC, 2007; Collier et al., 2008; Rosenzweig et al., 2001; Chakraborty et al., 2000). Local pesticides, on the other hand, are non-poisonous and do not affect the ecosystem. Hence, their usage could be of benefit in such changing conditions, as well as being cheaper, affordable and simple to prepare when compared to factory pesticides. Materials for preparation are readily available in the local environment, and hence are acquired at a low cost, making it easy for both rich and poor farmers to access and exploit them unlike factory pesticides.

Table 5.13: Factors affecting the use of local environmental knowledge in farming

Statement	Scores				
	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Lack of support from the government	226 (96.6%)	8 (3.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
It is gender sensitive	217 (92.7%)	12 (5.1%)	5 (2.1%)	0 (0.0%)	0 (0.0%)
Known by few	172 (73.5%)	62 (26.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
It is marginalised	164 (70.1%)	43 (18.4%)	16 (6.8%)	11 (4.7%)	0 (0.0%)
It is not reliable	174 (76.5%)	14 (6.0%)	15 (6.4%)	9 (3.8%)	17 (7.3%)
Threaten by changing conditions	152 (65.0%)	36 (15.4%)	0 (0.0%)	18 (7.7%)	28 (12.0%)
Specific to a given area, not applicable everywhere	118 (50.4%)	56 (23.9%)	16 (6.8%)	27 (11.5%)	17 (7.3%)
Threatened by increase in the use of modern technology	118 (50.4%)	67 (28.6%)	0 (0.0%)	4 (1.7%)	45 (19.2%)
Not written	134 (57.3%)	40 (17.1%)	0 (0.0%)	18 (7.7%)	42 (17.9%)
Connected with local beliefs and taboos	131 (56.0%)	33 (14.1%)	0 (0.0%)	19 (8.1%)	51 (21.8%)
Cannot be justified and proved	22 (9.4%)	33 (14.1%)	0 (0.0%)	67 (28.6%)	112 (47.9%)
Difficult to use/apply	12 (5.1%)	34 (14.5%)	0 (0.0%)	55 (23.5%)	133 (56.8%)

N = 234 and

Maximum score = 1170

Table 5.14: Cumulative score

STATEMENT	Cumulative score of the responses (%)
Lack of support from the government	**99.3**
It is gender sensitive	**98.1**
Known by few	**94.7**
It is marginalised	**90.8**
It is not reliable	**88.1**
Threatened by changing conditions	**82.7**
Specific to a given area, not applicable everywhere	**79.7**
Threatened by increase in the use of modern technology	**77.9**
Not written	**77.6**
Connected with local beliefs and taboos	**74.9**
Cannot be justified and proven	**41.7**
Difficult to use/apply	**37.5**

N = 234

Maximum score = 1 170

Table 5.15: Highland zone

STATEMENT	Cumulative score of the responses (%)
Lack of support from the government	**99.0**
It is gender sensitive	**98.1**
Known by few	**97.3**
It is marginalised	**89.1**
It is not reliable	**88.7**
Threatened by changing conditions	**88.2**
Threatened by increase in the use of modern technology	**86.3**
Not written	**79.8**
Specific to a given area, not applicable everywhere	**79.7**
Connected with local beliefs and taboos	**69.4**
Cannot be justified and proven	**45.0**
Difficult to use/apply	**38.3**

N = 117

Maximum score = 585

Table 5.16: Lowland zone

STATEMENT	Cumulative score of the responses (%)
Lack of support from the government	**99.7**
It is gender sensitive	**98.1**
It is marginalised	**92.5**
Known by few	**92.1**
It is not reliable	**87.5**
Connected with local beliefs and taboos	**80.3**
Specific to a given area, not applicable everywhere	**79.8**
Threatened by changing conditions	**77.3**
Not written	**75.4**
Threatened by increase in the use of modern technology	**69.4**
Cannot be justified and proven	**38.5**
Difficult to use/apply	**36.8**

N = 117
Maximum score = 585

Table 5.17: Ranking of the scores

STATEMENT	Ranking	
	Highland	Lowland
Lack of support from the government*	1	1
It is gender sensitive*	2	2
Known by few	3	4
It is marginalised	4	3
It is not reliable*	5	5
Threatened by changing conditions	6	8
Threatened by increase in the use of modern technology	7	10
Not written	8	9
Specific to a given area, not applicable everywhere	9	7
Connected with local beliefs and taboos	10	6
Cannot be justified and proven	11	11
Difficult to use/apply*	12	12

*statements with the same ranking order in both groups of respondent

5.5.1 Lack of government support

About 93% of the participants strongly agreed with the statement that some of the local farming methods and practices were based on a gender division of labour which in a way threatens their use and existence. This statement ranked second in both lowland and highland areas (Table 5.17). Participants during focus group discussions argued that some local farming methods and practices assigned specific roles to specific gender groups in the community. Hence some of the activities are done by men or women only, and if a man or woman was involved in certain tasks which are socially constructed to be masculine or feminine, the task could not yield desirable results. For instance, the task of ‘calling rain’, making farming tools from iron, wood carving and setting snares for trapping wild animals (e.g. vermin) are done by men only, while crop storage, seed management, cow milking, grain pounding, and the management of backyard farming are done mainly by women. This gender division of labour is claimed to have negatively affected the use and existence of some of the local practices because some people gained a lot of skills not shared with everyone in the community. This affects the survival of such skills because when they are not shared, and when the expert dies, that threatens the existence of such skills. But when the knowledge is widely shared in the community, it becomes a common practice, and in this way it can be improved by the user without any control or reference to the original source. It can as well be abandoned in favour of a new technology which is considered to be better (see Makwara, 2013).

5.5.2 Limited knowledge sharing

The majority of the participants (74%) strongly agreed with the statement that local knowledge and practices are known by few members within the community which threatens their application and existence (Table 5.13). This statement ranked third in the overall cumulative scores (Table 5.14) and in the highland zone (Table 5.15), but ranked fourth in the lowland zone (Table 5.16). According to respondent CH05:

"…most of the local farming methods and practices are only known by indigenous farmers of a specific area and a majority of whom are the elders and are passed over to selected trusted members of the clan…"

During focus group discussions, it was revealed that the knowledge, skills and practices for specific tasks were known by certain clans only and were not shared with everyone in the clan, nor in the wider society, but remained with specific and trusted members in the clan. Hence, it is the responsibility of the trusted members of the clan to choose and groom someone to take over the responsibility on behalf of the clan and community at large. For instance, the *Rutu* clan is expert in the design and construction of traditional water reservoirs and irrigation channels called *ndiva* and *thathi* in the local language; the *Shana* clan is expert in blacksmith work; the *Vungi* clan is responsible for 'calling rain', while the *Minja*, *Sofe* and *Suya* clans are designated as the rulers. Such specialisations limit the spread of knowledge and skills to the entire community, thus limiting widespread, application and existence of a given local knowledge.

5.5.3 Knowledge marginalisation

Participants agreed with the statement that most of the local methods and practices are marginalised which contributes to their limited application and existence. This statement ranked fourth in the overall cumulative scores (Table 5.14), and in the highland areas (Table 5.15), and third in the lowland areas (Table 5.16). Those who strongly agreed with this statement explained that most of their children have trained in schools where they learn more of scientific farming methods, hence they are more acquainted with scientific methods than local farming methods. According to District Official 05:

"…the marginalisation of the local farming methods is mostly caused by the government. The central government does not encourage farmers to get innovative in improving or at least expanding their local farming methods and practices so as to benefit the larger population. It appears there is some lack of understanding on the part of politicians and planners on how local expertise can contribute to national development. It is my belief that government does not have faith in local expertise because they are considered to lag behind the modern technologies...."

This emphasises that for local farming methods and practices to be accepted, they require recognition by the central government to support their existence by conducting research which can show and appreciate the role of local farming methods. Similarly, according to Respondent CH09*:*

"…the local farming methods are marginalised not only by the government but also by those who have at least applied the modern technology briefly, or have witnessed it operation. Usually, they become dissatisfied with the local farming methods over time, and keep yearning for this new technology without necessarily thinking about how their own methods can be modified to suit their local needs…"

However, it may be possible for some local farmers to adopt some aspects of the modern methods and apply them on their fields without necessarily adopting completely new methods which may be expensive and/or may have devastating effects when applied to the environment. According to Ward Officer 01*:*

"…local techniques and practices are marginalised especially by the majority of individuals who have received formal education. Formal education exposes them to the more competitive modern farming techniques, thus making them lose faith, over time, in the local techniques…"

According to Respondent KV36:

"…we feel that local farming methods are marginalised, but in reality some of these methods are outdated and not valued by the majority of the farmers…"

Marginalisation of the local farming methods increases because various government sectors do not offer initiatives to develop local methods due to their main focus on the application of modern methods, ignoring the potential contribution that local knowledge could make to the development of agriculture.

5.5.4 Unreliability of local knowledge

About 77% of the participants strongly agreed with the statement that some of the local farming methods were not reliable which made them inferior to scientific farming methods (Table 5.13). This statement ranked fifth in the overall accumulative responses (Table 5.14) and in both highland and lowland areas (Table 5.17). The participants who agreed with this statement argued that most of the local methods do not yield immediate results, unlike scientific methods. A majority of the farmers, although using local farming methods, did not consider them to be reliable. This may be due to the fact that the use of the methods over a long period of time has not yielded consistent results. Since local knowledge is mostly not documented, as opposed to the highly competitive publishing culture in the scientific community, there is very little knowledge sharing among interest groups. According to Respondent KW23:

“…farmers use local methods and practices because of poverty but it is not that they really value them… like using hand hoe, carrying crops or water by using my head? No one likes that, but because we are poor then we have no option… but people use these methods and when you look at them you think they are happy. They are not, it is because of poverty…”

Participants who disagreed with this statement claimed that, although local knowledge, skills and practices are usually termed unscientific and undocumented, farmers can still use them in some instances to predict future events so that they are and not met unprepared by unexpected environmental changes (such as floods and droughts). This is supported by the explanations made by Respondent MT18:

“…In terms of reliability, some of the local techniques are reliable depending on the locality, type of farming activity and the specific functions the methods are used for…”

This is true because the knowledge of local farmers is based on facts, experimentation and observation geared towards problem-solving which have been developed over time within a given locale and proved to be useful hence used in solving specific farming problems within the given locale. For instance, farmers use their knowledge in predicting expected weather conditions, determining availability of soil nutrients and managing pests and crop diseases. In addition, participants throughout the study explained that some of the LEWIPs and information from TMA were not accurate in providing reliable information on the expected amount of rainfall in the season. Participants said both methods could show similar signs and evidence that the season will have sufficient rainfall, but the season ended receiving low to moderate amount of rainfall. As argued by Respondent MB09:

“…currently days and nights can have higher temperatures from the hot sun which is reliable indication of the imminence of the onset of rainfall but it does not rain. Also it can be broadcast that the season will have sufficient rainfall from medium to high and farmers should take precautions and appropriate measures against floods, but the season ends by receiving rainfall below average. For example, in this year’s farming season [*masika* 2012], we only had two days with rainfall, one in March and another one in April, while the forecast predicted moderate to high rainfall…”

This shows how both local and scientific methods cannot provide reliable information hence making it difficult for farmers to depend on them in making informed decisions on effective farming activities.

5.5.5 Effect of changing climatic systems

About 65% of the participants agreed that local farming methods are threatened by the current changing conditions (Table 5.13). This statement ranked number six in the overall cumulative scores (Table 5.14) and in the highland zones but ranked eighth in the lowland zone (Table 5.17). Those participants who agreed argued that many of the local farming methods and practices which evolved through the process of trial and error were favoured by the environmental conditions of the time. The current changing conditions do not favour the application of some of these methods, hence most of them have become less applicable which threatens their existence. This has forced the majority of the farmers to adopt the use of modern farming methods, such as improved seeds, and the use of tractors, fertilisers and factory pesticides which can cope with the current changing conditions. However, those who disagreed with the statement explained that not all local farming methods were vulnerable to changing environmental conditions, some have the ability to adapt and cope with changes. It is only that they are not valued. Hence there is a need to conduct research to identify which farming methods can be used in managing farming activities under current changing conditions. In addition, the findings reveal that both local and scientific methods are vulnerable to changing environmental conditions because they were both developed under environmental conditions which are different from the present. As explained by Respondent KS02:

"…even improved seeds do not tolerate drought conditions, especially when situations are severe, they also fail. Also increasing rainfall variability affects their productivity…"

Similarly, Respondent CH17 said:

"…even those seeds which are claimed to survive or tolerate drought conditions also fail. They just cheat us. The world of today is not like in the past when we used to harvest until some of the maize was left to rot in the farm…today you cannot observe such a thing … the world has changed a lot…"

5.5.6 Specificity of the local knowledge

About 50% of the participants strongly agreed that local knowledge and practices are specific to a given area, hence contributing to the limitations of their uses. This statement ranked seventh in the overall cumulative scores (Table 5.14) and in the lowland areas (Table 5.17), while it ranked ninth in the highland zone (Table 5.17). For the knowledge to be applicable and receive massive acceptance, it requires to be applicable anywhere and yield positive outcomes. However, due to the fact that some of the knowledge is owned by only a few people in a given area, it cannot easily be applied elsewhere. Those participants who agreed with this statement argued that some of the farming practices were favoured by the specific environmental conditions of the area, and this reduces their applicability elsewhere. They claimed that the types of crops grown also determined

the methods used in their cultivation which made them different and not applicable elsewhere. As argued by respond Respondent MT19:
"…some of the farming methods are different from others hence they cannot be applicable everywhere… the application of a method also depends on the habits of the people. For example, some farmers use terrace farming while others do not, some burn crop remains while others leave them on the farm…"

This suggests that local knowledge depends on people's culture. Hence there is a need to appreciate the differences in the culture which shapes the applications of some local methods. This is due to the fact that local knowledge has been developed for a give purpose depending on the needs of the society in question which makes it unique from other places. The literature also considers local knowledge to be unique to a given culture or society (Warren and Rajasekaran, 1993). Altieri (1995:114) asserts that local knowledge systems are forms of knowledge that have originated locally and naturally. Similarly, Hammer (2009) contends that local knowledge systems are linked to the communities that produce them.

5.5.7 Effect of modern knowledge

About 50% of the participants strongly agreed that local methods and practices are threatened by the increase in the use of modern technology (Table 5.13). This statement ranked eighth in the overall cumulative scores (Table 5.14), seventh in the highland area (Table 5.15) and tenth in the lowland zones (Table 5.16). According to District Official 01:
"…generally speaking, scientific methods do not seem to borrow from the local knowledge and improve on their weaknesses. The reason for this could be due to the region-specific nature of local knowledge. Therefore, scientific knowledge rather introduces a new technique based on universal scientific principles with total disregard for local knowledge…"

This view suggests that although scientific methods have been developed through the use of research and have been tested and shown to be successful, their universal application cannot be guaranteed due to differences in preferences of the end-user and the environment. However, according to District Official 04:

"…the importation of so much produce for advanced farming techniques threatens investments of various organisations and government in our local produce which are often considered inferior to these imported materials. What is currently happening is that modern technologies are gradually being introduced into the country, but unfortunately, we, the under-privileged farmers, are unable to access these. Hence, our local expertise is gradually being side-lined and we fear they may fall out of use or importance as time goes on…"

It is therefore important for modern methods to be designed appropriately for the locality in which they are required; only then can local knowledge be seen to be making a contribution to modern technological advances. However, local knowledge systems have values not only for the culture in which they evolved, but also for scientists and planners who are striving to improve conditions in rural localities (Makwara, 2013). For instance, as argued by Robinson and Herbert (2001), incorporating local knowledge into weather forecasting and climate change policies can lead to the development of effective adaptation strategies that are cost-effective, participatory and sustainable.

5.5.8 Lack of documentation of local knowledge

About 57% of the participants strongly agreed that local farming methods are becoming extinct due to the fact that they are not documented (Table 5.13). This statement ranked ninth in the overall cumulative score (Table 5.14), and in the lowland areas (5.15), and eighth in the highland zones (Table 5.16). Participants acknowledged that most of those who were knowledgeable with given skills did not ensure their existence by documenting them, hence when the knowledgeable person dies knowledge and skills may be lost. However, 18% of the participants strongly disagreed and did not consider the non-written nature of local farming methods to be of much importance. Participants explained that writing down knowledge may be of limited use as such documentation depends on the literacy level of the community. If a majority of the rural farmers are skilled but uneducated, passing their skills on to future generations through documentation will be limited. According to Kijazi et al. (2012) local knowledge is under threat of disappearing due to a lack of systemic documentation and lack of coordinated research to investigate its accuracy and reliability.

5.5.9 The influence of local taboos

Some 56% of the respondents, the majority from the lowland, strongly agreed that some of the local farming methods are connected with local taboos, hence limiting their existence and applications (Table 5.13). This statement ranked tenth in the cumulative scores (Table 5.14) and in the highland areas (Table 5.15), but ranked sixth in the lowland areas (Table 5.16). Participants argued that some of methods and practices are connected with spiritual beliefs which cannot be scientifically proven, and also the performance of local rituals and taboos are not consistent with religious adherence (Christianity and Islam are the religions practised by the majority in the study area). For example, the act of “calling rain” by offering a sacrifice, managing the outbreak of armyworms by prohibiting farmers from going to the farm, and praying to the forefathers is not encouraged. It was argued further during focus group discussions and oral histories that even though some of the local practices are linked with local taboos and beliefs, which are now considered superstitious, they carried a useful message, but only that it was not explained to the users. However, participants who strongly disagreed with the statement argued that there was no problem with the use of taboos and beliefs as far as they delivered positive results which benefited everyone in the community. Respondent CH10 believes:

"…that everything happening today is caused by people's non-adherence to the local culture and taboos, so the forefathers are angry and are punishing the world…"

According to Respondent MS22:

"…Taboos were successful in the past because they were performed by clan elders. Rituals stopped yielding positive results because they were performed by defiled people and today if you dare perform them, you may end up making spirits of the forefathers angry, generating more punishments…"

5.5.10 Lack of justification of some of the local beliefs

Nonetheless, only 48% of the participants strongly disagreed with the statement that local farming methods and practices cannot be justified. The statement ranked number eleven in cumulative scores (Table 5.14) as well as in both lowland and highland zones (Table 5.17). Hence, it was not considered to be the most significant factor that limited the existence and use of local methods and practices. Participants who disagreed argued that even though some of the local farming methods and practices cannot be justified or proven, their desirable outcomes could provide an indication of their effectiveness. For example, the act of 'calling rain' is thought to be effective in situations where the incidence of rainfall coincides with the performance of rituals (such as the sacrifice of a goat or sheep) which 'causes rainfall'. An incidence of an outbreak of armyworms was seen to be controlled by the performance of rituals during which period farmers were prohibited from going to their farms for three days after the performance of the ritual and all the armyworms died. The performance of this ritual is known as *kubigha menda* in the local language. Similarly, the application of local pesticides showed effectiveness when applied and pests died. Thus, this shows that local farming methods and practices might be considered to be useful in the respective communities although the act cannot scientifically be proved.

5.5.11 Limited application of local knowledge

About 57% of the participants strongly disagreed that local knowledge was difficult to apply, while only 5% of the participants strongly agreed (Table 5.13). This statement ranked twelfth in both lowland and highland areas (Table 5.17), hence it was not considered to be significantly a limiting factor. Participants who strongly disagreed with the statement argued that, there was no consensus on the application of some of the local methods and practices. For instance, the use of local pesticides lacks application guidelines as everyone applies a different measure, as opposed to factory pesticides which have a general application manual. Also some of the local storage pesticides make food taste bitter and inedible or sometimes result in long-term effects if not handled with care. In addition, the use of rituals, taboos, clan and gender sensitivity of some of the local farming methods and practices make their application difficult, and hence they are avoided by farmers which contribute to their extinction.

5.6 Conclusion

The findings suggest that rural farmers are knowledgeable and use LEKEPs in their farming activities. However, the understanding of LEKEPs varied by age group, gender and the location of the participants. Local environmental indicators, such as plant phenology, animal and insect behaviours and the appearance of celestial bodies, are used to predict the commencement of the growing season and the onset of rainfall. Similarly, farmers use types of grass, shrubs, trees, soil colour and soil particles to determine levels of soil nutrients. Farmers have also developed a knowledge of local plants which are used as pesticides in managing and treating crops and animal disease.

It has been found that, although rural farmers use LEKEPs in managing farming activities, they do not necessarily appreciate the successful role that such knowledge has contributed to agriculture-dependent livelihoods under conditions of climate change and climate variability. Some farmers feel that the poor performance of agricultural activities is due to the use of traditional farming methods and practices, whereas others attribute this to the use of scientific methods and changing environmental conditions. They also feel that the knowledge is limited in meeting the current challenges facing farming activities.

Even though local farming methods have been shown to be environmentally friendly compared to scientific methods, both methods have their strengths and weaknesses in providing solutions for farming activities, especially under the current changing environmental conditions. The findings of this chapter therefore suggest that the local and scientific methods of farming are complementary rather than competitive. Hence effective and environmentally sound coping and adaptation strategies in relation to the impacts of climate change and climate variability can be attained through a combination of both local and scientific farming methods and practices. This will enable agriculture-dependent communities to make informed decisions on their farming activities in order to minimise losses associated with extremes of weather and climate variability.

Chapter 6

Adaptation and coping strategies for the impacts of climate change and variability

6.1. Introduction

Farmers in Mwanga District, like many other small-scale farmers in the world, have been adapting to the changing environmental conditions over generations by changing and improving their farming practices to cope with those changes. They have developed strategies to lessen the impacts arising from the changing environmental conditions and weather variability in different seasons of the year.

This chapter will demonstrate how subsistence farmers in Africa have taken initiatives in adapting to changing environmental conditions. The chapter will examine the extent to which the adaptation strategies opted for by farmers offer a pathway to improved living conditions by ensuring food security to the households while contributing to environmental conservation. In doing this, the chapter analyses both autonomous adaptation strategies implemented at the household level and planned strategies implemented by the government in collaboration with other non-governmental institutions. The chapter is divided into three main sections. The first section analyses the changes in farming practices. The second section deals with the implementations of adaptation strategies by small-scale farmers and the last section presents the roles played by the local government in the implementations of agricultural adaptation strategies in reducing rural community vulnerability to the impacts of climate change.

6.2. Changes in farming practices

Traditionally, rural communities believe that there is no home without food, thus sufficient food in the household is considered to be a sign of material wealth and prosperity (see also Madulu, 1998). Despite the natural environmental changes farmers have been able to cope with these changes and meet their livelihood needs. However, current climate change forces farmers to change some of their farming practices in order to cope with the changing conditions, and some of the farming practices adopted by farmers in the study area in coping with climate change are shown in Table 6.1. The majority of the highland farmers agreed that they have changed their planting dates compared to two decades ago. The statement ranked highest in both zones with the overall cumulative scores of 99%, 93% and 93% respectively (Tables 6.1, 6.2 and 6.3).

Table 6.1: Changes in farming practices in the Highland zone over the last 20 years

Statement	5	4	3	2	1	Score	Score as % of the max
You have changed planting dates now	97	6	0	0	0	509	99
You practise more conservation farming (zero tillage) now	88	15	0	0	0	500	97
You practise more terrace farming now	72	25	0	4	2	470	91
You use more manure now	15	28	0	21	39	268	52
You retain more crop residuals and grass on the farm now	12	14	0	32	45	225	44
You have more weed control now	0	0	0	69	34	172	33
You practise more burning of the crop residuals and grass now	0	12	0	28	63	167	32
You use more factory fertilisers now	0	0	0	61	42	164	32
You use tractors more now	0	0	0	0	103	103	20

Note: Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1

N = 103

Maximum score (103*5) = 515

Table 6.2: Changes in farming practices among farmers who owned farms in both zones over the last 20 years

Statement	5	4	3	2	1	Score	Score as % of the max
You have changed planting dates now	9	5	0	0	0	65	93
You use more factory fertilizers now	8	6	0	0	0	64	91
You use more manure now	5	3	0	4	2	47	67
You practise more terrace farming now	0	6	0	3	5	35	50
You practise more conservation farming (zero tillage) now	0	3	0	8	3	31	44
You practise more burning of the crop residuals and grass now	0	0	0	3	11	17	24
You retain more crop residuals and grass on the farm now	0	0	0	0	14	14	20
You use more tractors now	0	0	0	0	14	14	20
You have more weed control now	0	0	0	0	14	14	20

Note: Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1

N = 14

Maximum score (14*5) = 70

Table 6.3: Changes in farming practices in the Lowland zones over the last 20 years

Statement	5	4	3	2	1	Score	Score as % of the max
You have changed planting dates now	81	33	0	3	0	543	93
You retain crop residuals and grass on the farm now	18	60	0	12	27	381	65
You practise more conservation farming (zero tillage) now	26	6	0	38	47	277	47
You use more tractors now	15	15	0	52	35	274	47
You use more factory fertilisers now	0	15	0	64	38	226	39
You use more manure now	0	11	0	64	42	214	37
You have more weed control now	0	0	0	78	39	195	33
You practise burning of crop residuals and grass now	0	0	0	42	75	156	27
You practise more terrace farming now	0	0	0	0	117	117	20

Note: Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1

N = 117

Maximum score (117*5) = 585

6.2.1 Changes in planting dates

About 94% of the responses in the highlands, 69% in the lowlands and 64% of the farmers who owned farms in both zones strongly agreed that they had changed their planting dates. One of the participants during focus group discussions in the highlands reported that for a successful harvest, planting should now be done with the immediate onset of the rain. In addition, the participant explained further that with variable rainfall concentrated within a short period of time, planting early when the soil is still wet helps crops to survive and to tolerate drought conditions until further rains arrive. However, this was reported to be successful only if drought tolerant hybrid seeds are planted.

Another participant reported that, traditionally, the first rain was an alert for the commencement of the season and the majority of the growing farmers would start field preparation ready for planting at that time, while a few would sow their seeds to exploit early rains and benefit from the earlier harvest. Nowadays, farmers have abandoned such traditional practices, and instead the first rains are now used for crop sowing rather than farm preparation.

Similarly, changes in weather conditions have led to farmers abandoning early planting strategies when they used to scattered seeds on the ground a month earlier before the beginning of the rain. This was done in August in the highland areas and in some cases was supported by cool weather conditions and traditional irrigation programmes in areas with water, while in other places households used hand-held buckets to irrigate their crops until the rainy season begun. In the lowlands, seed planting was done during the time of farm preparations and some would begin germinating just with the presence of morning dew and survived until the first rain began. The early timing in planting before the commencement of rainfall is called *kutupia* in local the language and early planting along wetlands, rivers and streams is popularly known as *champombe* farming.

Participants reported that early planting is no longer feasible due to irregular and unpredictable rainfall, as early planted maize dries and withers due to drought, while others are eaten by termites. Another participant in the focus group discussions reported that the shortened growing season limits the staggering of planting dates and also has forced farmers to abandon their plots in the lowland zones. The participant explained that in the past, one would sow seeds on the lowland farms, followed by highland farms, but the shorter rainfall season now makes farmers concentrate on their highland farms. Staggered planting dates reduce the impacts of crop damage from extreme weather events, the outbreak of crop diseases and insect pests. This minimises the chances of no harvest within the season because crops are planted at different times and in separate plots (see Whitmore, 2000). A shortened growing season and limited staggering dates increases the risks of crop failure and damage from insect pests, diseases and extreme weather events, leading to food insecurity in the household.

Despite early planting as a measure for coping with the shortened growing season and rainfall variability, farmers reported that they were not assured of a good harvest because sometimes rainfall commenced early, but was highly variable, requiring early planted crops to survive under heat stress conditions. Progressive changes in the commencement of rainfall were reported to have contributed to the loss of the most valued indigenous traditional maize and bean species.

6.2.2 The use of zero tillage

Participants also reported to practising more zero tillage now than two decades ago. This statement ranked second in the highland zones, fifth among farmers who owned farms in both zones, and third in the lowland zones (Tables 6.1, 6.2 and 6.3). Under this technique seeds are sown on uncleared farms immediately after the first rain. The technique is popularly known as *kitang'ang'a* in the local language. The majority of the participants (85%) in the highlands strongly agreed to be practising this method. There are a number of reasons to explain why farmers used this method. Participants during focus group discussions reported using *kitang'ang'a* more now than in the past due to increased rainfall variability, changes in the onset rainfall and the failure to observe traditional seed sowing times due to rainfall unpredictability. Sometimes, farmers are caught by the rain before they start preparing farm plots, or in other occasions it rains so heavily that it becomes impossible to use tractors to plough the land. The use of hand hoes takes longer time than tractors and farmers do not want to risk missing the first rain, thus they feel compelled to resorted to practising *kitang'ang'a*. Lowland group discussions revealed that the technique was seen to be more economical, as it saves money by not hiring agricultural labour for farm preparations. Another participant reported that some farmers spend money on using a tractor, but, due to drought, conditions crops failed and farm plots remained bare. The method also reduces the cost and number of weeding because farm clearing is done during weed germination thus germination takes place on a clean farm plot. The participants confirmed that currently, by practising zero tillage, the number of weeding events has been reduced to one per season.

There exist a number of benefits of practising zero-tillage methods. A study by Govaert et al. (2005) suggested that the method improves productivity and sustainability in cropping systems in subtropical highlands. Through zero-tillage techniques, farmers reduced the rate of surface soil erosion as soil particles remain compact and undisturbed during heavy rain and the presence of crops remains. Grass also provides a shield for the top soils against surface water run-off and wind erosion, and hence increases the rate of water infiltration and water use efficiency (see also Govaerts et al., 2005). The method increases soil biological activities due to an increase in the numbers and varieties of living organisms in the soil (see Baeumer and Bakermans, 1974; Carter and Rennie, 1982; Nyborg and Malhi, 1989; Govaerts et al., 2005; Strudley et al., 2008; Kassam et al., 2009). However, the study recommends a deeper understanding of the ecological conditions of the study area in order to maximise resource use and to protect the environment. Doranl (1987) argues that the shift to conservation tillage systems has been stimulated by the need to decrease fuel and labour costs, and to maintain production on fragile land (steep, dry, sandy, etc.).

Despite the reasons which compelled farmers to practise *kitang'ang'a*, and benefits obtained from the method, farm observations showed that on plots where crops were planted through *kitang'ang'a* most of them withered quickly due to prolonged drought and those which survived were weaker than crops found on cleared farm plots before seed sowing. Current changes in climate and weather variability, coupled with low, variable and insufficient rainfall, has led to challenges of the technique by some farmers and extension officers. About 40% of the participants from the lowlands strongly argued that the technique was more appropriate in the past due to more reliable and sufficient rainfall at that time. Participants reported that the method inhibits rainwater percolation to the deeper soil layer because soil particles are compact, and it accelerates the rate surface run-off as most plots remain bare due to a prolonged period of droughts from June to October. Similarly, those highland participants who opposed this method argued that when weeding was delayed, or not finished in time, this resulted in germinating crops competing for light, soil nutrients and moisture with other fast growing weeds. The method also exposes crops to pest and diseases, thus making them vulnerable to the damaging effects of pests and diseases. More importantly, the technique contributes to poor crop yields, as reported by District Official 01. The Official added that compact soil retains water on the surface for longer which causes seeds and crop roots to rot. This finding agrees with the body of literature on zero tillage, which suggests that the method inhibits crop root penetration and has smaller soil temperature amplitude associated with a low depth of microbial biomass because crop remains are retained at the soil surface, thus resulting on reductions in crop yields (Baeumer and Bakermans, 1974; Nyborg and Malhi, 1989). A study by Unger et al. (1991) suggested that farm tillage helps to control water erosion especially when precipitation rates exceed infiltration rates and excess water is temporarily stored on the surface.

6.2.3 Use of tractors, oxen plough and power tiller

This study assessed the use of tractors, oxen plough and power tiller during farm preparations in the lowlands and terrace farming in the highlands. The use of tractors ranked fourth in the lowland zone with 47% of the overall cumulative scores (Table 6.3). About 13% of the respondents strongly agreed to the use of tractors during farm preparation more now than two decades ago, while 30% strongly disagreed. Although hand hoes form the principal tool for farm operation (tillage, planting and weeding) in the study area, studies suggest that its use limits soil aeration, root penetration and soil mixing to allow more water to infiltrate to the soil, while the use of tractor, oxen and power tiller to till the land increases the rate of rainwater infiltration and soil water-retention capacity, reduces the rate of surface water run-off and helps in breaking down heavy soil particles (see Madundo and Galema, 2000; Starkey and Mutagubya, 1992; Du Plessis, 2003). The use of oxen is mostly practised in Ngullu, Kwakoa and Kigonigoni wards. However, during focus group discussions and farm observations, it was revealed that farmers used both hand hoes and tractors in farm preparation. The strategy is seen to reduce higher losses due to bad weather. Lowland farm plot observations revealed that plots which were prepared by using tractors had crops which better survived drought conditions and grew to the flowering stage although they could not necessarily yield crops due to increased drought conditions and rainfall variability, whereas most of the crops withered at early stages of growth on the farm plots which were cultivated by using the hand hoe.

According to District Official 03, farmers, especially in the lowland areas, are encouraged to use tractors, power tillers or oxen during farm preparation in order to increase water infiltration and reduce surface run-off. These views are supported by the statement made by FAO (2008a) in the framework for action on conservation agriculture in Giller et al. (2009, 24):

"…The plough has become the symbol of agriculture and many, including farmers, extension agents, researchers, university professors and politicians have difficulty in accepting that agriculture is possible without tillage..."

Although the use of tractors in tilling the farm contradicts the views of conservation agriculturalists who support zero tillage, the method would appear to be the best farming practice under current climate changes.

An interview with District Official 03 indicated that Mwanga District has 27 tractors and 10 small-sized power tillers, which are hired by farmers for farm preparation. Twenty-one out of the 27 tractors were in good condition, six needed major and minor repairs, while all power tillers were in a good condition and working (see Plate 6.1). Whereas ownership of the big tractors was in private hands, the power tillers were under both private and communal ownership (three privately owned, six owned by SACCOS, and one owned by the village authority of Kirya).

Plate 6.1 Tractor and power tiller at the District premises

On the other hand, the use of tractors, oxen and power tillers in the highlands is impaired by topography, and so all primary and secondary farm operations are done by using a hand hoe. Nevertheless, farmers in the highland areas practise contour and terrace farming to stabilise slopes and retain rainwater in the soil, hence reducing the rate of surface run-off and soil erosion (see Plates 6.2 to 6.4).

Plate 6.2 Stone bench terraces grown fodder at the edge in Ngujini Ward

Plate 6.3 Stone bench terraces in Kilomeni Ward

Plate 6.4 Traditional terraces in Ngujini Ward

6.2.4 Use of terrace farming method

Through terrace farming, farmers are able to control soil erosion which affects crop yields through the removal of soil nutrients, reduced plant rooting zone, reduced soil organic matter, reduced soil water holding capacity, and changes in soil structure (Gebremedhin et al., 1999). The use of terrace farming ranked third in the highlands, fourth among farmers who owned farms in both zones and ninth in the lowland zones (see Tables 6.1, 6.2 and 6.3). Farm observations revealed that farmers in the study area incorporate both traditional and modern terrace farming methods where the study observed built stone bench terraces and traditional contour terraces called *fanya juu chini*. During focus group discussions one of the participants reported that the construction of stone bench terraces is highly labour intensive and required much time to construct. Also the terrace requires an increased use of manure because the top fertile soil which developed over generations is removed and replaced with inner soil which is less fertile. The *fanya juu chini* technique is highly favoured by the majority of the households when compared to the stone bench terrace method because it is easy to prepare, less labour intensive and retained the fertile top soil layer more effectively (see also Gebremedhin et al., 1999; Branca et al., 2011). However, farm observations revealed that there was increasing decline in the maintenance and constructions of new terraces among many farmers in the highlands, although the study observed the increased cultivation of animal fodder across plots which is another method that farmers now rely on in controlling surface water run-off, hence reducing soil erosion and strengthening the edge of the terraces. The types of fodder planted include elephant grass (*Pennisetum purpureum*), Guatemala grass (*Tripsacum laxum*) and setaria (*Seteria splendida*).

Land management practices, such as contour and terrace farming, help in reducing soil erosion, hence increasing soil fertility. However, prolonged cultivation without additional soil nutrients affects crop productivity. As discussed in Chapter Five, this study assessed the use of manure and factory fertilisers as one of the strategies in adapting to environmental changes. During focus group discussions in both zones, the study revealed that, traditionally, farmers in the study area practised farm fallowing, which allowed the farm plots to naturally regenerated soil fertility. The system worked because of low population densities and the availability of sufficient land suitable for agriculture. However, population growth, especially in the highlands has reduced the availability of arable land and has resulted in more farm plots coming under continuous cultivation, which reduces the chances of fallowing. Continuous cultivation in the same plot accelerates decline in soil fertility which in turn affects crop productivity and food insecurity (see also Tinker et al., 1996). Farmers in the study area recognise the declining soil fertility on their farms and now they apply either animal manure, industrial fertilizers or retain crop residuals after crop harvests as well as grass on the farm plots during farm preparation, all of which helps in improving soil fertility. A study by Dick (1992) suggested that soil amendments through additional organic matter helps in the improvement of soil fertility, increases soil air space, increases crop productivity, aids soil development and soil water retention.

6.2.5 Application of animal manure

The study also observed the application of manure and fertilisers in improving soil fertility and boosting crop productivity. Data obtained from this study (Tables 6.1, 6.2 and 6.3) suggest that the majority of the highland farmers applied manure on their farms more now than in the past when compared with the lowland farmers. The use of manure in the highlands was also evident during farm and transects walk observations (Plates 6.5 and 6.6).

Plate 6.5 Application of animal manure in Ngujini ward

Plate 6.6 Application of animal manure in Usangi Ward

Although highland farmers reported applying more manure on their farms, farm observations revealed that the application of animal manure is restricted mainly to those farm plots surrounding the homestead (banana farms), and those which are nearby, while distant farm plots, where maize and beans are grown, did not have manure applied. The evidences from observations were supported by the views made by one of the participants during focus group discussions in the highlands that:

"…manure is not enough to apply in all farm plots due to shortage of fodder which makes households keep few livestock ..."

Respondent SF10 commented that carrying manure to the farms was difficult because farm plots are far from the homestead and the supply of manure is not enough to apply on all farm plots.

On the other hand, the study did not find any evidence of manure applications on the lowland farms. This may have been caused by severe drought conditions which were observed in the lowlands. However, participants in the lowlands did not consider their soils to be unfertile. The statement ranked sixth with 37% in the overall cumulative score. The limited application was confirmed by one of the participants in the group discussions that: "…the soil is still fertile and the major problem in farming is drought which affects crop productivity…"

Respondent KW25 reported that during heavy rains his farms were flooded by rainwater from the highlands, thus they benefited from the fertile soils eroded from the highlands which makes their soil fertile.

Farm observations showed heaps of decomposed and fresh animal manure collected outside the animal kraal and not applied in the farm (see Plate 6.7).

Plate 6.7 Animal manure dumped outside the animal kraal in Kisangara ward

These findings on the limited application of animal manure in general and increased applications of manure on homestead farms are similar to findings observed by other researchers. A study by Zingore et al. (2007) showed that soil fertility on the smallholder farms declined with the increase in distance from the homestead. The study found that higher transport costs, lack of efficient labour, limited availability of animal manure, and risk associated with erratic weather conditions limited the application of animal manure and fertilisers on the farm (Zingore et al., 2007). However, Kaliba et al. (2000b) consider the limited application of animal manure to be caused by the increased demand for land for crop production, coupled with population growth which pushes livestock keeping far from the village arable land to the village peripheries and marginal areas. This makes transportation of manure from livestock areas to the farms to be very expensive and is thus avoided by the majority of the farmers. However, under current changes farmers must use manure to increase soil fertility to boost crop productivity.

6.2.6 Retention of crop residuals on the farm

Farmers also retain crop residuals and grass on the farm after crop harvests and during farm clearing aimed at increasing soil nutrients geared to improved crop productivity (see Plates 6.8 and 6.9). Studies conducted elsewhere show that the retention of crop residuals on the farm helps to improve the farm's soil fertility, reduces the rate of evapotranspiration and soil erosion from surface run-off during heavy rains. This increases water use efficiency, regulates surface layer soil temperatures and increases aggregate soil stability (see Govaerts et al., 2005; Karlen et al., 1994; Bruce et al., 1990; Giller et al., 2009; Nyong et al., 2007). In addition, a study by Erenstein (2002) suggested that when an average of 30% of soil was covered by crop residuals this can reduce soil erosion by up to 80% or more, while Hudson (1957) indicated that the retention of grass on the farm as mulch on clay loam soils can reduce annual soil losses by up to 5 t/h when compared with bare soils without residue application. Mulching is also considered to be effective in reducing the risk of crop failure in semi-arid regions due to the better capture and use of rainfall (see Giller et al., 2009). The method is also considered to be among the conservation agricultural management options that can enhance soil organic carbon stabilisation (see Chivenge et al., 2007).

Plate 6.8 Retained crop remains on the farm after crop harvest in Ngujini ward

Plate 6.9 Retained grass remains on the farm in the highland

However, the retention of crop residuals and grass is challenged by an increased demand for livestock fodder, as most of the crops remains and grass are now collected and stored for feeding livestock as a means to manage fodder scarcity (see Plates 6.10 to 6.12). About 55% of the participants reported not retaining crop residuals and grass on the farm but rather collected the remains as livestock fodder. Focus group discussions in the highlands also showed that some of the households retained crop residuals on the farms due to costs of transporting the residuals from the farm to the homestead. However, the remains were collected by the lowland agro-pastoralists and farmers who lived on nearby their farms. In the lowland zones, the retention of crop residues is also jeopardised by the presence of termites which quickly feed on crop remains after crop harvests, leaving the farm bare. Similar findings on the effect of termites on crop residuals was observed in Malawi (see Giller et al., 2009). However, various studies (Chivenge et al., 2007; Mann et al., 2002; Giller et al., 2009) show that the limited retention of organic residues on the farm may accelerate soil erosion leading to the decline in the farm soil fertility. This study considers the use of mulching from crop residuals and grass remains to be important component in agricultural adaption strategy to the current changing climatic conditions and weather variability.

Plate 6.10 Storage of maize stalk as livestock fodder in the Lowland zone

Plate 6.11 Storage of maize stalk as livestock fodder in the Highland zone

Plate 6.12 Storage of beans remains as livestock fodder in the Highland zone

A further reason for the limited retention of crop remains on the farm is due to crop failures caused by erratic rainfall and increase in droughts in both zones. However, shortages of fodder in the lowlands is due to increases in drought conditions which have made agro-pastoralist turn from farm plots to grazing *in situ* immediately after crop harvest or crop failure (see Plates 6.13 and 6.14).

Plate 6.13 Grazing livestock in the farm after crop harvest in the lowland zone

Plate 6.14 Using farm plot as a grazing in situ after crop failure in the lowland zone in Kisangara Ward

6.2.7 Use of industrial fertilisers

The study assessed the use of inorganic fertilisers among farmers in the study area as one of the farm change strategies in adapting to changing conditions. The statement ranked eighth among the highland farmers, second among farmers who owned farms in the both zones, and fifth in the lowland zone with overall cumulative scores of 32%, 64% and 39% respectively (Tables 6.1, 6.2 and 6.3). This study did not observe any evidence on the use of inorganic fertilisers, despite the fact that factory fertilisers were among of the inputs provided to farmers under subsidised prices. Focus group discussions in both zones revealed that the use of industrial fertilisers was limited by extreme droughts, insufficient rainfall and limited purchasing power among households. The participants who reported using factory fertilisers applied them only to their vegetable gardens. The views that the application of fertilisers was limited by drought conditions is supported by the findings of Kaliba et al. (2000b) which suggested that the successive application of inorganic fertilisers depends on a sufficient availability of moisture. One of the participants during focus group discussions in the highland zone said that households avoided the use of inorganic fertilizers for the reason that once used it can lead to soil exhaustion unless it is applied continuously.

District Official 03 reported that the limited application of manure and factory fertilisers has resulted in average maize production per plot in the district remaining low compared to the estimated potential yields of 4-5 metric tonnes per hectare. A study by Kaliba et al. (1998) suggested average maize yields in Tanzania have declined to less than 1.5 t/h. The limited application of manure and fertilisers, aggravated by increasing droughts, is to blame, threatening Tanzania’s green revolution ambitions propagated by the government through the political slogan of *Kilimo Kwanza* in Swahili, which literary means Agriculture First i.e. agriculture to be given first priority.

The burning of grass, trees and crop remains are no longer used as farming practices by the majority of farmers. The remains are now either retained on the farm to improve soil fertility, to reduce soil moisture losses through evapotranspiration and to reduce soil erosion from run-off during heavy rains or to be collected as animal fodder (see previous discussion). Despite this change in the use of burning as farm clearing method, the study found that the burning tradition of the residuals and bushes on the farm plot is still practised by a few households as a way of eradicating crop diseases, vermin and insect pests, as well as a measure to protect their plots from wild animal encroachment (see Plate 6.15). It was further explained that burning is mostly practised on the newly created farm plots and on those plots which had been fallowed for a long period of time.

Plate 6.15 Evidence of burnt grass residuals on the farm at Sofe village in Kilomeni Ward

Finding on the burning of crop residuals is supported by a body of literature which suggests some benefits from burning residuals on the farm. Kanmegne (2004) suggested that burning can enhance soil fertility in the short run by increasing the availability of minerals such as potassium (K), magnesium (Mg), Calcium (Ca), nitrate and sulphate, and by helping in weed and pest management and the control of the vermin population. Burning is considered to be a fast way of clearing agricultural fields (Giller et al., 2009; Juo and Manu, 1996). However, Giller et al. (2009) found that the burning of crop residuals among farmers in southern Malawi, parts of Zambia and Central Mozambique was practised by households who owned fewer livestock and used hand hoe for tilling the land.

However, according to District Official 06 and Ward Officer 02, the burning of grass on the farm is discouraged and considered to be dangerous because of fires which sometimes get out of control and burn crops on others farm in the neighbourhood. Although there are no accurate statistics on the number of forest fires caused by burning residuals, several incidences of forest fires were reported to have been caused by the burning of residuals. Participants during focus group discussions reported that the most recent incident occurred in March 1997 in Mbambua village.

The fire went out of control and encroached into Kindoroko forest where several hectares of the reserve were burnt down. There are side effects of burning residues on the farms, such as increased concentration of carbon dioxide in the atmosphere which impacts upon global climates and also affect the earthworm population density (Kotto-Same et al., 1997; Tinker et al., 1996). A study by Kanmegne (2004) estimated that burning can result in up to a 95% loss in earthworm density. Thus avoiding burning could increase soil microbial biomass and community functional diversity (Zhong and Cai, 2007) which are important in soil development and the decomposition of soil organic matter.

6.2.8 Weed management

Another change in farming practice has been in farm weed management. This ranked sixth in the highland zones, ninth among farmers who owned farms in both zones and seventh in the lowland zones with 33%, 20% and 33% of overall cumulative scores respectively. The majority of the participants in all groups strongly disagreed with the statement that an increase in droughts has reduced weeding demands to only once, as opposed to the past when weeding was done thrice in the highlands and twice in the lowlands. The first weeding began immediately after seed germination, followed by the second weeding several weeks later, normally before or during crop flowering, and the last was done after crops flowering. One of the participants reported that in the past weeds flourished quickly as they were favoured by higher.

6.3. Implementation of agricultural adaptation strategies

6.3.1 Mixed cropping

Mixed cropping is a key of the adaptation strategy employed by the majority of the farmers in the study area. The method ranked highest in the highland zone, fifth among farmers who owned farm plots in both zones and fourth in the lowland zones with 89%, 90% and 64% of the overall cumulative scores (Tables 6.4, 6.5 and 6.6). Farmers grow simultaneously selected varieties of crops on the same farm plot at different times, hence maximising production from the single farm plots. They ensure that the crops planted together do not compete with each other for physical space, nutrients, soil moisture and sunlight, but grow together for mutual benefit. For instance, some crops provide shade, shield crops against wind effects and rainfall damage, and improve soil nutrients/fertility (compost mulches form foliage and nitrogen fixation plants), hence increasing crop productivity through the maximising of scarce resources. As opposed to monoculture cropping, mixed cropping benefits rural farmers in various ways such as balancing soil nutrients' input and output, lowering the rate of weed growth, minimising the damaging effect of insect pests and crop diseases and resisting climate extremes. The evidence gathered through farm observations and focus group discussions, revealed that mixed cropping techniques were influenced by a household's preference for crops as well as location which made crop mixing vary from one farm plot to another. In all observed farm plots, each had at least two or more crops grown together. For instance, in the highland zone, besides maize, beans and bananas which were the major crops grown on farm plots, farmers also grew cassava, sugarcanes, yams, sweet potatoes, pumpkins, groundnuts and sunflowers. Together with crops, farmers also planted selected types of trees that shielded crops form sunshine, wind and rainfall impacts. Such trees included *Grevillea robusta*, *Cordia Africana, Acrocarpus fraxinifolius, Ficus sp., and Albizia gummifera.* They also planted fruit trees such as avocado (*Persea americana)*, jackfruit (*Artocarpus genus*), mango tree (*Magifera indica*), pawpaw (*Carica papaya*) and guava (*Psidium guajava*). The jackfruit was popularly grown and thrives well at Ugweno and Usangi wards. According to Ward Office 01, some of the tree species, such as *Grevillea robusta, Cordia africana, Acrocarpus fraxinifolius, Ficus species* and *Albizia gummifera*, improve soil nutrients from their foliage and nitrogen fixation from roots nodules. The observations from these findings are consistent with the literature in agroforestry studies. For instance, Charles et al. (2013) suggest that trees help to buffer subsistence farmers against environmental extremes by modifying temperatures, providing shade and shelter and acting as alternative sources of feed for livestock during periods of drought. (Singh and Pandey, 2011) suggested that trees do not only help in fixing nitrogen, but also can enhance the physical, chemical and biological properties of the soils by adding substantial amounts of organic matter, reducing soil erosion and providing long-term vegetation cover.

In the lowlands farmers also practised mixed cropping and grew together maize, greengram, cowpeas, groundnuts and sunflowers. However, it is important to note that not all farmers here practised mixed cropping, as farm observations showed only about 68% of farms were under mixed farming and cropping, and 32% were grown with maize alone. Discussions with Ward Officer 03 revealed that to some extent monoculture was cause by rainfall variability, as maize is sown first before other crops and after its germination other crops (beans, groundnuts, cowpeas) are sown. A prolonged rain break after the first rains discouraged farms from growing other crops after maize. It is also important to note that, apart from in the river channels and swamps, locally known as *kitivo*, beans, sugarcane and bananas were grown at a limited scale as they are badly affected by droughts. Most of the farm plots in the lowlands were planted less with perennial crops, and more with annual crops (maize and legumes). However, there were a few and scattered trees such as mango trees (*Mangifera indica*), coconut trees (*Cocos nucifera*), baobab (*Adansonia digitata*) and Ficus species (along the water channels). Some of these trees are planted while others grew naturally. Plates 6.16 to 6.19 illustrate some mixed cropping systems practised in different locations of the study area.

Table 6.4: Adaptation strategies by highland farmers

Statement	5	4	3	2	1	Score	Score as % of the max
You practise mixed cropping more than past decades	77	15	0	4	7	460	89
You grow more improved maize varieties now than past decades	56	39	0	4	4	448	87
You cultivate fewer plots now than in past decades	37	55	0	8	3	424	82
You grow more drought-resilient crops now than in past decades	21	56	0	9	17	364	71
You depend more on remittances now than in past decades	37	24	0	18	24	341	66
You cultivate more crops other than maize and beans now than in past decades	42	17	0	16	28	338	66
You depend more on non-farm activities now than in past decades	39	14	0	17	33	318	62
You keep more livestock now than in past decades	8	33	0	44	18	278	54
You use more industrial insects and pesticides now than in past decades	5	14	9	30	45	213	41
You depend more on traditional weather predictions now than in past decades	0	17	3	32	51	191	37
You practise more irrigation now than in the past decades	3	8	0	11	81	150	29

Note: Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1

N = 103

Maximum score (103*5) = 515

Table 6.5: Adaptation strategies among farmers who owned farms in both zones

Statement	5	4	3	2	1	Score	Score as % of the max
You grow more improved maize varieties now than in past decades	12	2	0	0	0	68	97
You depend more on non-farm activities now than in past decades	12	2	0	0	0	68	97
You cultivate fewer plots now than in past decades	11	33	0	0	0	67	96
You cultivate more crops other than maize and beans now than in past decades	11	3	0	0	0	67	96
You practise mixed cropping more now than past decades	9	4	0	1	0	63	90
You grow more drought-resilient crops now than in past decades	5	4	0	5	0	51	73
You practise more irrigation now than in past decades	5	1	0	3	5	40	57
You use more industrial insects and pesticides now than in past decades	0	5	0	5	4	34	49
You depend more on remittances now than in past decades	2	0	0	4	8	26	37
You keep more livestock now than in past decades	0	0	0	9	5	23	33
You depend more on traditional weather predictions now than in past decades	0	0	0	4	10	18	26

Note: Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1

N = 14

Maximum score (14*5) = 70

Table 6.6: Perceptions on adaptation strategies by the lowland farmers

Statement	5	4	3	2	1	Score	Score as % of the max.
You depend more on non-farm activities than in past decades	94	23	0	0	0	562	96
You grow more improved maize varieties	87	25	0	5	0	545	93
You cultivate fewer plots now than in past decades	75	20	0	5	17	482	82
You practise mixed cropping more than past decades	26	43	0	26	22	376	64
You use more industrial insects and pesticides than in past decades	14	37	24	17	25	349	60
You grow more drought-resilient crops than in the past	26	18	0	36	37	311	53
You depend more on remittances more than in past decades	18	23	0	35	41	293	50
You cultivate more crops other than maize and beans than in past decades	12	18	0	26	61	245	42
You keep more livestock than in the past decades	0	27	0	43	47	241	41
You depend more on traditional weather predictions more than in past decades	0	16	0	33	68	198	34
You practise more irrigation than in past decades	0	8	0	16	93	157	27

Note: Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1

N = 117

Maximum score = 585

Plate 6.16 Maize grown together with cowpeas in Kisangara ward

Plate 6.17 Maize grown together with banana and fruit trees in Ngujini ward

Plate 6.18 Banana grown together with cocoyam in the highlands

Plate 6.19 Mixed cropping of maize cassava, sunflower and ground nuts in Kilomeni ward

Focus group discussions in both the lowland and highland zones revealed that intercropping was seen to be beneficial to farmers because of uncertainties in weather conditions and lack of knowledge on specific types of crop which could perform better in a given season. In addition, practising monoculture was seen to be a risk in case of bad weather or outbreak of diseases which could lead to crop damage or failure (Charles et al., 2013). According to Respondent MS21, intercropping provides the best method of land utilisation due to land shortages, while Respondent MS26 reported that the technique was aimed at food diversification thus avoiding dependence on one common food type in the household.

6.3.2 Growing of improved maize varieties

Farmers manage the changes in environmental conditions, such as decline in rainfall, rainfall variability, shortened growing season and increases in temperature associated with occasional and severe drought conditions, by cultivating improved and short maturing maize varieties and slowly abandoning some of their indigenous maize species. Evidence from focus group discussions and farm observations suggested that farmers in the study area are slowly abandoning the tradition of growing indigenous maize species, popularly known as *mwasu*, which was common and successful in the past due to reliable rainfall patterns. The quick maturing, drought resistant hybrid seeds, and other exotic and composite varieties of maize and legumes, are replacing the indigenous species. The growing of improved maize varieties ranked second in both highland and lowland zones and ranked first among those households who owned farm in both zones with the overall cumulative scores of 87%, 93% and 97% respectively (Tables 6.4, 6.5 and 6.6). Household interviews and focus group discussions reported some of the hybrid and other exotic maize species which are currently grown in the study area (Table 6.7). The most common types of hybrid seeds, with codenames DK 8053 and DK 9089, were grown by the majority of the farmers in the highland zones, while SEED-CO 625 (also known as *Chapa Zebra* in Swahili) and SEED-CO604 (also known as *Chapa Nyani* in Swahili) were grown by the majority in the lowland zones. It is important to note that about 21% and 14% of the participants from highland and lowland zones respectively reported growing only hybrid seeds which they referred to either as improved seeds or factory seeds (*mbegu za kisasa* or *mbegu ya dukani* in Swahili) but they did not report their codenames. Some of these seeds were reported to be bought from the market and other unauthorised dealers. About 36% of the participants, who owned farms in both zones (Table 6.8), and 35% of the participants from the highlands and 8% of the participants from the lowland zones (Table 6.7) reported growing recycled seeds obtained from the previous season’s harvest. However, recycled seeds among farmers who owned farms in both zones were grown in the highland farm plots only. Focus group discussions in both zones reported that farmers recycled improved seeds, and also obtained seeds from unauthorised dealers, due to droughts, delayed availability of improved seeds in the authorised dealers’ shops, high price of seeds, high transport costs and lack of information on the benefits of growing improved seeds.

Table 6.7: Types of hybrid seeds grown in the study area

Highland			Lowland		
Maize codename	Freq.	% of the responses	Maize codename	Freq.	%of the responses
HDK 8053	56	54	Seed-Co625	78	67
HDK 9089	43	42	SEED-CO604	67	57
Hybrid	22	21	SEED-CO 513	42	36
Pannar 690	18	17	SEED-CO 407	36	31
Pannar 614	16	16	Hybrid	16	14
Pannar 628	12	12	TMV2	15	13
SEED-CO625	3	3	Pannar 627	14	12
TMV1	8	8	Stuka	9	3
Recycled seeds	36	35	Recycled seeds	4	8

Table 6.8: Types of seeds grown by farmers who owned farms in both zones

Highland Farms			Lowland farms		
Maize codename	Freq.	% of the responses	Maize codename	Freq.	% of the responses
HDK 8053	9	64	SEED-CO604	1	7
HDK 9089	7	50	TMV2	1	7
Pannar 614	7	50	SEED-CO 407	1	7
SEED-CO 407	6	43	Stuka	1	7
Pannar 690	6	43	SEED-CO 513	0	0
Hybrid	5	36	Hybrid	0	0
TMV1	4	29	Pannar 627	0	0
Pannar 628	4	29	SEED-CO 625	0	0
SEED-CO625	4	29	Recycled seeds	0	0
Recycled seeds	5	36		0	0

According to District Official 01, the hybrid and other exotic maize seed varieties are produced by agricultural research centres such as the National Maize Research Program (NMRP), or Water Efficient Maize for Africa (WEMA) in collaboration with the Ministry for Agriculture, Food Security and Cooperative (MAFSC) through the department of Research Development (DRD). The official reported further that experts from Water Efficient Maize for Africa (WEMA) recommend that types of hybrids with codenames WE 2109, WE 2112 and WE 2113 should be grown in the lowland (0–900 masl) and mid-altitude zones (ecology) (900–1 500 masl). The official added that in terms of strength, hybrid varieties are believed to have higher yields, perform well under low rainfall conditions, tolerate drought and resist common maize diseases and pests thus making them ideal to be grown in the study area. The cultivation of different hybrid seed varieties is also recommend by other researchers as appropriate in adapting to current changes in climate and weather variability (Kaliba et al., 2000b; IPCC, 2007).

However, District Official 03 said that for farmers to accept and grow a given type of maize variety, the type must meet and satisfy their expectations, including yields as well as taste (flavour). The majority of farmers judged the performance of the maize seed varieties on the basis of their past experiences. These views match those from a study by Kaliba et al. (2000b) which suggested that farmers preferred improved maize seeds that are stable in yields at different levels of moisture availability, and they avoid those which are highly variable in terms of yield as they pose food insecurity issues to the household. The study also mentioned other factors such as price of input, taste and preference of individual households and input distribution and availability to enhance or limit the adoption of the technology. A study by Nkonya et al. (1997) reported that the adoption of a technology varies over space and time because of natural resources, and cultural, political and socioeconomic differences.

However, some of the respondent appreciated the growing of some improved maize seeds, such as Respondent CH03:

"…despite seeds been received in the planting season and after the first rain, if a farmer grew improved seeds and the season experienced prolonged periods of rain break, one will be surprised to see that improved seeds survived dry spell conditions and ended up with some good yields when compared with local seeds and those bought from the market…"

The participant added further that if everyone would grow improved maize varieties, this would reduce food shortages in the village which could also reduce the price of maize in the market.

Respondent SF14 reported a preference for growing a maize seed variety called *Stuka* and explained that the type has higher yields, takes a shorter time to maturity and is suitable for roasting as it tastes sweet. The participant mentioned another type of maize variety called Malawi, confirming that although the type had good yields under good weather conditions and had bigger maize corn when compared with *Stuka,* it was not suitable for roasting.

During focus group discussions participants reported having stopped growing some of the maize varieties such as *Katumani, Staha, Kito, Cargill* and *Kilima* because they were prone to maize diseases (MSB) and did not resist MSV. A study by Kaliba et al. (2000b) showed that these maize varieties were produced in 1994 by the NMRP and were considered to be high yielding and to be resistant to MSV and MSB. According to Ward Officer 01, the maize types mentioned required extensive applications of fertilisers which is not common in the study area, were prone to maize diseases and were affected by the soil type (acidic) found in the area. The abandonment of these maize varieties may be because that increasing drought conditions favour the survival of MSB which would have a damaging effect on the maize crop (Kaliba et al., 1998).

6.3.3 Use of pesticides

Although improved maize varieties are believed to resist maize diseases, projected increases in temperature will favour the survival and proliferation of insects, pests and diseases which will require farmers to apply approved agrochemicals in managing the effect of diseases, pests and insects. Participants in the study area reported to have changed from the use of traditional herbicides to the use of industrial agrochemicals now more than in the past decades. The statement ranked fifth in the lowland, ninth in the highland and eighth among farmers who owned farms in both zones. During farm plot and transect walk observations, the study observed farmers in the fields applying agrochemicals and reported that many of the insect pests, fungi and diseases have become resistant to some of the traditional herbicides, thus they were obliged to resort to industrial agrochemicals for their effective pest and disease management (see Plate 6.20).

Plate 6.20 Application of pesticide in Kilomeni ward

However, evidence of the applications of agrochemicals was observed in the highland zones with none in the lowland zones despite the majority reporting using more pesticides now than in the past. Farm observations, interviews and focus group discussions revealed that the district has been experiencing prolonged drought conditions which have frequently led to crop failures which limit the application of agrochemicals. Even though the use of agrochemicals is considered to be beneficial and effective in the management of insects, pests and diseases, rainfall uncertainties and increases in drought conditions limit the effective use of agrochemicals. The lack of protective gear was also reported by one of the participants during focus group discussions in the highlands as a hindrance to the application of agrochemicals as farmers' feared health effects associated with the application of agrochemicals. Even though there is no evidence linking the use of agrochemicals to certain human diseases, exposure to agrochemicals may cause health effects thus the applications of agrochemicals may require the use of safety precautions during applications. However, the reported ineffectiveness of some of the local and indigenous herbicides may be caused by their continuous applications in every season.

In adapting to changing climatic conditions, farmers in the study area are managing the increase in maize diseases through growing improved maize varieties. According to District Official 01 and the Ward Officers, as well as evidence from the focus group discussions, it was clear that planting hybrid and other improved maize varieties has reduced the rate of maize diseases in the study area. The improved seeds are reported to resist most of the common maize diseases in the study area, such as leaf rust, purple leaf sheath and ear rot which affected both yields and the quality of the grain. However, diseases were reported to vary from one location to another, and also depended on the type of seeds planted and the weather conditions of the season. For example, during focus group discussions in the highlands, one of the participants reported that *masika* season has more crop diseases and insect-pests than *vuli* season. The respondent expounded further that even though improved seeds were resistant to diseases, they were more vulnerable to storage pests, whereas large stocks were destroyed even before they were removed from the fields. The most common pest that destroys maize grain, as reported by the participants, was the maize weevil, nicknamed as *scania* and other corn beetles.

The planting of hybrid and other exotic maize species, which thrive under moisture stress conditions, was reported to have increased maize harvests compared with harvests from local and indigenous maize varieties under harsh weather conditions. During focus group discussions both in the highland and lowland areas, it was revealed that shortened growing periods caused by a short rain season resulted in most of the indigenous maize varieties failing. Thus by growing hybrid and other improved exotic maize species farmers are assured of a bigger harvest. One of the participants in the focus group discussions in the highland areas reported that hybrid maize ears were filled with grain and there were no gaps between the kernels although the size of maize ear was small. Respondent MB15 said that if it happened that the season had sufficient rainfall and farmers planted improved seeds, referred to as *mbegu za kisasa* in Swahili, especially SEED-CO604, the chances of harvesting sufficient crops were higher than farmers who recycled maize seeds. The participant commented further that some of the hybrid seeds tolerate drought well.

6.3.4 Reduced farm size

Farmers are also adapting to the changing climatic conditions by reducing the size and number of plots cultivated in a given season. The statement on the number of plots cultivated ranked third among all groups with 82%, 96% and 82% of the overall cumulative scores respectively (see Tables 6.4, 6.5 and 6.6). The study revealed that farmers now cultivate smaller farm plots, but maximise plot use by planting different types of crops in the same farm plot simultaneously which increases the chances of reaping more on a smaller farm plot. Thus by reducing the size and number of plots cultivated, the household effectively invests resources and energy on a small area, ensuring effective land use that would otherwise not be utilised under monoculture system. During focus group discussions in the highlands, one of the participants said that:

"…people cultivate fewer farm plots and of smaller sizes because the moment one finishes weeding on one farm plot, the soil is already dry. Hence working on another farm plot increased soil moisture loss which affected crop growth leading wilting and drying up…"

The majority of the participants in the focus group discussions reported reducing the size and number of plots due to droughts and rainfall uncertainties which affected crop growth and yields. The group discussions confirmed that some farmers risked and cultivated larger farm areas with the expectations that if the conditions became favourable, they could reap enough for the family use and for the market. During farm and transect walk observations, it was rare to find a farm plot which was fully cultivated, and on those which were cultivated, farmers did not finish or never turned up for weeding mainly because of drought and loss of interest in farming due to rainfall variability (Plate 6.21). Respondent SF04 reported that some households allowed a portion of their farm plot to remain fallow for the purpose of collecting livestock fodder. However, farmers not only reduced the size of their plots due to drought conditions, but also because of shortage of labour at the household level and farm exhaustion cause by declining soil fertility, as reported by Respondent CH15.

Plate 6.21 Unweeded farm due to increasing drought conditions in Kisangara ward

Increases in temperature and decline in rainfall have made most of the lowland zone unfavourable for intensive agriculture activities. However, in the highlands, changes are attributed to the creation of more favourable and conducive conditions for the intensive cultivation of maize, beans sugarcane and bananas which were previously affected by cold conditions. For instance, the study shows that maize, which was only grown in the highlands during *vuli* season, is now grown in *masika* season as well. This trend has motivated farmers to open up new farm plots in the highland areas as well as undertaking intensive farming in the dual seasons (*masika* and *vuli*). During a focus group discussion, one of the participants reported that current changes in temperature now favour the growing of maize and beans in the previous coffee farms which was not the case in the past decade.

Another participant reported that maize was previously only grown in the lowlands during *masika* but changes in rainfall patterns, coupled with increasing temperature, has been taken as a positive step forward as the majority of farmers now concentrate more on highland farm plots in both seasons. Changes in weather conditions now favour the growing of maize in the highlands which has led to the abandonment of many lowland farms. Other remarks made during focus group discussions and oral history interviews suggested that maize planting in the highlands, particularly in Ngujini ward, started in 1975 and gradually it became successful and by the 1980s it was adopted by many villagers as a common practice. Nonetheless, participants noted that although the highland zones are not as dry as the lowland zones, increases in temperature and increased rainfall variability has exposed the highlands to harvest variations over the past two decades. The participants used the word *kushasha* in the local language which literally means ‘gleaning’ to express how little and uncertain the harvest has been in recent times when compared to previous decades.

6.3.5 Use of traditional weather forecast

As noted in the previous chapter, traditionally Pare farmers depended on the use of local methods of predicting weather conditions, particularly the commencement of the growing season and the onset of rainfall. The methods were more successful in the past when weather conditions were predictable and reliable, which enabled farmers to successfully manage farming activities. The statement on dependence on traditional weather predictions and indicators was ranked tenth in both highlands and lowlands and eleventh among farmers who owned farms in both zones with 37%, 34% and 26% of the overall cumulative scores respectively. During focus group discussions, households' interviews and oral histories, it was evident that the current climatic changes and weather variability have made most of the traditional weather predictions unreliable, hence reducing farmers' reliance on them and making them more dependent on modern weather forecasts made by Tanzania Meteorological Agency (TMA) via radios, television broadcast and newspapers. One of the participants in the focus group discussions in the highlands said:

"…Currently even if I see heavy rain clouds I never plant unless it has rained, the signs are currently misleading because they show good signs for rain but it does not rain. In the past heavy rain cloud was a reliable sign for the beginning of rain season and people would begin sowing seeds..."

Another participant was of the views that currently neither traditional nor modern weather forecasts were reliable. "…currently local environmental indicators and signs would indicate the commencing of the rainfall but it did not rain. Or it could be broadcasted that the season will have moderate to higher rainfall but the season ends by receiving low rainfall which is not sufficient for crop growth..."

6.3.6 Use of irrigation

The use of irrigation is a very important farming strategy in adapting to current changes in environmental conditions. However, irrigation activities in the study area ranked eleventh in both zones and seventh among farmers who owned farm plots in both zones with 29%, 27% and 57% of the overall cumulative scores. From the observations, most of the irrigation activities were undertaken along the rivers, streams and in few local and modern constructed water reservoirs. Households irrigated small plots of maize but most efforts were concentrated on vegetable gardens (see Plates 6.22 and 6.23).

Plate 6.22 Irrigation of vegetables and maize in Kisangara Wards

Plate 6.23 Horticulture at Kwalutu hamlet in Kisangara Ward

An interview with District Official 01 revealed that the district has an area of 5 605 hectares suitable for irrigation, but only 2 911 hectares are currently utilised (Table 6.9). However, irrigation activities have become seasonal, mostly along the streams and are typically carried out towards the end of the rain season. District Official 05 pointed out that irrigation schemes in Mwanga District have received greater attention from a number of funding organisations in collaboration with the District Agricultural Development Plans (DADPS) to improve and maintain irrigation activities. Some of the organisations include the Traditional Irrigation Programme (TIP), funded by the government of Netherlands, and the Mixed Farming Project (MIFIPRO), supported by the government of Belgium and other non-governmental organisations such as the Participatory Agricultural Development and Empowerment Project (PADEP). These organisations engaged with the local communities to rehabilitate, utilise and manage traditional irrigation infrastructures. For example, TIP constructed the largest irrigation water reservoir locally known as *ndiva* at Kwalutu hamlet in Kisangara Ward, but the project became bankrupt and could not accomplish its intended outcomes before PADEP took over and completed the project (Plate 6.24). PADEP is also involved in rehabilitating traditional water banks and open water distribution channels to ensure the availability and effective use of irrigation water through the constructed reservoir. The reservoir was aimed at enabling farmers in Kisangara village to irrigate their crops as a strategy towards managing increasing drought conditions. According to Respondent KS06, villagers irrigate their plots during the day on Monday, Wednesday, Friday and Saturday, while water is directed to the neighbouring sisal estate during the nights of Tuesday, Thursday and Sunday. However, further discussions with the farmers, and evidence from focus group discussions, revealed that current water shortages caused by extreme drought conditions, have challenged the project. Now, households who own farms close to the reservoir concentrate only on vegetables rather than perennial crops in order to allow more water allocation to the sisal estate. Shortage of water from the highlands has resulted in the reservoir not to being in full operation since its completion.

Table 6.9: Potential and currently irrigated areas in Mwanga District

Name of the scheme	Potential area for irrigation (ha)	Area under irrigation (ha)
Kirya	890	120
Kivulini	900	410
Kileo	600	380
Kituri	600	250
Butu	900	250
Kigonigoni	1,600	200
Total	5,490	1,610

Source: Mwanga District Profile 2012

Plate 6.24 Irrigation reservoir (*ndiva*) at Kwalutu area in Kisangara Ward

Focus group discussions and the interview with District Official 05, show that despite the existence of potential area for irrigation in the district (Table 6.9), increasing drought conditions leading to insufficient water, lack of proper-developed irrigation infrastructures, such as water reservoir and irrigation channels, as well as lack of efficient and organised irrigation management teams hinder the development and improvement of irrigation activities in the district. However, irrigation activities are aimed at improving and stabilising agricultural production, improving food security, increasing farmers' productivity and incomes, as well as producing higher value crops (see The United Republic of Tanzania National website http://www.tanzania.go.tz/agriculturef.html accessed on 04/07/2013). With the current increase in drought conditions, it is unlikely that the benefits of the irrigation will be achieved in the study area.

Participants have involved themselves in other non-agricultural activities as a means of increasing their resilience to climate change and weather variability. The statement on household involvement with non-agricultural activities is ranked first in the lowland zones, second among farmers who owned farms in both zones and seventh in the highlands, with 96%, 97% and 62% of the cumulative scores respectively. The findings show that due to an increase in drought conditions, the majority of the lowland farmers are involved more with non-agricultural activities.

6.4 The role of District Council in promoting agricultural adaptation strategies

Mwanga District Council (MDC) is very concerned about the effect of droughts undermining agricultural production, particularly maize production as the main staple food for the population in the district. The district has now started campaigns to promote the cultivation of drought-resilient crops to be undertaken by small-scale farmers as a substitute for maize which is affected by recurrent drought conditions. Such crops include sorghum, roots and tubes to be grown in the lowlands and emphasis on the cultivation of modern breeds of avocados, bananas and Irish potatoes in the highland zone. These crops flourish under low soil moisture conditions with moderate soil fertility and require only a minimum use of external farm inputs. The campaign is not only aimed at reducing dependence on maize, which is very susceptible to adverse weather conditions, but also at improving the livelihoods of small-scale farmers and revitalising the districts ailing economy District Official 07 was quoted as saying that:

"…the erratic natural of and changes in the rainfall pattern in the past two decades has made maize production a risky business. As a result the district depends on relief food all the time. Planting of drought tolerant crops will help to improve the livelihoods of the dwellers as well as the overall economy of the district..."

6.4.1 Promotion of sorghum production

According to District Official 07, the promotion of sorghum cultivation in the district is done under the programme of Development of a Robust Commercially Sustainable Sorghum for Multiple Uses (SMU) value chain in Tanzania and Kenya. The programme is coordinated by the district under the department of Research and Development (DRD), in collaboration with the Moshi-based Dunia Trust and the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) based in Nairobi. The project is funded by the International Fund for Agricultural Development (IFAD).
The aim of the programme is to transform small-scale farmers into commercial farmers. The Moshi based Dunia-Trust, in collaboration with INCRISALT, provided about 1.5 tonnes of sorghum seeds to the district, which were then distributed among those small-scale farmers who demonstrated a willingness to grow sorghum. Eight villages, namely Mbambua, Kisangara, Lembeni, Kwakoa, Kigonigoni Kiverenge, Kivisini and Kwanyange, together with Kiruru Prisons, benefited from the programme. Sorghum growers are assured of a ready market available in the brewing industries for the production of beer brewed from sorghum. However, according to the agreement between the farmers and the buyers, the Moshi Dunia-Trust will purchase sorghum grain from smallholders and sell it to a local brewing company, Serengeti Breweries Limited (SBL), and others depending on the nature of demand and supply. In a bid to enhance household incomes through sorghum production, the programme links farmers to other commercial buyers such as World Food Program (WFP), East African Breweries Limited (EABL), East African Malting Limited (EAML), Millers and various animal feed manufacturers.

Despite the plans aimed at introducing sorghum in the district as a realistic substitute for maize in those dry areas which are no longer suitable for maize production (Wiseman et al., 2010), the campaign did not prove to be successful in 2012 because of several challenges as reported by District officials and farmers.

Firstly, drought was cited as key problem in the implementation of the strategy. District Official 07 reported that the *masika* season of 2012 received low and variable rainfall that resulted in most of the sorghum planted both early and late failing due to extreme conditions (see Plate 6.25). Secondly, the study revealed that the project did not ensure the timely delivery of seeds. Observations and further discussions with those farmers who were willing to grow sorghum revealed that due to the delayed delivery of seeds some did not dare to plant as the seeds were delivered after the first rain. However, some of the early planted sorghum in Mbambua and Kigonigoni villages dried and although some survived, it did not yield well due to shortages in rainfall and a prolonged period of drought. Even though the literature suggests that sorghum thrives and give yields under harsh environmental conditions with minimum input management (Gerik et al., 2003), in reality its growth, development and yield are indeed affected by environmental stresses (water stress, rainfall variability and severe droughts) and poor management (Wiseman et al., 2010). Sorghum like any other crops responds to optimum growing conditions and proper timing of input management for maximum yield.

Plate 6.25 Wilting sorghum in Kisangara Ward

Thirdly, for the focus group discussions it was evident that some farmers were not willing to change their *status quo* and accept new farming strategies as most of them were reluctant to accept new ideas. The study revealed that there is the perception that sorghum grain is inferior and useful only during famines, hence is not on the local people’s usual “food menu”. Participants reported that they are not accustomed to eating sorghum and considered the crop to be eaten by poor people with limited food options together with low purchasing power. Although sorghum offers the potential to contribute to the economic uplift of the district, due to its multipurpose uses (consumption and industrial), the farmers did not consider it as a main food crop to be grown in their farms. The main problem for sorghum is that, unlike maize which is consumed at different stages of its growth, which helps in the management of food security in the household, participants felt that growing sorghum could be a barrier in food security as it cannot be consumed in that way.

A comment made during focus group discussions by one of the participants that: *mtama wethishotwa* (in the local language) meaning ‘sorghum cannot be grilled’ (as you do to green maize). The participants view were also ascertained from personal communication with District Officer 01 who said that households in the study area have developed specific food preferences (maize and beans) and are not willing to stop growing maize, although the crop is not drought-resistant, for crops which are drought resistant. Even though maize was not performing well due to periodic droughts and rainfall fluctuations, households still did not stop growing it. It has been observed elsewhere that different groups and individuals in the community have different preferences about adaptation measures, depending on their worldviews, values and beliefs, hence their difference, in understanding can be a challenge for adaptive actions (Adger et al., 2007). A study by Grothmann and Patt (2005) showed the difference that exist between the perceived abilities to adapt and observable capabilities to adapt. The study suggested that the lack of farmers not taking action was not due to the lack of means, but due to the lack of adaptation intention and limited confidence that their own action would keep them from harm. Thus the divergence between perceived and actual adaptive capacity is a real barrier to adaptive action (Adger et al., 2007).

Fourthly, participants reported that the idea of growing sorghum for commercial purposes was good, but was limited by shortages of land and sizes of farm plots caused by the subdivision of the farms into uneconomically small units. Many plots were also reported to be scattered in different locations which makes them economically unviable as farmers cannot reap substantial benefits from growing sorghum on such small plots.

Respondent MB19 said that:

“…the government has to reduce the area under sisal cultivation and allocate more land for farming. It has always been the case that we raise this every time with our parliament representative but it has never been considered. The plots are not even sufficient for growing maize, then they are suggesting that we use them for growing sorghum for commercial purpose. This is impossible…”

Fifthly, sorghum is vulnerable to vermin attack, especially birds which challenges the growing of sorghum. For instance, households in Mbambua village experienced significant bird damage to their sorghum. This was also observed during farm visits where most of the sorghum had been damaged by birds. Respondent MB17 reported that the type of the sorghum proposed by the project was highly preferred by birds and the damage was significant because unfortunately farmers did not have effective skills in dealing with the birds’ invasion on such a large scale. Their tactics of covering sorghum with plastic bags, paper, rag clothes and scare-crows, as a means to deter birds from causing damage to sorghum grains had only a very minimal effect and did not prove to be successful as much of the sorghum grains were still damaged by birds (Plate 6.26). Participants in the focus group discussions reported that the project had promised to provide repellent sprays to repel the birds by making the grain unpleasant to birds thus allowing the sorghum to ripen. Nevertheless, the promise was not actualised, and more than 80% of the sorghum was damaged by birds. Another proposition made was that of exterminating migratory birds; however this was seen to be contradictory to the principles of wild life management and conservation. Clearly, there was lack of research done to identify the most appropriate variety of sorghum which could be accepted by the farmers, thrive well in the given environmental conditions and also meet various market needs.

Plate 6.26 Damaged sorghum grains by birds and some covered with plastic bags and rags against birds' damage in Kisangara Ward

Farm fragmentation was also reported to be a in the management of birds. Many participants reported owning from two to six plots in different locations. However, only a few plots were grown with sorghum, hence birds had limited farm plot options to feed. One participant reported:

"…if all of the plots could be planted with sorghum, it could be easy for the management of birds. However, just a few farm plots are grown and are scattered in different locations which makes it very difficult for managing the influx of birds…"

The participant reported owning five plots which, he suggested, if all of them were to be planted with sorghum, it would require five people to chase birds which is not possible, and if he did not turn up all sorghum could be damaged by birds.

A similar issue of vermin in the adoption of a agricultural adaptation strategy was reported in the highlands. Participants reported that they were advised to grow cassava and potatoes but they were not told how they could manage vermin which were already a problem.

This argument was put by Respondent SF07 who said:

"…they tell us that we have to grow cassava and potatoes but they do not tell us how to manage vermin such as wild pigs, baboons and mole rats which are already a problem in our area…"

Another participant during focus group discussions said:

"…I asked the ward agricultural officer how I can control mole rats, but he said we do not have to kill them because they help in mixing up the soil which helps in improving soil conditions and development…"

Sixth, participants reported being discouraged by sorghum prices that had been set by Moshi-based Dunia Trust, buyers of sorghum from the farmers to supply to SBL and other brewery plants. During the focus group discussions, it was argued that the market price for one kilogramme of sorghum grain was Tsh 1500/= (~£0.60) which was more than three times the price that had been proposed by the Moshi-based Dunia Trust of Tsh 450/= (~£0.18), per kg. Low prices discouraged small-scale farmers and they claimed that they were exploited by poor prices offered compared to that in the market. Farmers in Kwakoa and few in Kisangara wards consequently refused to take the sorghum project seeds for planting. Farmers, however, were willing to purchase their own seeds, so that they could sell produce at the prevailing market price.

According to the Ward Official KW 03:

"…the idea of growing sorghum is good but the conditions that have been provided to the farmers discourage them from growing the crop... although they are assured of the market, the price set which is half that of the free market discourages them… and this is exploitation of the farmer…"

Finally, there was lack of education about growing drought-resilient crops, as the study witnessed much debate in various parts of the study area as smallholders continued to be reluctant to grow sorghum, arguing that the amount of rain (soil moisture) that sorghum requires to flourish is more or less the same as for maize production. There is a need to increase awareness and advocacy in helping farmers to understand what they need to cultivate to enhance productivity and food security, rather than cling to maize cultivation which is adversely affected by periodic droughts, making the households experience food insecurity and increasing their dependence on food aid.

6.4.2 Promotion of root and tuber crops

The MDC is also promoting the production of roots and tubers crops which form an important source of food and cash for many small-scale holders in Tanzania (see Legg et al., 2011; Mkamillo and Jeremiah, 2005). The most popular ones include Irish potatoes and cassava. In Mwanga District, Irish potatoes flourish in the highlands, but production is still low and done only for subsistence. In promoting the production of Irish potatoes among the small-scale farmers in the highland areas, the district introduced and distributed improved varieties from Uyole Agricultural

Research Institute (UARI) in Mbeya region. In November 2011, selected small-scale farmers in Ngujini, Chanjale, Songoa, Kilomeni, Sofe, Mangio, Mwaniko, Mriti, Ndorwe, Mshewa, Vuagha and Kironganya received potato seeds on condition that every recipient after the first harvest should give back the same amount received in order for every household to benefits from the improved seeds.

Cassava is another root crop that MDC is promoting to be grown both in the highland and lowland zones. The advantage of promoting cassava production in Mwanga District is that the crop is drought-tolerant, flourishes under low soil fertility and in marginal lands and reduces soil and wind erosion. Furthermore the crop can ensure food security and income when sold as a cash crop. Cassava is cultivated in the lowland plains, especially in Lembeni and Kigonigoni wards, and also in the highland areas, but only on a small scale. During focus group discussions, particularly in the highlands, it was revealed that cassava is ideal for vegetables because fresh root consumption is not advisable for human use due to toxins associated with the plant. The consumption of cassava was reported during focus group discussions to have caused several deaths in the past (in the highlands) which resulted in its cultivation being stopped, unlike in the lowlands where the roots and leaves are consumed without fear of causing deaths. Discussions revealed that fresh roots of cassava, especially those cultivated in the highland zones, contained a higher content of linamarin (cyanogenic glucosides) which can cause death if the roots are consumed without effective detoxification (see also FAO, 1990; Chiwona-Karltun et al., 2002; Gleadow et al., 2009). Cassava production is geared towards improving the food insecurity situation amplified by inadequate rainfall affecting maize production in the district. The fact that cassava is a high temperature-tolerant plant with low soil moisture requirements, as well as being resistant to pest and diseases due to its higher contents of linamarin, makes it an ideal crop for Mwanga District, with its increasingly drier conditions.

The cassava production campaign is championed by the Department of Research and Development (DRD) under the Ministry of Agriculture, Food Security and Cooperatives (MAFC), in collaboration with the Root and Tuber Crops Research Program (RTCRP) centres based in Tengeru in Arusha region and Naliendele in Mtwara region. The dual agriculture research centres identify high yielding improved varieties, resistant to diseases, early maturing and suitable for growing in both highland and lowland areas. It is worth mentioning that cassava is also susceptible to diseases and pests, such as the cassava mosaic diseases caused by the East African Cassava Mosaic Virus (EACMV) (spread by whiteflies called *Bemisia tabaci* Genn (sweet potato whitefly)), and cassava mealy bug (CMB), cassava green mite (CGM), cassava bacterial blight (CBB) and nematodes (Fauquet and Fargette, 1990; Maruthi et al., 2005; Legg et al., 2011; Ntawuruhunga and Legg, 2007; Ogwok et al., 2010; Legg and Thresh, 2000; Mkamillo and Jeremiah, 2005). According to District Official 07, the research centres also identify suitable disease and pest control measures and develop best practice for cassava production including post-harvest processing and detoxification so as to create safe food product.

However, some primary measures to start the campaign have begun with the identification of the local sweet cassava variety known as *Kibandameno*. The type has been adopted because it is preferred by local farmers, perceived to be high yielding and tasty. The cassava cuts for *Kibandameno* seedlings are raised in a nursery farm in Kigonigoni ward where the cutting is done for subsequent distribution to the cassava growers.

6.4.3 Avocado farming

In the course of improving the household incomes, the MDC is also promoting a fruit culture based on avocado, particularly in the highlands, where an investor from Arusha-Building Africa has agreed to support avocado (*Persea americana*) production in the district. The avocado growers will be provided with early maturing avocado seedlings from Tengeru Horticultural Research Institute in Arusha which take three years from planting to harvesting of fruits. Accordingly to District Official 07, the investor will be one of the major buyers of avocados produced by farmers for input to meet cosmetics production. The growing of avocado trees will promote a green economy by preventing soil erosion, enhancing water infiltration, shielding crops against wind and heavy rainfall effect, improving the micro-climate, and benefiting dwellers from the trees' aesthetic value and carbon sequestration and storage (Eldridge and Greene, 1994). Growing avocado trees also reduces the risk of losses during drought, floods and landslides, as trees are reported to be more resilient to such weather conditions than other crops (Charles et al., 2013; Ulsrud et al., 2008). The Ward Officer 01 reported to be expecting 2,000 avocado seedlings to arrive in October, 2012. The beneficiaries had already been identified and preliminary preparations like the excavation of holes and adding of manure ready for planting had started. However, each beneficiary who had registered for the seedlings was required to pay Tsh 500/= (~£0.20) per seedling upon receiving the seedlings as administration fees. This discouraged poorer farmers even though they were willing to grow more avocados. Clearly, poverty affects farmers' decisions in adapting and coping with a given strategy towards adapting to changing environmental conditions.

6.5 Conclusion

The chapter makes a contribution to current debates on the knowledge surrounding effective agricultural adaptation strategies in coping with weather variability and climate change. The chapter suggests that, over generations, small-scale rural farmers have been adapting to natural climatic changes which proved to be successful through their traditional farming practices. However, with the current climate changes and variability, rural farmers are obliged to change and improve their farming strategies in order to cope with the new emerging conditions. The major changes made by farmers which are discussed in this chapter include changes in planting dates, use of hybrid and other improved varieties as opposed to local types, practising irrigation and adopting mixed cropping strategies. The study has also shown that farmers adapt to the changing conditions through increasing dependence of indigenous crops such as yams, sweet potatoes and bananas. Through agricultural diversification strategies, rural farmers have been able to cope with the changing conditions and hence reduce their vulnerability to the changes.

However, the important question, as far as this research is concerned, is whether or not the adaptation strategies being implemented in the study area are effective in helping small-scale rural farmers to cope with, and adapt to climate change and to attain sustainable livelihood. The effectiveness of the adaptation strategies and the limitations encountered are the issues discussed in the next chapter.

Chapter 7

Challenges Facing Small-scale Farmers in Adapting to Climate Change

7.1. Introduction

This chapter presents the major challenges encountered by small-scale farmers in Tanzania in the processes of managing farming activities under changing climatic conditions and variability. (Adger et al., 2007) define limits to adaptation as the conditions or factors that render adaptation ineffective as a response to climate change. According to Adger et al. (2007) these limits are dependent upon the values of diverse groups and are closely linked to the rate and magnitude of climate change as well as associated key vulnerabilities, and they categorise these factors into physical and ecological limits, technological limits, financial barriers, information and cognitive barriers, as well as social and cultural barriers. Generally, limitations and barriers to climate change are grouped here into two major categories; those related to physical and environmental factors and those related to institutional arrangements (Table 7.1).

The frequencies and percentages of each factor were determined through the Likert scale score from strongly agree, agree, not sure, disagree and strongly disagree. Table 7.2 displays the total scores and percentages of the cumulative score of the responses obtained from each of the 12 statements. The score of the perception was calculated by summing all the scores for each factor, where the maximum score on any given factor is 5; and from the 234 respondents the maximum possible score is 1 170 points (234 multiplied by 5); the top factor summed to 1 131 points, accounting for 96.7% of the maximum score (Table 7.2). The same procedure was used to obtain the scores for the highland (Table 7.3) and lowland zones (Table 7.4), and the overall scores from each factor were ranked from the highest score to the lowest (Table 7.5).

Table 7.1: Limiting factors to climate change adaptation in Mwanga District

Factor	Perceived and observed condition	Remarks
A. Physical and Environmental factors		
• Climate variability	Drought, increase in temperature, erratic rainfall, wilting of crops	Major problem
• Soil fertility	Crops failure, erosion, stunted crop growth, change in crop colour, Low crop yields	Major problem
• Pests and diseases	locusts, beetles, whiteflies, aphids,	Major problem
• Destructive animals and birds	Baboon, black monkey, wild pig, birds, mole rate	Medium problem
B. Institutional arrangements		
• Insufficiency and untimely delivery of agricultural inputs	Delayed supply of Improved seeds and Fertilisers	Major problem
• Low financial capacity at different levels	Limited use of improved seeds Limited use of industrial pesticides Limited maintenance and development of irrigation schemes	Major problem
• Top-down strategy	Lack of participation of local community at the designing and planning stage	Medium problem
• Unreliable weather forecast information	Unreliable information on the expected amount of rainfall and starting time	Major problem
• Poor agronomic practices	Zero tillage, hand hoe, unimproved seeds, limited use of fertilisers and organic manure	Major problem
• Lack of education on climate adaptation mechanisms	Lack of training on adaption farming methods	Major problem
• Emphasis of modern farming methods at the expense of traditional practices	Lack of incorporating traditional farming practices with modern technology	Major problem

Table 7.2: Cumulative score for each perception

Factor	Score	Cumulative score of the responses (%)
Climate variability (drought, increase in temperature and erratic rainfall)	**1 131.0**	**96.7**
Insufficiency and untimely delivery of agricultural inputs	**1 061.0**	**90.7**
Low financial capacity at different levels	**1 038.0**	**88.7**
Top-down strategies	**1 030.0**	**88.0**
Pests, crop diseases and vermin	**1 009.0**	**86.2**
Unreliable weather forecast information	**1 007.0**	**86.1**
Soil fertility	**1 003.0**	**85.7**
Poor agronomic practises	**984.0**	**84.1**
Lack of education on climate change adaptation mechanisms	**934.1**	**79.8**
Increasing cases of human diseases (Malaria and HIV/AIDS)	**924.0**	**79.0**
Emphasis on modern farming methods at the expense of traditional practices	**657.2**	**56.2**
Migration of the youth to other areas	**473.4**	**40.5**

Note: Total number of respondents (N) = 234

Maximum score for any one factor = 1170

Table 7.3: Cumulative score for each perception in the Highlands

Factor	Score	Cumulative score of the responses (%)
Climate variability (drought, increase in temperature and erratic rainfall)	**562.0**	**96.1**
Insufficiency and untimely delivery of agricultural inputs	**557.0**	**95.2**
Low financial capacity at different levels	**557.0**	**95.2**
Top-down strategies	**547.0**	**93.5**
Pests, crop diseases and vermin	**516.0**	**88.5**
Unreliable weather forecast information	**510.0**	**87.2**
Soil fertility	**493.0**	**84.3**
Poor agronomic practises	**482.0**	**82.4**
Lack of education on climate change adaptation mechanisms	**456.0**	**78.0**
Increasing cases of human diseases (Malaria and HIV/AIDS)	**424.1**	**72.5**
Emphasis on modern farming methods at the expense of traditional practices	**326.2**	**55.8**
Migration of the youth to other areas	**261.4**	**44.7**

Note: Total number of respondents (N) = 117

Maximum score = 585

Table 7.4: Cumulative score for each perception in the Lowlands

Factor	Score	Cumulative score of the responses (%)
Climate variability (drought, increase in temperature and erratic rainfall)	**569.0**	**97.3**
Insufficiency and untimely delivery of agricultural inputs	**525.0**	**89.7**
Low financial capacity at different levels	**522.0**	**89.2**
Top-down strategies	**520.0**	**88.9**
Pests, crop diseases and vermin	**514.0**	**87.9**
Unreliable weather forecast information	**510.0**	**87.2**
Soil fertility	**491.1**	**83.9**
Poor agronomic practises	**468.0**	**80.0**
Lack of education on climate change adaptation mechanisms	**452.1**	**77.3**
Increasing cases of human diseases (Malaria and HIV/AIDS)	**446.0**	**76.2**
Emphasis on modern farming methods at the expense of traditional practices	**331.2**	**56.6**
Migration of the youth to other areas	**212.4**	**36.3**

Note: Total number of respondents (N) = 117

Maximum score = 585

Table 7.5: Ranking from the Cumulative score of the responses

Factor	Ranks		
	Overall	Highland	Lowland
Climate variability (drought, increase in temperature and erratic rainfall)	**1**	**1**	**1**
Insufficiency and untimely delivery of agricultural inputs	**2**	**4**	**5**
Low financial capacity at different levels	**3**	**5**	**3**
Top-down strategies	**4**	**6**	**4**
Pests, crop diseases and vermin	**5**	**3**	**9**
Unreliable weather forecast information	**6**	**8**	**2**
Soil fertility	**7**	**2**	**10**
Poor agronomic practises	**8**	**7**	**7**
Lack of education on climate change adaptation mechanisms	**9**	**10**	**6**
Increasing cases of human diseases (Malaria and HIV/AIDS)	**10**	**9**	**8**
Emphasis on modern farming methods at the expense of traditional practices	**11**	**11**	**11**
Migration of the youth to other areas	**12**	**12**	**12**

7.2. Physical environmental factors

7.2.1 Climatic variability

The study shows that farmers are aware of the limits and barriers that affect their adaptive capacity to deal with the current changing climatic conditions. The majority of the participants perceived that climate variability was the major physical barrier in farming activities and for the implementation of adaptation strategies. This factor was ranked first both in the lowland and highland zones (see Table 7.5), with 97% in the overall cumulative score of the responses (see Table 7.2), and about 96% in the highlands (Table 7.3) and 97% in the lowland zone (Table 7.4). About 83% of the responses (195 participants) strongly agreed with this statement. However, in determining farmers' perceptions on climate variability as a barrier to agricultural adaptation, variables such as drought, increase in temperature and erratic rainfall were used. Both lowland and highland zone farmers were of the view that drought conditions have increased and were now the major barrier to many of the agricultural adaptation strategies that are currently being implemented. Studies conducted in other parts of Africa on farmers' perceptions contend that drought is perceived to be the major factor limiting most adaptation strategies (Juana et al., 2013).

Respondent KS01 commented:

“…even though farmers grow improved seeds and other drought and heat tolerant crops, nonetheless prolonged periods of sunshine, insufficient rainfall and rainfall variability has resulted in most of the drought and heat tolerant and resistant crops withering and drying out. Even crops like sorghum, which is drought resist and tolerant to drought and high temperature, failed in this year due to poor rainfall and prolonged drought conditions…“Drought limits everything” concluded the respondent.

A similar sentiment was made by respondent MB15:

“…every crop requires a certain amount of rainfall and to soil moisture to survive and grow to maturity, but due to low rainfall with prolonged periods of sunshine, it is surprising to see that even sorghum, which is said to resist drought, could not resist drought conditions in this season. Something must be done…”

Meanwhile, during focus group discussions in Kisangara ward, one of the participants reported that due to increased drought conditions, it has become easier for the termites to feed on cassava, leaving most of the lowland farms bare. Cassava and sorghum are among the drought resistant crops which are been introduced in the study area to cope with changes in climatic conditions. However, increasing drought conditions are threatening their success.

Both highland and lowland farmers perceived that increasing drought conditions are associated with rising in temperatures in both the cold and hot seasons. During focus group discussions, lowland participants reported that temperature and sun intensity have substantially increased over the past twenty years. In explaining this situation, one participant commented: *jua limekuwa kali sana na linachoma mno kama limesogea chini kidogo,* meaning that “the sun has become so hot and is burning so much as if it has moved a little bit closer to the earth”.

Participants shared common views that days are very hot, to the extent that they influence night temperatures, as explained by Respondent KS05:

“…during the day temperatures are high which also makes night temperatures remain higher until mid-night…”

Respondent KS04 said:

“…drought has increased such that from July until October, all crops and grasses are dry and trees shed their leaves with the exception of the evergreen *Mwarubaini* [*Azadirachta indica*]…”

Even though *Azadirachta indica* trees tolerate drought and can keep the area green throughout the year, as dry seasons are reported to become even windier and dustier, only a few are planted around the houses, with even fewer on the farms and then only for marking plot demarcation. Focus group discussions suggested that the tree species use most of the soil nutrients making the soil unproductive and so limiting crops growth.

Drought was so intense at the time the field work that most of the crops, especially in the lowland areas, withered before they had reached their flowering stage, while in the highland areas, crops were in a better condition but were still also affected by limited rainfall and increasing drought conditions. More than two-thirds of the observed farm plots showed wilting conditions; however, this figure was closer to 100% in the lowland zones (see Table 7.6). Soil cracks were mostly evident along the dried wetlands, while crop failure was clearly evident in both zones.

Table 7.6 Evidence of drought conditions from farm observations

Evidence	Overall n = 50		Highland (n = 25)		Lowland (n = 25)	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
Wilting of crops	33	66	8	32	25	100
Soil cracks	25	50	10	40	15	60
Crop failure	48	96	23	92	25	100
Poor crop yields	50	100	25	100	25	100
Stunted crops growth	50	100	25	100	25	100
Extent of weed on the farm	50	100	25	100	25	100
Dried springs and streams	31	62	22	88	9	36
Surface sheet erosion	20	40	18	72	2	8
Dried wetlands and ponds	19	38	11	44	8	32
Sedimentations	2	4	1	4	1	4

7.2.2 Irrigation activities

During focus group discussions, one of the participants mentioned that increasing drought conditions and erratic rainfall have affected most of the traditional and modern irrigation activities that had been developed in the study area as an adaptation strategy. According to Ikeno (2011), historically traditional irrigation activities in the study area (North Pare) date back to the 1880s and depend on sufficient rainfall being received in both rainfall seasons (*masika and vuli*). Irrigation was practised during those seasons when rainfall was below average and during the dry seasons (June to September and December to February). The major sources of water for irrigation are from small rivers and streams originating in the highlands. The research witnessed failed and abandoned modern and traditional irrigation schemes, both in the lowland and highland areas due to an insufficient water supply (see Plates 7.1, 7.2 and 7.3).

Plate: 7.1 Underutilised irrigation reservoir at Kwalutu hamlet in Kisangara ward

Plate: 7.2 Abandoned irrigation reservoir at Kwalutu hamlet in Kisangara ward

Plate: 7.3 Abandoned traditional irrigation reservoir at Ngujini ward

Plate 7.4 Traditional irrigation channel in Ngujini ward

As discussed in Chapter Four, participants during focus group discussions in the lowland zone argued that due to more frequent drought conditions, many springs and streams flowing from the highlands have dried up, while others have become only seasonal flows during and immediately after rain, but no longer flow continuously. This has made many rivers flowing from the highlands to the lowland zone to have insufficient water for irrigation activities (see Plate 7.5).

Respondent KS05 reported:

"…rivers used to have flowing water all the year round and the volume declined only towards the end of the dry season in August to October and water increased again as *vuli* rain starts in October.

But since the 1990s, most rivers have started to dry and now there are just a few flows during the rain seasons, depending on the amount of rainfall received..."

Observation found a large number of dried rivers and insufficient water flow from the rivers and streams originating from the highland zones. This was reflected in the observations where-by all 22 streams and springs recorded showed low water flow from the highlands to the lowland zones which was just within the middle (April) of the masika rainfall season (see Plates 7.5 and 7.6, which were taken on 11 April 2012 at Kwalutu and Dindimo hamlets respectively) while most of the rivers in the lowland zone had dried completely. Increasing drought conditions had led to the drying of the wetlands where 19 cases of dried wetlands were observed (see Plate 7.7, which was taken in June 2012).

Plate 7.5 Low volume of water in Ngujini river

Plate 7.6 Declining water flow in the stream in the highlands

Plate 7.7 Shrinking wetland at Kisanjuni in Ugweno ward

Some dwellers in the lowlands excavate ditches along the river channels to access water for livestock, brick work and irrigation of vegetables. However, this was reported to last only for a short while, and ditches were abandoned as drought conditions increased, due to a decline in the ground water table. Respondent KS04 said that:

"…before drought conditions had increased in recent years, irrigation was done by rotation where farmers would irrigate crops twice in a week. Water was sufficient to do this and soil remained damp for longer. But due to the increase in drought conditions and prolonged hours of sunshine, two days per week seems to leave too long period between irrigation because water evaporates quickly leaving the soil dry. Irrigation in the morning can be dry by afternoon and there are still three days to pass before irrigating the crops again. In the meantime, the crops are stressed by prolonged hours of sunshine, forcing them to produce flowers at a very young stage of growth resulting in poor yields…"

An interview with respondent KS06, who practised irrigation farming, confirmed that increasing drought conditions affected the quality and quantity of the crop yield as crops are forced to ripe prematurely which reduces the amount for both household food and for sale. Hence, due to increasing drought conditions farmers are forced to harvest crops, especially beans, early before they become too dry (see Plate 7.8) and the quality becomes poor and unsuitable for consumption and for sale. Early harvesting was also reported to be practised by highland dwellers as a means of avoiding the effect of drought on crops. However, early harvesting is also practised by many of the small-scale farmers as a strategy for coping with food shortages in the household as well as the source for earning cash income. As explained by respondent KS11:

"…I harvest some of the crops early before they dry to meet food shortages because nowadays the harvest from the previous season does not last until the next harvest. But currently I harvest much of the beans now before it dries, because if left until it dries, the quality becomes poor…"

Plate 7.8 Extraction of beans from the bean pods before drying

However, participants reported that the increase in drought conditions has led to the abandonment of many of the traditional irrigation activities in the highland areas. Ironically, heavy rainfall events have also caused damage to much of the traditional irrigation infrastructure. Heavy rainfall erodes traditional water reservoirs (*ndiva)* and irrigation furrows, and filled the reservoirs and furrows with sediment. The study observed abandoned water reservoirs (see Plates 7.1, 7.2 and 7.3) and also others some of the reservoirs which were filled with sediment by heavy rainfall. Some of the reservoirs had now been planted with crops such as yams, sugarcane and banana plants while some of the irrigation furrows were now covered with soil and grasses, and others had been turned to pedestrian paths.

However, the reduction of the indigenous traditional irrigation activities in the study area is not only caused by changing environmental conditions but also by other factors. Evidence suggests other possible factors such as the increasing involvement of young people in non-agricultural activities, which has deprived traditional irrigation farming of a labour force for the construction and maintenance of traditional irrigation infrastructures. Many young people get involved in more profitable activities such as quarrying, collection of sand and the manufacturing of bricks. Moreover, the knowledge and skills for building and maintaining traditional irrigation structures (*ndiva* and irrigation furrows) is now retained by only a few members of the Pare clan called *Warutu*, the majority of whom are elderly and no longer participate in farming activities. The limited involvement of elders in farming activities and involvement of youth in non-agricultural activities threatens the performance of indigenous traditional irrigation activities in the study area.

According to respondent CH16 in Chanjale village:

"…hand hoe farming was effective in the past when rain was sufficient, land was fertile and irrigation was possible in seasons with poor rains, but at current hand hoe farming kills... you cultivate by using all of your energy but end up with nothing or harvesting very little. The harvest does not worth the energy spent in cultivating the land…"

This argument also justifies why the majority of the youth are losing interest in farming activities under current changing climatic conditions which lead to poor performance in agriculture.

Traditional irrigation activity is also threatened by the increased concentration of farming activities close to the river banks and in the wetlands. The study observed farming activities and vegetable gardening concentrated close to the river banks and along the wetlands in many of the highland areas (see Plates 7.9 and 7.10). Cultivating along the water courses and wetlands exposes water sources to direct sun light which may result in increased evaporation and also drying of the water courses. A similar case of over-cultivation around the water sources has been observed in Lushoto district by Kaswamila and Tenge (1997).

Plate 7.9 Crops (cocoyam) grown on the drying wetland in Usangi ward

Plate 7.10 Crops (bean, maize and cocoyam) grown in the dried wetland

Increasing rates of deforestation from logging and forest fires is another threat to traditional irrigation activities. Participants in the highland areas suggested that increasing cases of logging and forest fires have reduced the density of the Kindoroko Forest Reserve, hence exposing the water catchment to direct sunlight leading to increased evaporation. This has caused a decline in the volume of running water in many of the springs and streams that originate from this forest. Although the government of Tanzania recognises irrigation farming as one of the strategies for agriculture development and a move towards reduced dependence on rain-fed farming (URT, 2001), and the World Summit identifies the importance of promoting agriculture through integrated water resource management (Jonch-Clause, 2004), increasing drought conditions places these plans in jeopardy.

7.2.3 Effect of wind

Participants throughout the study area perceived an increase in wind conditions and reported its effect on crop growth and productivity. They also considered it to be a barrier to climate change adaptation. Participants both in the lowlands and highlands reported that in recent years they have noticed that both rainy seasons (*vuli* and *masika*) are associated with strong winds which affected crop productivity. It was reported that winds blew crop flowers (especially beans), caused damage to crops, such as maize and banana plants, and made soils dry quickly by reducing soil moisture. A specific effect of wind was raised in the highlands during a focus group discussion where one participant commented that, due to current changes in the beginning of the rainfall season especially in *vuli* season, crop flowering (especially for beans) now coincides with the occurrence of winds in mid-December. This is reported to affect bean productivity because many of the flowers are blown away by wind; also the conditions accelerate a reduction in soil moisture leaving behind dry soils. Another participant reported that on many occasions rainfall has been associated with strong winds which cause damage to banana plants as many of them are weak after surviving in a prolonged period of drought from June to October. Hence, they cannot withstand strong winds. Bananas are among the major crops grown in the highlands and support livelihoods as a source of both food and cash income.

7.2.4 Effect of insect pests, vermin and crop diseases

Another physical environmental challenge for the implementation of agricultural adaptation strategies is that of insect pests, vermin and crop diseases. This factor was ranked fifth in the overall score (Table 7.5) with 86% of the cumulative score of the responses (Table 7.2), and ranked third in the highlands with 95% of the cumulative score of the responses (Table 7.3), and ninth in the lowlands (Table 7.5) with 77% of the cumulative score of the responses (Table 7.4). About 154 (66%) responses strongly agreed with this factor. The assessment of insect pests, diseases and vermin was based on farmers' perceptions and observations on the presence of insects on the farm plots, as well as their damaging effects on crops. The increase in the number of insect pests and vermin was most commonly reported in the highland zone and was also evident during transect walks and farm plot observations. This was more evident in the highlands, where drought conditions were less severe than in the lowland zones, and crops were in better condition generally than in the lowlands. Participants reported that they have experienced an increase in the population of insect pests which cause damage especially to the early planted crops. Table 7.7 represents the most common insect pests and crop diseases in the study area. Beans weevils (*Laprosema indica*) also known as *Nasheve* (in the local language) and maize stock borer (*Buseola fusca*) were observed on all farms, with almost 100% cases occurring in the highland zones, followed by grasshopper, blister beetles (*Epicanite nyasseasis*), also known as *mbariti* (in the local language), aphids and white flies (Table 7.7). More cases of maize spider were observed to occur in the lowland zones.

Table 7.7: Observed insects and crop diseases in the study area

Name	Overall		Highland		Lowland	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
Bean weevils	43	86	25	100	18	72
Grasshoppers	40	80	24	96	16	64
Maize bore	32	64	25	100	7	28
Blister beetles	30	60	25	100	5	20
Aphids	20	40	16	64	4	16
White flies	19	38	8	32	11	44
Maize spider	12	24	5	20	7	28

Farmers applied local pesticides, but they did not prove to be very effective. This was evident from farm observations where pests and insects still continued to cause damage to the crops even after the application of pesticides. Interestingly, during focus group discussions it was revealed that some of the households mixed industrial agrochemicals with locally prepared pesticides. The common practise is that of mixing wood ash with industrial pesticides, or mixing wood ash with paraffin oil (kerosene), while others applied only wood ash to the affected crops. The reasons given as to why farmers mixed wood ash with industrial pests include the lack of proper equipment for the application of pesticides; hence by mixing pesticides with ash ensures effective applications of the pesticides and reduced wastage. The technique reduced the possibility of applying excess amounts of pesticides to the crops which could damage them, and, lastly, it is possible to use small amount of pesticides on many farm plots as possible because through mixing, the amount increased.

Limited application of pesticides and increased use of inefficient pesticides raises an interesting suggestion that not only the warming conditions from the changing weather and climate contribute to the growth of insect pests and crop diseases, but other factors, such as the non-use or only limited application of agrochemicals, inappropriate timing in their application and incorrect measurements may also contribute to the proliferation in the population size of insect pests and crop diseases. The repeated growing of the same type of crops on the same plot of land in every season (for instance, maize and beans) may have also contributed to insect pests and crop diseases to developing resistance to the applied agrochemicals. However, many researchers suggest that changes in climatic variables (especially increases in average temperature, changes in precipitation patterns, increase in drought conditions and water shortages) are expected to favour the increase and proliferation of the population size of pests, insects, crop diseases and weeds, and also to aid the expansion of their geographical range or damage niches (Parmesan, 2006; McDonald et al., 2009; Prospero et al., 2009). Evidence from the literature suggests that the increase and spread of needle blight in British Columbia was caused by the increase of local summer rainfall which is associated with changes in climatic conditions (Woods et al., 2005). Similarly, a study by Mitchell et al. (2003) suggested that an increase in fungal pathogen load in grassland communities was a response to climate changes events, such as rising levels of $CO_{2,}$ declining plant diversity and increased nitrogen deposition. These evidences provide a clue of the types of responses that might occur from insect pests as the result of changes in climatic variables, especially increases in temperature. Thus increases in insects and crop diseases may affect farmers' ability to adapt to climate change due to abject poverty and limited application of industrial agrochemicals, as well as the ineffectiveness of the locally derived pesticides and herbicides. The expected expansion in the geographical range of insect pests and crop diseases will be an issue for adaptation because farmers may have only a limited knowledge of the management of the alien species. Additionally, farmers' vulnerability will increase due to the absence of local environmental predators which could naturally control the population of the alien species.

However, due to the limited application of pesticides and the increasing damaging effect of insect pests, planting of replacement crops for those damaged by pests is done immediately on the arrival of the next rain. However, this is now seen to be problematic due to less rainfall with greater variability within the growing season. Replanting is also considered to be expensive because the majority of the farmers have only limited purchasing power and cannot afford to buy improved seeds more than once in a season. It is important to note that the early grown seed varieties are the best and the only seeds available for growing in that season. Hence farmers plant unimproved or less expensive seed varieties as the replacement which affects crop productivity.

Participants also reported the increasing damaging effect of vermin as an important barrier in adapting to changing climatic conditions. Although there was no direct evidence to support the increase in the population of vermin, there is some evidence from the household interviews and perceptions of the participants to support this argument. Focus group discussions and household interviews suggested that increasing drought conditions have affected the productivity of wild fruits, making vermin experience food shortages, which in turn has resulted in them searching for food on the farm plots. Although participants reported that it was not new for the vermin to feed on the crops, they asserted that the rate has increased in recent years compared to the past. One participant mentioned that some of the vermin, such as wild pigs, baboons and birds, feed on planted seeds even before they have properly germinated. He explained further that most of these vermin are now living close to farms. From the discussion, it was clear that due to increased drought conditions, many farm plots now remain fallow or are not cultivated in full, and such fallow plots surrounding the cultivated farms provide hiding places for vermin, further encouraging vermin to live much closer to the few cultivated farm areas. The vermin that are common in the study area, and whose populations were said to have increased and caused more destruction to crops, include vervet monkey, black monkey, baboon, birds (red-billed quelea), mole rat, squirrels and wild pigs (Table 7.8).

Table 7.8: Types of vermin observed in the study area

Name	Overall		Highland		Lowland	
	Freq.	%	Freq	%	Freq	%
Mole rat	18	72	15	60	3	12
Black monkey	11	44	11	44	0	0
Vervet monkey	10	40	4	16	6	24
Birds	8	32	0	0	8	32
Baboon	8	32	3	12	5	20

The mole rat has the highest cases (60%) and mostly occurring in the highlands (see Table 7.8 and Plate 7.11). Mole rats cause damage mainly to tuber and root crops, potentially potatoes and cassava, which are among the most drought resistant crops proposed by the District Agricultural and Livestock department. However, mole rats are now reported to be feeding also on shoots of banana plants and sugarcane. The growing population of mole rats is hence threatening highland livelihoods which depend mostly on these crops for food scarcity and cash income. One of the participants explained that the population of mole rats was naturally controlled by heavy and prolonged rainfall seasons, when many mole rats died from drowning because their burrows filled with water and most of them failed to escape to the surface in time. Also, through traditional irrigation farming, farmers controlled the population of mole rats by filling their burrows with water during irrigation, but in current years the method is less effective due to short and moderate rainfall which has also resulted in the reduction of traditional irrigation farming. However, the Ward Officer KW03 and District Official 01 reported that there are chemical tablets which can be used to manage mole rats, called phostoxin, but they are expensive and dangerous especially when they are not handled well or if they contaminate human food. Their application needs professional and trained operators. Hence they have not yet introduced these chemicals to rural farmers because of their concerns on the health and safety issues. Transect walk and farm observations suggest that the application of chemicals in the management of mole rats is difficult and may be very dangerous to farmers because the same farm plot growing banana plants is mixed with potatoes, cocoyam and sugarcane. The damaging effect of birds was observed more in the lowland zones, especially in those plots where farmers had grown sorghum. On the other hand, farmers in the study area have limited financial capacity and lack proper knowledge and information on how to manage insect pests, crop diseases and vermin, hence the current and expected increase in the population of insect pests and crop diseases may limit farmers' ability to adapt to the changing conditions.

Plate 7.11 Mole mounds at Msangeni village in Ugweno ward

7.2.5 Soil fertility

Soil fertility is another physical environmental limiting factor in farming activities and a barrier in the implementation of agricultural adaptation strategies. This factor was ranked seventh in the overall score, second in the highlands and tenth in the lowlands (see Table 7.5), with 86% of the cumulative responses (Table 7.2). The majority (about 60%, equivalent to 141 participants, the majority in the highlands) strongly agreed with this factor. From the focus group discussions and interviews, it was evident that smallholder farmers in the study area understood factors that are responsible for the declining trends in soil fertility and the associated impacts on yields and food security, as they were able to report the major factors that have contributed to the declining soil fertility on their farms (see also Mowo et al., 2006). One of the participants reported that most of the plots have been cultivated for generations without sufficient addition of manure or fertilisers but depended on natural soil nutrient regeneration, specifically from plot fallowing and decaying crop remains and grass left on the farm during farm clearing. However, increases in population have reduced land availability for farming, hence farm plots are increasingly cultivated without fallowing. This has resulted in the rapid loss of soil nutrients, declining crop yields and increased environmental degradation in the highlands. The removal of crop remains and grass from the farm as livestock folder has also contributed to the depletion of soil nutrients. This was explained by Respondent CH12:

"…farmers in the highlands practise mixed farming, drought has reduced the availability of animal fodder, hence crop remains and grass which were formally left on the farm, are now collected as fodder which result to most of the farms to remain bare and with no additional of soil nutrients…"

According to Respondent ML38:

"…in the past, some households burned grass and shrubs mostly on fallow farms during farm clearing but in recent years there is nothing or very little to burn on the fallowed farms because most of the grass is collected as fodder…"

However, farm observations witnessed only a limited burning of grass on the farms. As shown in Table 7.9, only 7 cases equivalent to 28%, were observed and most of these were from the highlands, especially in Kilomeni ward.

According to District Official 03:

"…the declining soil fertility especially on the highland farms is exacerbated by steep slopes where most of the top fertile soil is eroded by rain, leaving behind poorer soils with low levels of soil nutrients. The rate of erosion increases as farmers cultivate on the steep slopes without well maintained terraces. Also, the majority of the farmers do not have the culture of using manure nor fertilisers which has resulted to higher reduction of soil nutrients…"

The decline of soil fertility, especially in the highland farms, was also evident through transect walks and farm observations where crops showed signs of mineral deficiency due to insufficient soil nutrients. The evidence through the observation of crop leaves, colour, growth, flowering and yield rates indicated that crops in some areas experienced stunted growth, poor yields and which had leaves turned yellowish, purplish and reddish, signs of deficiency in or low availability of minerals nutrients in the soil. Such nutrients include nitrate ions (NO_3), phosphate ions (PO_4), potassium (K_+) and magnesium ions (Mg_{2+}) (see Plates 7.12, 7.13 and 7.14). However, poor crop development and yields may also be caused by increasing drought conditions, limited use of improved seeds and increased rainfall variability.

Plate 7.12 Changes of crop leaves colour due to low soil nutrients at Chanjale village in Ngujini ward

Plate 7.13 Stunted and wilting crops at Chanjale village in Ngujini ward

Plate 7.14 Poor crop yields at Chanjale village in Ngujini ward

Observations also showed that there was only a limited use of terrace farming as a means of reducing soil erosion and of retaining rainwater in the soil, as well as only a limited application of organic manure to increase soil nutrients. Participants during focus group discussions and household interviews reported that the use of modern terrace techniques was highly labour-intensive and is mostly men's work. With fewer younger men engaging in farming, this is now a problem because older farmers are less likely to adopt soil conservation practices because of their shorter planning horizons (see also Maddison, 2007).

Respondent ML39 reported that:

"…the majority avoid building stone terraces because the method involves the removal of the fertile top soil layer which has developed over generations leaving behind a less fertile soil which demands intensive application of organic manure and fertiliser…"

There are also appeared to be a limited use of organic manure and fertilisers to improve soil fertility. As discussed in the previous chapter that application of organic manure was only applied on farm plots near to their homes, while more distant plots are not applied with manure due to difficulties involved in transporting manure to these distant plots. The major limiting factors were insufficiency of the manure and long distance from the home to the farm. Interestingly, participants in the focus group discussions reported that due to increasing drought conditions, application of fertilisers would damage their crops due to low soil moisture. One of the participants said: "…how can one apply industrial fertilisers on such dry farms? Will not this just waste money but also time and end up burning the crops…" Another participant reported that farmers believed that once industrial fertilisers were applied to the farm, soils would become barren and hence would require continuous use in every season. This is believed by most of the highland farmers when responding to the question whether they were using more the industrial fertilisers now than in the past.

On the other hand, the lowland farmers did not consider their soil to be unfertile, although they admitted that the use of manure and industrial fertilisers was important. However, they did report that drought was the major natural limiting factor for the farming activities. Other authors also consider the declining soil fertility and loss of topsoil through erosion to be a threat to agriculture production and sustainability, especially in Sub-Saharan countries (Mowo et al., 2006; Sanchez, 2002). Changing climatic conditions, coupled with erratic rainfall concentrated in few days or months in the seasons, would require higher applications of soil moisture conservation management, especially in the highland areas, in order to reduce loss of soil nutrients through soil erosion. However, the limited use of soil moisture conservation measures results in a loss of volumes of rainwater through run-off and soil evaporation which affect crop yields. A study conducted by Mwalley and Rockström (2003) showed that a combination of land mismanagement and the intensity of tropical rainfall, an average of 70 to 85% of rainfall drains off the land without contributing to crop growth.

7.3. Institutional arrangements

Institutions also play important role in the implementation of the agricultural adaptation strategies and hence they may as well be a barrier in the implementation of different adaptation strategies. This subsection attempts to understand households' perceptions on the role of institutions in the implementation of adaptation strategies, and. seven factors were considered.

7.3.1 Insufficiency and unavailability of farming inputs

Insufficiency and untimely delivery of agricultural inputs is one of the institutional factors considered in this study. This factor was ranked second in the overall score (Table 7.5) with 91% of the cumulative score of the responses (Table 7.2), and about 65% (151 participants) of the responses strongly agreeing to this factor; it was ranked fourth in the highlands and fifth in the lowlands (see Table 7.5). Participants during interviews and focus group discussions reported to be receiving farming inputs especially, seeds and fertilisers, from the government through the district agricultural office and from NGOs such as the Red Cross/red crescent and religious organisations (e.g. Pentecost Church and CARITAS). However, participants claimed that they were delivered late and were not sufficient to cater for their demand for seeds. According to MS21:

"…if farming inputs, especially improved seeds, could be delivered early enough before the rain season started, it would help in adapting to the changing conditions which require crops to be planted with the first rain…"

Participants both in the lowlands and highlands reported during focus group discussions that delayed delivery and insufficiency of seeds made households use seeds bought from the market and other unauthorised dealers, while others recycled seeds for the previous harvested. They also explained that some of the seeds had low germination rate, and such views were also supported by District Official 01:

"…due to the delayed delivery of seeds farmers buy and plant any type of seeds available in the shops or market which in a way contributes to a poor crop harvest. Some of these seeds have already expired. However, the district authority is working very closely with the Ministry of Agriculture, Food Security and Cooperatives to make sure that farming inputs are delivered in time to ensure that they are distributed to the farmers earlier…"

However, Respondent CH14 said that because of limited purchasing power, she cannot afford to buy enough of the improved seeds in every season, so she carefully sorts the best maize after harvest and preserves them for planting in the following season. She added that sometimes she has to borrow maize from a neighbour who had planted improved seed and had had good harvest. As the planting season approached, the farmer bought a few kilogrammes of improved seeds, and mixed these with locally prepared maize seeds which ensured enough seeds for planting in all of her farm plots (see Plates 7.15 and 7.16).

The growing of traditionally selected seed varieties from previous maize harvests has also been reported among the small-scale farmers in places such as Zimbabwe (the Shona) (see Mapara, 2009: 150) and in Honduras (Hintze et al., 2003: 17). However, evidence from the literature shows that a poor availability of quality seeds and their higher price is indeed an impediment to the growing of new maize varieties (Maddison, 2007; Chauhan et al., 2002) and use of inorganic fertiliser for maize production (Kaliba et al., 2000a). This sets a barrier in adapting to climate change as farmers cannot implement the right strategy in coping with the changing conditions.

Plate 7.15 Traditional maize seed preservation

Plate 7.16 Local maize seeds preparation

The interview with District Official 01 and evidence from the report on the amount of inputs received in the district from the Department of Agriculture and Livestock Development office (DALDO) confirmed that the number of vouchers received under the country's agricultural development strategy, *Kilimo kwanza* in Swahili (Agriculture First), were not sufficient, and even more disappointing is that the number has been decreasing. From the report, the district received 4,812 vouchers for the 2011/2012 farming season, which was 48.2% less than the amount of vouchers received in the previous year 2010/2011 which was 9,288. The district has a total number of 22,683 household farmers which means for the amount of vouchers received only 4,812 households benefited, leaving 17,871 household without access to improved seeds and fertilisers.

This suggests that limited resources at the national level contributes to poor harvests, and hence food insecurity, because the majority of small-scale farmers have only a low purchasing power and cannot afford to pay for the farming inputs and implements such as improved seeds, pesticides, fertilisers and tractors. Studies show that the government has a great role in the implementation, promotion, encouragement, and facilitation of the adaptation process (Ishaya and Abaje, 2008). Hence where certain governmental institutional features are not coordinated properly, then government can also be an impediment to adaptation capacity (Maddison, 2007). ICRISAT (2006) found that despite the availability of improved varieties and massive investments in seed multiplication and distribution, formal seed supply systems have failed to ensure that farmers have access to sufficient high quality seed.

7.3.2 Limited purchasing power

Low financial capacity at different levels, coupled with inadequate finances for the purchase of farming inputs is another barrier in adapting to climate change which was ranked third in the overall scores (Table 7.2), and fifth in the highlands and third in the lowlands (see Table 7.5). The majority of the participants, about 65% (151 participants) strongly agreed with this factor. During focus group discussions in the lowlands at Kisangara, one of the participants said that they had no access to bank loans because they lacked collateral. The respondent reported further that some farmers had made attempts to apply for bank loans using their farm plots and houses as collateral, but they were told that because the location of their houses and land was in the rural area and had low value, it could not be used as collateral or security in acquiring a bank loan. In addition, it was explained further that the only few households living within Mwanga town were allowed to use their houses and farm plots as collateral in accessing bank loans, as they are located within the commercial area in Mwanga town. On the other hand, one of the participants during focus group discussions said he would not dare take a loan to invest in agriculture due to the fear of losing the collateral (house and or land) due to weather uncertainties, but would consider taking a loan to invest in other non-agricultural activities (business). He explained further that: "…if I were to take a loan from a bank and buy a tractor, expecting that people would hire it during farm preparation, this would be a very risky business because of drought risks and very few households using a tractor during farm preparations…"

Similarly, the lack of funds for constructing and maintaining irrigation infrastructure was evident in the lowlands, especially in Kisangara Despite the construction of irrigation reservoirs, as observed in area (e.g. Kwalutu hamlet), many farmers were still using open traditional irrigation channels in directing water to the farm which leads to inefficient water use, as much of the water is wasted along the way before it reaches the farms. This has confined irrigation activities just within the reservoir vicinity and distant farms are not irrigated.

According to District Official 03:

"…there are not enough funds allocated for maintaining the existing irrigation infrastructure as well as constructing new ones. Most of the existing irrigation schemes in the district have been constructed under donor-funded projects. But currently they are underutilised because after the project finishes, it is the responsibility of the beneficiaries to manage theme, but the majority are poor and cannot afford to maintain the facilities. Also increasing drought conditions discourage all of their efforts…"

Further remarks also were made by District Official 04:

"…the major reason for poor agricultural performance is the lack of farming implements, inputs and limited benefits accrued from small-scale agricultural farming. Financial institutions lack confidence in agriculture because the agriculture practised is not for commercial purposes to tell the truth; it is for subsistence based on business as usual (*kilimo cha mazoea*) and largely dependent on rainfall. This makes financial institutions hesitate and hence they are reluctant to give loans to farmers due to the fear that in the case of poor rains farmers will not harvest sufficiently to meet their food demands and for business, which may make them fail to recover the loan. The solution is to change agriculture from not continuing to depend on the hand hoe. This could even boost the confidence of financial institutions in lending money to farmers for they could be assured of the loans' recovery…"

Although irrigation activities reduced dependency on rain-fed farming, they require large investment capital which the majority of the smallholders and subsistence farmers cannot afford. However, inefficiency of irrigation activities in the area is not only caused by the lack of funds, but also is influenced by the lack of effective leadership and policies on the utilisation of the available irrigation facilities in the area. One of the participants reported that there was no effective leadership in overseeing the operation and maintenance of the reservoirs, and suggested that there exist conflicts between farmers in the highlands and lowlands and also with the neighbouring sisal estate on the use of water from the Ngujini River. The conflict is reported to have increased due to the declining water volume in the river which sets a barrier in effective irrigation activities. As the water volume in the river declines, farmers are not allowed to use water for irrigation as it is needed in the sisal factory.

An interview with the Sisal Estate Official and District Official 05 confirmed the existing conflicting interests on the use of water in the area.

According to the Sisal Estate Official:

"…Water along the Ngujini River is protected by the law which restricts its use to the sisal estate only, and hence irrigation is allowed only when water is sufficient. As levels of running water in the river decline, farmers are strictly speaking not allowed to use any water from the river for irrigation. The Chanjale/Mringeni River is tapped and distributed for domestic uses for both highland and lowland dwellers, but due to increasing drought conditions the remaining water in the river after tapping for domestic use is not sufficient for irrigation…"

Hence under current climate changing conditions, there are calls for the need to amend water use policy in the area, with a high priority being put on effective irrigation strategies.

Some of the literature on agriculture adaptation to climate change shows that limited and inadequate access to inputs is exacerbated by limited access to credit, as well as the expensive nature of adaptation measures, such as the construction and maintenance of irrigation infrastructure, purchase of improved seed varieties, use of fertilisers, insecticides, herbicides and fungicides (Juana et al., 2013; Acquah, 2011; Nhemachena and Hassan, 2007). Deressa et al. (2008) show that there is a positive relationship between the level of adaptation and the availability of credit. Farmers who have access to credit have higher adaptive capacity than those with only limited or no access to credits (Pattanayak et al., 2003).

7.3.4 Top-down planning strategy

Most of the adaptation strategies in the study area adopted a top-down planning strategy. The lack of involvement of farmers in decision making especially in the design of agricultural coping and adaptation strategies is further a barrier in managing farming activities under changing climatic conditions in the study area. This statement was ranked 4th in the overall cumulative score of the responses (Table 7.2), but sixth in the highlands and fourth in the lowlands (Table 7.5). Participants during focus group discussions and household interviews in both zones argued that many of the agricultural adaptation strategies were top-down and did not consider the local community's demands, perceptions or preferences. For example, during focus group discussions in the lowland area, one of the participants said:

"…they tell us that we have to grow sorghum which is a bird and chicken food…we are not birds…"

Another participant in the highland area said:

"…some of the seeds grow to be very tall but end up with limited yields. We need experts to do research first and know which types of seeds can perform well, given the type of soil and environmental conditions. Some of the seeds that grow well in the lowlands might not fit in the highland zone…"

The respondent suggested that less was known about their soils and environmental conditions hence some of the strategies sounded good, but their implementation was not unsuccessful due to an incompatibility with the local conditions.

Respondent MB20 said:

"…we are only told that experts (visitors) from the district crops and livestock department are coming to the area to educate farmers on how to manage farming activities under current changing conditions, so we gather and listen to them. But during the meeting they just report to us the already agreed strategies. They normally do not come to seek ideas but they come to implement the already decided strategy. We fail to know if this is from the government or is someone else's project to help him or her to earn money by using our name…"

From the discussions, it was evident that neglecting the beneficiaries (local farmers) in designing the adaptation strategies resulted in the rejection or limited support for the implementation of a given adaptation strategy by the beneficiaries. This was evident in places such as Kisangara and Ngullu wards where the majority of the farmers did not agree to grow sorghum which is a suggested crop as an alternative to maize. Farmers refused to grow sorghum on their farm plots, despite the area being earmarked by the district authority for the cultivation of sorghum as a drought-resistant crop. Even though sorghum seeds were issued freely, aiming at attracting many households to grow the crop, still the majority did not perceive the growing of sorghum to be the best strategy for them. The apparent unwillingness of farmers to change and adapt to new farming strategies set another barrier in adapting to changing climatic conditions. Although the non-involvement of the households in decision making in the design of the appropriate adaptation strategies was important, other factors may have also contributed to the limited level of acceptance. For instance the growing of sorghum as discussed in Chapter Six offers the best example of top-down strategies.

Such top-down rural development approach have been criticized for adopting a centralist view of development and assuming that the development activities of rural people respond only to externally-initiated change (see Briggs, 1985). An alternative approaches, that takes into consideration and makes effective use of knowledge and experiences of the local people in identifying their priorities and motivations, and hence incorporates local inhabitants in the planning as well as in the implementation stages of development projects has been proposed. The approach is termed as development from below as it suggests that development should proceed *with* the people to be affected rather than *for* them (Briggs, 1985: 170).

7.3.4 Lack of reliable weather information

A lack of reliable weather forecast information especially on the amount of rainfall expected in the season is another challenge affecting adaptation strategies in the study area. This factor was ranked sixth in the overall scores, eighth in the highlands and second in the lowlands (Table 7.5). Information guides the types of crops to grow and the amount of investment to be made in farming. The majority of the respondents suggested that they were disappointed by information broadcast via radio and television. The information given is too general covering the whole region, whereas, farmers needed a more place specific information. The lack of information on climatic change characteristics is a common barrier to agricultural adaptation to climate change throughout Africa (Deressa et al., 2008; Ziervogel and Calder, 2003; Ziervogel et al., 2010; Mukheibir and Ziervogel, 2007). Studies by Ziervogel and Calder (2003) and Archer et al. (2007), conducted in southern Africa, pointed out the weakness of the weather forecast information that it did not specifically target vulnerable groups and was often not tailored to suit them in content and delivery. According to Ziervogel and Calder (2003), most of the forecast information is probabilistic and not a definitive prediction of what the season would be like, and therefore should be used as a guide only (Gandure et al., 2013).

7.3.5 Use of cheap agronomic methods

Use of cheap and poor agronomic methods and practices was also considered to be a problem. Although participants claimed to have adopted more improved farming methods and practices, transect walk and farm observations showed that there was only a limited use of improved farming methods. For example, there was limited use of organic manure, limited soil tillage, an increased use of inappropriate pesticides in managing insect pests and treating crop diseases and the use of mixed cropping without proper crop spacing and selection (see Table 7.9).

Table 7.9: Observed agronomic farming practices in Mwanga District by zone

Type of practice	Overall (n = 50)		Highland (n = 25)		Lowland (n = 25)	
	Freq.	%	Freq.	%	Freq.	%
Random planting	49	98	25	100.0	24	94.0
Hand hoe	47	94	25	100.0	22	88.0
Mixed cropping	48	96	25	100.0	23	92.0
Inefficient pesticides	23	46	23	92.0	0	00.0
Zero tillage	27	54	12	48.0	15	60.0
Use of unimproved seeds	16	32	10	40.0	6	24.0
Traditional irrigation	16	32	4	16.0	12	48.0
Limited crops rotation	19	38	11	44.0	8	32.0
Burning	7	14	7	28.0	0	0.0

As Table 7.9 shows, the use of cheap agronomic practice was more dominant in the highlands than the lowland zone. Physical landscape may contribute to the use of certain method such as the increased use of random planting, or mixed cropping may be favoured more in the highlands, while the use of tractor and irrigation facilities are more favoured in the lowlands. Highland farmers have limited access to the market which reduces their incentive to utilise modern technologies. Three major factors contribute to this: higher prices for the agricultural inputs; poor transport facilities in accessing the market; and limited access to extension services. Small-scale highland farmers have limited incomes, thus they cannot afford to pay the higher prices for improved seed varieties and pesticides. Thus they resort to the use of cheaper but less efficient local inputs. Highland farmers have limited access to the market partly due to inefficient transport facilities and poor infrastructure which leads to higher transport costs. A study by Maddison (2007) hypothesises that, as distances to output and input markets increase, adaptation to climate change decreases. Thus, closeness to the market is thought to be an important determinant of adaptation, most probably because the market serves as the means of exchanging information with other farmers (Deressa et al., 2008). Lastly, the limited access to agricultural extension services, which was reported during focus group discussions, is also contributing to the increasing concentration of poor agronomic practices in both zones. Extension services are critical in the provision of information that could change farming activities from subsistence farming to modern and commercial farming, thus improving households' food security, increasing income and reducing poverty. As hypothesised by Gbetibouo (2009: 21) "…access to extension services is positively related to adoption of new technologies by exposing farmers to new information and technical skills…".

7.3.6 Limited adaptation knowledge and skills

Lack of education about climate change adaptation mechanisms is another barrier to climate change adaptation. Respondents KS02 and KW24 shared similar sentiments that there was limited contact with the ward extension officer due to increasing drought conditions which discouraged extension officers from visiting the farmers on the farms themselves. Focus group discussions showed that farmers were only told that improved seeds and fertilisers (vouchers) at subsidised prices are available at the shop of selected agent for collection, but there were no instructions on where certain type of seeds could be grown or at which stage of maize growth it was convenient to apply fertilisers. Participants explained that seeds grown in the lowlands are the as those grow in the highlands. Another participant reported that there was no guidance from the extension services but everyone did what s/he thought was correct. Highland farmers felt that less is known about the types of maize that can perform better on their farms because there was no research that had been conducted to identify such types. One participant explained that due to a lack of proper information on soil types and weather conditions, some of the seeds grown have not been performing well despite them been referred to as improved seeds. The participant explained that some of the maize seeds planted keep on elongating upward and do not give substantial yields, while others produce flowers at a height of a metre or less resulting in low yields. Lack of training and limited access to agricultural extension services for the dissemination of knowledge, technologies and agricultural information reduced the ability of farmers to keep pace with adaptations to changing climatic conditions. This raises an important policy issue concerning the role of agricultural services to current changing climatic conditions. According to Deressa et al. (2008), education is considered to improve the ability of farmers to adapt to climate change as it increases the level of access to information, new technologies and improved production methods.

7.3.7 Abandonment of traditional farming knowledge and practices

Traditional farming knowledge and practices are not intergrated into the modern farming technology. This may be a limiting factor in the implementation of agricultural climatic adaptation strategies. Some people argued that through the use of modern farming technology, most of the valued traditional environmental farming practices, which were useful and helped small-scale farmers to survive through difficult weather conditions, have been abandoned. Participants gave some of the examples, such as neglecting traditional local beliefs which prohibit farming activities along the water catchment areas or in some of the valued traditional forest reserves called *mbungi* (in the local language), by naming them to be sacred and resting places of their gods and hence used for worship and other traditional rituals and practices. This belief was reported to help in conserving forest biodiversity, hence in protecting water catchment sources. The introduction of modern religions (particularly Christianity and Islam) has challenged such traditional beliefs and taboos making them been ignored and regarded to be superstition and as practices belonging to black ages (see also Gyampoh et al., 2009). This was reported to have led to the clearing of *mbungi* resulting to the loss of forest biodiversity, and drying of catchments which originated from the *mbungi*. This argument was supported by the sentiment made by Respondent CH13 that:

"…clouds used to gather on top of the *mbungi* which increased rainfall intensity, but today clouds have nowhere to stand because all of the trees have been chopped down and these areas are now open and used for farming activities, and others have been built with churches, schools and dispensaries …."

The lack of incorporating local farming methods with modern technology is said to have resulted in the disappearance of some of the most valued local maize and bean species, commonly referred to as *mwasu* (in the local language). Farmers have been repeatedly told to stop growing traditional maize species and to grow improved varieties. This is reported to have resulted in the abandonment, and hence disappearance, of some of the most valued local maize and bean species. Some of the *mwasu* maize and bean varieties had better yields, even more than some of the improved varieties, especially when weather conditions were favourable. In addition, participants explained that the local varieties resisted most of the common storage pests which most of the improved seeds are not capable of. Another participant pointed out that improved maize varieties are seen to lack taste, flavour and smell when eaten as *ugali* (Swahili name for the food made from maize flour), and another commented that nowadays one has to add spices such as lemon, salt and chilli powder to the roasted maize, for the maize to taste better. Without these spices, the maize tastes flat in the mouth.

The idea that some of the valued local species have disappeared due to the use of modern farming methods and practices, was supported by District Official 05:

"…the fact that modern methods have proved to be successful and superior to local traditional and environmental knowledge and practices, has made most farmers abandon even those farming practices which could prove to be successful under current conditions... most of the good practices are now lost because they were not used, this includes the use of traditional crop species. In addition, local methods are not considered in the development of adaptation strategies because there is no research that has shown their efficiency and success in farming activities…"

A study conducted by Gyampoh et al. (2009) suggested that local traditional knowledge could provide the basis for development of more effective adaptation strategies. Another study, by Bellon (1995), which was conducted among the Chiapas maize farmers in Mexico, showed that small-scale farmers were willing to combine both traditional and modern technology in their farming activities. Thus there is a view that the traditional knowledge can be used to complement modern farming technology rather than be seen as a competitor (DeWalt, 1994; Briggs, 2005). In other instances the combination of traditional and modern technology has been challenged by Critchley et al. (1994: 297) who made self-evident (but nevertheless useful) point that, ‘if IK and ISWC [indigenous soil and water conservation] were truly effective, there would not be the problems of food shortages and land degradation that are evident today”. However, the authors hypothesised two underpinning potential considerations of the ISWC; that much can be learned from ISWC: systems, and that ISWC can often act as the most suitable starting point for the development of appropriate and suitable technologies and programmes.

Despite traditional farming methods being practised throughout the study area, participants during focus group discussions and household interviews reported that most of these methods are no longer relevant and now farming should use modern farming practices. One participant during focus group discussions said:

“…we now farm by using modern technology more than using traditional, traditional farming was done in the past by our forefathers how had not received formal education…”

While comparing past farming tools with the present tools, the participant said that:

“…traditional farming involved the use of crude farming tools and technologies which are not applicable in the modern days farming…”

Respondent KW25 said that:

“…Whoever practises traditional farming today does not want to harvest and is wasting his or her time… in current farming you must prepare your plots before planting and you must make sure that you plant improved seeds and where necessary apply manure or fertilisers otherwise you will harvest very little or nothing completely…”

Another participant ascertained that:

“…the current changes in weather conditions associated with low rainfall and changes in living conditions where now people live modern life do not favour true traditional farming methods and practices. Therefore, there is an increase in the use of modern farming methods than the use of local methods and practises...”

Inaddition, there could be also a lack of confidence among farmers on the use of their own local farming knowledge, even if they are still using it in their farming activities. A study conducted by Briggs (2005, 99) in Coastal Region in Tanzania quoted a local farmer saying: “if indigenous knowledge is so good, why is my farm so poor?” The farmer also considered adopting modern farming methods if he could afford them. Similarly, a study by Briggs and Moyo (2012) in Malawi suggested that even though indigenous knowledge has been used for decades as a means of raising production, for the majority of rural people in Africa, it can only be described as disappointing at best. This is so because the knowledge has not been capable of rising to the challenge of increased food production, and ultimately the economic transformation of rural livelihoods in Africa. Production has continued to remain low despite the continued use of the local farming knowledge.

7.4. Conclusion

The findings of the study set out some very important factors which have clear implications for rural farming in adapting to changing climatic conditions. Despite the increased investments on irrigation projects and provision of improved maize seed varieties which survive under low soil moisture conditions and tolerate high temperatures a progressive decline in rainfall, increasing drought and windy conditions set a barrier in a successful implementation of agricultural adaptation strategies under current climatic changes. The findings reveal further that declining rates of soil fertility due to limited replacement of soil nutrients, increase in the population of vermin, insect pests and crops diseases also set a barrier in farming activities as well as adaptation strategies. However, some of these factor although accelerated by unprecedented changing climatic conditions they are also influenced by human activities such the use of crude and poor agronomic farming practices such as use of improper pesticides in the treatment of diseases and limited use of soil conservation measures.

Similarly the findings also revealed that non-environmental factors have a stake in limiting implementation of appropriate agricultural adaptation strategies. Such factors include lack of funds, limited agricultural extension services, delayed delivery and insufficiency as well as limited accessibility to farming implements and inputs, and farm fragmentation are among of the non-environmental factors which limited farming activities under changing weather and climatic conditions. The results revealed further that although migration depraved farming activities with usefully labour force for the implementation of adaptation strategies, but participants did not consider it as a major problem rather as a useful tool for supporting life in the affected area through remittance as well as a means for securing employment opportunities which are not available in the study area.

The results however, revealed a limited involvement of rural farmers in deciding the appropriate strategies which could reflect local need by considering beneficiaries perceptions and priorities in farming activities. The strategies and plans were top-down and involved farmers only at implementation stage. This may be contributing to a limited acceptance on the implementation of a given agricultural adaptation strategy by households as they felt that the strategy did not reflect their needs and perceptions hence it did not belong to them. The study suggests that for a successful implementation of adaptation strategies, small-scale rural farmers should be involved in the identification of the strategies which may make it easier for its implementation rather than imposing strategies to them. Also the findings have also shown that farmers have limited access to the require information on weather conditions (expected amount of rainfall and the starting dates for rainfall). Information on weather conditions is important as it could guide farmers on the type of crops to grow and how much they have to invest in agriculture depending on the expected weather conditions. Education could help in accessing adaptation technologies thus improve their adaptive capacity and increase their resilience to climate change through implementing proper adaptation strategies that could lead to higher productivity.

Chapter 8

Conclusions

The findings from this study show that the changes in climate and environmental conditions are happening in the study area and are affecting agricultural livelihoods. Participants showed an extensive knowledge and understanding of their local environmental conditions, and they were able to attest to the environmental changes that they perceived to have occurred over the past two decades, and associated them with climate change. The majority of the participants about 77% associated the causes of the changing climatic conditions with an increase in environmental degradation, deforestation, forest fires, and the expansion and intensification of agriculture activities; only about 23% of the participants perceived environmental changes as being due to socio-cultural and religious factors. These findings on farmers' perceptions on climate change are also evident in the literature (IPCC, 2007; 2014)

Most participants understood and associated the impacts of climate change with increases in drought conditions, rise in temperatures, decline in rainfall, occurrence of floods, increased rainfall variability, greater weather unpredictability, increases in pests and deaths of livestock caused by diseases and shortages of fodder. Participants perceived the local impacts of climate change as shortened growing seasons, changes in the duration and commencement of the rainfall season, increased crop failures, food shortages and increases in the occurrence of extreme weather events, such as drought and floods. Most participants in the study area perceived that temperature has increased and rainfall has decreased over the past two decades. They observed an increase in day temperatures, reflected by an increase in the intensity of sunshine and higher night temperatures, decline in rainfall and increased rainfall variability, accompanied by changes in the seasons. Participants' views and perceptions of the changing environmental conditions were confirmed by evidence from rainfall and temperature data obtained from local weather stations in the study area and regional rainfall and temperature data obtained from the Tanzania Meteorological Agency (TMA), which all indicated that the area has been experiencing increased fluctuations of both rainfall and temperature in the past 30 years. Similarly, the findings on the perceptions of the farmers on the changes in rainfall and temperature, and the associated physical impacts of climate change, are similar to the other findings in climate change literature (Parry, 2007; Rosenzweig et al., 2001; Collier et al., 2008; Hulme et al., 2001; Deressa et al., 2009). The IPCC 2007 reported an increase of 0.74°C of the global temperature near the surface of the earth from 1906 to 2005 and also estimated the likely increase of about 6.4°C on average during the 21st century. However, the IPCC (2014) report shows that the global average land and sea surface temperature data combined has increased by 0.85°C making the previous three decades the warmest period in the last 1,400 years. The warming effects are projected to affect agriculture activities, ecosystems and biological behaviours (Chaudhary and Aryal, 2009). Some of the effects include droughts, desertification, floods, frequent fires and the increase of disease incidence leading to serious consequences for human wellbeing (IPCC, 2007; Chaudhary and Aryal, 2009). Similarly, the study area falls within the region of sub-Saharan Africa where climatic models project that climate change will have major impacts on the livelihoods of the people and ecosystem goods and services on which they depend (Thornton et al., 2006).

The study concludes that participants' knowledge and understanding of the concept of climate change and its impacts on agricultural production is well developed because of their everyday involvement in agricultural activities from which they earn their livelihoods. Undoubtedly, as they survive on these activities, they are observant and discerning about subtle changes in climate. The majority of these farmers are educated and literate. Some have access to radio, television and newspapers, which facilitate access to current information about climate change. A number of sensitisation programmes organised by the government agencies and NGOs in the study area, which sometimes have climate change components in them, have also contributed to the raising of awareness on issues of climate change and climate variability. However, this study suggests that there is still only a limited understanding among farmers of the underlying causes of climate change, as some respondents still related climate changes to socio-cultural and religious factors. The study suggests that this limited understanding may create a barrier in the implementation of climatic adaptation strategies aimed at curbing the current and expected future impacts of climate change. Thus, this study suggests the need for environmental education, which will enable farmers to grasp the causes of climate change, and hence protect their environment from further degradation, and to implement realistic adaptation strategies that will reduce further changes in climatic conditions.

The findings from this study show that farmers are making efforts to adapt their farming practices to changing climatic and environmental conditions. The adaptation practices employ both autonomous strategies (involving farmers' efforts based on their local knowledge, experiences and practices) and planned adaptation strategies made by the central government through different policies and strategies, such as *Kilimo kwanza* (agriculture first) and the National Strategy for Growth and Reduction of Poverty (NSGRP), known as MKUKUTA in Swahili, which focuses on alleviating poverty in the country, as well as NGOs, which have climate change adaptation strategies/components in their programmes. However, this study concludes that some of these strategies do not sufficiently meet the needs of the farmers in adapting better to the changing conditions. For instance, the study observed that most of the farming inputs do not reach the farmers in time (before the growing season starts) and the amount provided under subsidised prices (e.g. fertilisers and improved seeds) was not enough to cater for farmers' needs. Because some farmers cannot afford such inputs due to limited purchasing power, they resort to the use of cheaper strategies that do not yield substantial results, thus increasing their vulnerability to the changing conditions. It is on this basis that the study suggests that the government should revisit the adaptation policy to ensure that it considers all characteristics of the farmers in the rural community, as well as the timely delivery and availability of farming inputs.

Another important conclusion drawn from this study is that virtually all farming activities in the study area depend entirely on rainwater. Thus, there is only limited use of irrigation in the management of farming activities, despite a number of studies suggesting irrigation to be an effective method of reducing climate-related production risks in the agricultural sector (see IPCC 2007; Branca et al., 2011; Parrott and Marsden, 2002; Pretty et al., 2006). However, changes in climate and environmental variability affect water and rainwater availability for agricultural activities in the study area, in the country and in Africa in general. In the study area, many rivers and streams are reported to overflow in seasons with heavy and long rain, and are dry in the seasons with low rainfall. Nonetheless, the study observed no concrete structures near rivers built to collect and store rainwater (from run-off) and water in the rivers for irrigation during seasons with low and variable rainfall. Although the establishment of irrigation schemes requires large physical infrastructure and capital investment, trained and experienced irrigation personnel and engineers, experienced farmers in irrigated agriculture and the use of modern technology so as to reap large benefits from the scheme (Biswas, 1986), this study suggests the development of small-scale irrigation schemes (SSIS), which by their nature do not require large capital and investments (see also Biswas, 1986; Burney and Naylor, 2012). SSIS are suitable in the study area, and elsewhere in the country and in Africa at large, because most rural farmers in developing countries have low investment capacity when compared with the cost of the establishment of large irrigation schemes. Thus, SSIS can be developed at a relatively low cost and can be cost-effective and suitable for the irrigation of most of the crop varieties, including the basic staples (maize and beans). SSIS could effectively make use of traditional irrigation skills that are cheaper, more affordable and readily available to rural farmers. This is supported by Burney and Naylor (2012), who suggest that farmers normally start with low-cost technologies and then move up to the ladder and invest in higher quality irrigation systems. SSIS is cheaper, as it makes use of the easily obtainable rainwater (e.g. run-off water and natural water flow) captured and stored for use during the dry season. Also, SSIS does not require the displacement of inhabitants, which is one of the major drawbacks of the establishment of large irrigation schemes. Similarly, environmental and health problems, such as waterlogging and soil salinity, and waterborne diseases such as schistosomiasis and malaria, which are associated with irrigation activities, are low and can be manageable due to the nature of SSIS (Biswas, 1986). The study suggests that the construction of concrete water storage structures, shallow wells and irrigation channels can be done through public private partnerships (PPP). For instance, in the case of the study area, Kisangara Sisal Estate is one of the potential private organisations that could be responsible for the water scheme's constructions and management to ensure that smallholder farmers benefit from water storage facilities. The development of irrigation schemes should go hand in hand with the identification of potential areas for irrigation. Similarly, the study suggests the rehabilitation of the existing irrigation schemes to ensure their effective utilisation. As the study findings show, most of the existing irrigation structures (traditional and modern) are old, dilapidated and underutilised, which affects farmers' adaptive capacity. The use of partnerships between public and local private actors can help rural farmers benefit from improved irrigation facilities, which will enable them to cope with climate change, hence improving their adaptive capacity.

The study has also shown that farmers are adapting to the changing climatic conditions through crop-diversification strategies that involve the growing of other drought-resilient food crops, hence reducing dependence on the single food crop of maize (the main staple food crop grown in the area). Such diversification of crops also varies depending on the location. However, the study suggests that there are only a limited number of crop diversifications in the study area. This study thus recommends further research on crop diversification of both food and cash crops so as to increase farmers' income and food production, hence reducing dependence on monoculture with its associated high risk of yield and income loss during adverse weather conditions.

Another important conclusion draw from this study is that farmers still make use of their local environmental knowledge and practices in managing farming activities, including adapting to changing climatic conditions and environmental variability. However, the findings suggest that there is less recognition of the role of local environmental knowledge and practices in farming activities, and more emphasis is put on the use of scientific farming technology. This side-lining of local knowledge and practices is not only done by the development practitioners, but also by the farmers themselves, as the knowledge is perceived to fail to yield sufficient output under current changing environmental conditions, resulting in farmers losing confidence in their own knowledge (see also Briggs, 2005; Briggs and Moyo, 2012). Although the knowledge and practices are becoming less effective, hence starting to be neglected by the farmers themselves, they are still nonetheless used by the majority of the farmers as they play a dominant role as a decision making tool in farming activities and rural livelihoods. Such knowledge is cheaper and readily available in the local environment when compared to scientific knowledge and practices. The use of local environmental knowledge and practices has kept less developed countries' emission rates of GHG low when compared to the industrialised countries. Hence local knowledge and practices remain the most green technology based on the low carbon economy with a low carbon footprint (Parry et al., 2007). Less recognition of local knowledge and practices by the government has made the implementation of some of the adaptation strategies difficult and even impossible. However, many development practitioners and researchers acknowledge the role indigenous knowledge plays in the development of society as well as challenges and difficulties involved in the use of local indigenous environmental knowledge (Moyo and Moyo, 2013; Briggs et al., 2007; Briggs, 2013; Orr et al., 2000). This study has shown further that the knowledge is neglected which might lead to its extinction as there are no deliberate measuares in place to investigate its contribution to the current adaptation strategies to the changing conditions. It is from this that this study suggests that the design and implementation of the adaptation strategies and policies should depart from the exclusionary strategy and pay greater attention to the local knowledge and practices of the local-level actors. This can be achieved through synergies of the local knowledge and practices with modern science, leading to the development of a hybrid technology that can benefit both local farmers and the ecosystem. This could improve the capacity of farmers in adapting to the impacts of climate change by identifying the areas for cooperation, hence providing solutions to the constraints that cannot be solved through the use of one type of technology. This is of importance because modern science and technology alone cannot sufficiently provide solutions to the problems facing the majority of the people in LDCs (see also Briggs et al., 1998). Also, as argued by Brown (2003: 90):

> "…a form of 'fusion knowledge', neither strictly local or traditional, nor external or scientific, may be most useful in developing locally appropriate (in terms of culture and resource) and adaptive systems of managing diverse…resources. It is often at the interface between different ways of knowing and different forms of knowledge that innovations in resource management and practice can be made…"

Therefore, this study concludes that policy makers should not neglect the role of local knowledge and expertise that have already being gained by the local people, as some of their practices provided a basis for managing climate change in the past and they were able to survive such events (see also Gyampoh et al., 2009).

Another important conclusion drawn from this study relates to the limited involvement of the local farmers, who are the victims of the changing environmental conditions, in the design of the agricultural adaptation strategies. The findings show that most of the strategies implemented in the study area follow a top-down approach or else do not involve a large proportion of the local population during their design, but only involve them at the implementation stage. This limits support amongst farmers during the implementation of the proposed strategies. The study concludes that, although changes in environmental conditions are projected to occur all over the world due to climate change, the changes will vary over both spatial and temporal scales and also will depend on the local conditions of a given area. Therefore, even if a strategy is successful elsewhere, it may not be applicable in the given environment but may require some flexibility or adjustment in order to be of value. It is important that the development of adaptation strategies involves a sufficient number of local people and considers their knowledge of and experience and expertise in best practice that they already possess. Many studies recommend the involvement of stakeholders in the design of community-based development plans (Reed, 2008; Chess et al., 2000). A study by Thabrew et al. (2009) considers the involvement of stakeholders in decision making as a critical aspect that enables stakeholders not only to interpret and make decisions based on expert judgements, but also to appropriately involve the relevant parties in the research and decision-making process. The study suggest further that scientific analyses in multi-stakeholder contexts have to be more transparent, participatory and stakeholder-based in order to provide useful information to assist in decision making. Through the involvement of the beneficiaries, adaptation strategies can make use of the existing indigenous knowledge and skills of the local people, their environmental conditions and resources, rather than imposing new and expensive practices that farmers are not familiar with and that create a barrier during their implementation process (see also Simms and Murphy, 2005).

Since agriculture forms the mainstay of the economy and livelihood of the people in the study area, and in Tanzania as a country (URT, 2001b), the need to strengthen extension services cannot be ignored. The findings show that farmers in the study area lack proper information with regard to farming activities, which is important in adapting to changing environmental conditions. Information can improve farmers' adaptive capacity and increase their resilience to the impacts of climate change and environmental variability in agriculture by accessing up-to-date information on the expected weather conditions (e.g. expected amount of rainfall and likely commencement time), use of improved seeds, and advice on the use of factory-made pesticides and fertilisers (when to use, how to use and what amount to use). Such information could empower farmers and enable them to make informed farming decisions. It therefore is recommended that extension services are improved, which can also go hand in hand with the provision of education on the efficient use and protection of natural resources such as forests, water and soil so as to increase productivity in a sustainable way.

Furthermore, this study draws an important conclusion that farmers have limited access to reliable weather predictions and forecasts. Although the majority of the participants reported receiving information from the Tanzania Meteorological Agency (TMA) via radio and television, they claimed that the information was too general and too difficult to comprehend. For instance, TMA produces information covering a very broad spatial scale within the country, with no specific focus on regions or districts. Moreover, the language used is difficult to understand by the target population and is too general. This limits the use of the available information for planning and decision making in agriculture, thus making farmers depend on traditional weather forecast and experiences based on their own farming calendar, which is not sufficiently reliable due to current environmental changes. This study therefore suggests an improvement in the collection, processing and dissemination of the weather information to consider a more specific area rather than generalisation based on the zones. This can be supported by the government through the meteorological weather agency to ensure the availability of up-to-date weather stations for data collection and processing and for the dissemination of the information to the farmers to ensure that they access and make use of the information in planning and decision making to manage agriculture-dependent livelihoods.

The highlands are the major sources of food and water used in the lowland zones and elsewhere in the country. Water originates from the catchment forest reserves of Kindoroko, Kamwala and Kirongwe. However, the study observed increasing environmental degradation, especially in the forests, and declining soil fertility, which affect both food production and water availability in the district. This study recommends deliberate measures to be taken by the government and private sectors to focus on soil and water conservation in the highlands. The efforts should concurrent with the employment of experts at the ward level to provide the necessary technical support in the conservation process. Similarly, there is a need to improve rural roads and transport facilities to allow rural farmers to access district towns, making it easier to transport crops from the villages to the market at lower costs. The literature also cites the improvement of infrastructure such as roads to be an important component in rural development (Tumbo et al., 2010).

The findings of this study agree with the general literature on climate change, which suggests that changes in climatic conditions are affecting agriculture-dependent livelihoods. According to the IPCC (2001), the global climate is expected to change both now and in the future, affecting more agriculture-dependent communities. More severe impacts will be experienced in developing countries due to their increased dependence on rain-fed agriculture and low population adaptation capacity, coupled with fragile environments. Hence, agricultural adaptation strategies to climate change are important in promoting agricultural production during periods of extreme weather and climatic events. The findings of this study provide onsite information that shows that the Mwanga District has been experiencing changes in rainfall and temperature over the past three decades, which is an indication of climate change and environmental variability.

The findings of this study also show that both autonomous and planned strategies have a stake in adapting to climate change. However, some of these strategies do not sustainably grant farmers' livelihood needs, while at the same time sustaining the life support systems of the earth (Turner et al., 2003), as they either limit the effective implementation of agricultural adaptation strategies or contribute to environmental degradation through changes to and removal of land/vegetation cover. The results of this study therefore may inform policy makers in the design and implementation of different agricultural adaptation strategies and policies in the attempt to reduce the vulnerability of agriculture and the environment to the current and future projected impacts of climate change.

The findings also may contribute to the design of more resilient agricultural adaptation strategies that could be cost-effective, sustainable and capable of facilitating increased food security as climate change impacts continue to bite. According to the UNDP (2008), “humanity is living beyond its environmental means and running up ecological debts that future generations will be unable to repay as a result of global climate change”. Thus, the results of this study may lead to the assessment of current adaptation strategies and implementation plans to find out whether or not they need to be changed completely or improved upon to benefit the target groups and ecosystems.

The contribution of local environmental knowledge to the development of Tanzania has been widely underestimated. Meanwhile, a number of Africa-based studies have suggested that a proper understanding of local knowledge and practices would serve as a valuable tool for any African country that seeks to develop itself (Magubane, 1979; Mwami, 2001). Hence the development of adaptation strategies will require an understanding and consideration of the indigenous farming knowledge and practices of the local community. This thesis provides the foundation for further research, and could stimulate further debates on the issue of climate change in a typical African country.

This thesis not only explored the impacts of climate change on agriculture and the respective adaptation strategies in the face of economic challenges, it also showed the role played by local environmental knowledge in the sustenance of rural agricultural livelihoods. Providing a background to the complexity of the major factors of rural livelihoods, and the adaptation strategies in response to environmental changes, this thesis recommends the integration of local environmental knowledge and conventional scientific methods in the development of appropriate and widely acceptable adaptation strategies for climate change. This would require a broadened interdisciplinary research approach in developing countries to holistically address the role of local environmental knowledge and how it can enhance resilient livelihood strategies and adaptive capacity for rural farmers to respond to climate change.

This study intended to investigate the knowledge of farmers about climate change, their perceptions on changing environmental conditions and its impacts on agricultural dependent livelihoods. The study has also examined the perceptions of farmers on agricultural adaptation strategies and the role of indigenous environmental knowledge in farming. The findings have shown that farmers are aware of their weather conditions and how the changes affect their livelihoods. They are also aware of both autonomous and planned adaptation strategies, and they are making use of both. The only disappointment revealed by this research is that the so called smart climatic adaptation strategies as revealed in the literature (Cooper et al. 2013; Beckford and Barker, 2007; Thomas et al, 2007; Kristjanson et al, 2012; Olokesusi, 2004; Nyong et al, 2007 and Giller et al, 2009) can not be universally applied but are place specific. The applicability is limited due to social, cultural, economic, political and environmental conditions of a given geographical location.

This study also observed that there is a problem in the approach used in the design and implementation of adaptation strategies. The top-down approach used in the implementation of the strategies leads to failure even if the strategy might promise positive results. Furthermore, some of these adaptation strategies need high purchasing power (e.g. buying improved seeds, application of pests and insecticides and use of tractors during land preparations) which the majority of the farmers cannot afford due to abject poverty. The farmers thus opt for alternative off-farm activities by involving themselves in illegal livelihood activities for their survival such as logging and sand quarrying which results in negative impacts on the environment and directly increases the farmer's vulnerability to environmental hazards.

Although the information presented in this thesis has focused on the agricultural adaptation strategies implemented by the government and individual farmers, it is important to note that private sector organisations, such as NGOs, religious organisations and other local and international institutions, are also concerned with the development and implementation of agricultural adaptation and mitigation measures in the agricultural sector. However, given the limited resources, this study did not focus on the role played by the third sector. This is unfortunate, as it would seem that NGOs have become important contributors in some places. For example, Friendship in Development Trust (FIDE) is an NGO which is helping destitute rural farmers to improve their livelihoods in the study area while reducing the impacts of changing environmental conditions. The NGO is supporting farmers to revamp coffee economy and has introduced new coffee species with higher yielding capacity, short time to maturity (three years) and resistant to common pest and diseases; and has helped in improving productivity for cows, chicken and goats. In achieving this, the NGO has initially distributed 78 dairy cows, fifty seven of which were high quality bulls intended for crossbreeding; has introduced new goat breed from Isiolo Kenya and forty improved roosters (cockerels) for crossbreeding to improve indigenous chicken breed for better yields. FIDE is also commited in improving banana farming geared on improving banana production in the highlands. Up until 2011, more than 40 farmers had received training on improved banana cultivation methods, hence contributing to the improvement of the livelihoods of vulnerable rural poor households stricken by poor agricultural performance resulting from changes in climatic conditions. Another NGO which is involved in supporting farmers in managing the impacts of changing climatic conditions is the Same and Mwanga Environmental Consavation Advisory Organisation. The NGO works for Same and Mwanga districts to sensitise communities on climate change and food security, environmental conseravation and renewable energy, human rights, gender, entrepreneurship skills and HIV- AIDS awareness. Through education and support provided by the organisation, people in the study area (Ngujini and Kwakoa wards in particular) have learnt how to use an effective fuel-saving stove known as *jiko banifu/mkombozi* in Swahili. The use of *Mkombozi* stove reduces the rate of tree logging for firewood which is the sole source of domestic energy for cooking. The reduced rate of logging for domestic use will increase the rate of carbon storage, prevent soil erosion, modify micro-climate and benefit the villagers through the aesthetic value of the forests.

Beacause agriculture is vulnerable to changing climatic conditions, it is important to note that farmers have developed alternative, non-agricultural diversification strategies that enable them to mitigate their rural nature-dependent livelihoods under changing and variable climatic conditions. This study, however, did not focus on these; thus this is an area worthy of further exploration to develop a more holistic understanding of the agricultural adaptation strategies and limitations facing agriculture in rural areas.

Appendix **1**

Household Questionnaire Survey

Questionnaire number ………………..

Name of the village: ………………..Ward……………, Division ………………..

SECTION A

Demographic information

1. Gender of the respondent ………………..

2. Age ………………………………………...

3. Occupations ……………………………….

4. Education level: a) Adult education, b) Primary, c) Secondary, d) College, e) University

6. Number of family living away from the village

a) Males	b) Females	c) Total

SECTION B

Land ownership for agriculture

1. Do you own any farm land? Yes, No

2. If yes, how many plots………………….?

3. What is the size of farm plot in acres…………..?

   a) Less than 2
   b) Between 2- 3.9
   c) Between 4- 5.9
   d) 6 or more

4. a) Main crop grown

   a) …………. b) …………. c) ………….d) ………….

4. b) Other types of crops

   a) …………. b) ………….c) …………. d) ………….

5. Number of people working in the farm.

a) Males	**b) Females**	**c) Total**

6. Amount of crops harvest in the last season?

a) Main cops	**b) Area grown in acre**	**c) Amount Harvested (No of Tins)**
1.		
2.		
3.		
4.		
b) Other crops		
1.		
2.		
3		
4		

7. Describe the amount of crops harvested in the past 10 years (2002-2012).

a) Enough
b) Surplus
c) Deficit

Livestock Keeping

1. Number of livestock kept by the household.

a) Types of livestock	**b) Number.**

2. Major challenges facing livestock keeping**.**

3. Household source of cash income

a) Source of income	**b) Yes (1) No (2)**

SECTION C

Knowledge on local farming methods and practices

1. Name local farming methods and practices known to you.
2. Which one among those mentioned do you practise?
3. How do you determine soil fertility of a farm plot?
4. Mention traditional environmental weather predictions known to you.
5. What are your views on indigenous knowledge and practices in farming activities

Perceptions of the factors affecting effective application of indigenous environmental knowledge and practices

Statement	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Lack of support from the government					
It is gender sensitive					
Known by few					
It is marginalised					
It is not reliable					
Threaten by changing conditions					
Specific to a given area, not applicable everywhere					
Threatened by increase in the use of modern technology					
Not written					
Connected with local beliefs and taboos					
Cannot be justified and proved					
Difficult to use/apply					

Note! *Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1*

SECTION D

Information on climate change and environmental variability

1. What do you understand by the term climate and climate change?
2. What do you think are the causes of climate change?
3. How are you affected by the current changing conditions?

SECTION D

Perceptions of climate change and environmental variability

a) Perceptions of climate change

Statement	*Strongly agree*	*Agree*	*Not sure*	*Disagree*	*Strongly disagree*
Drought period seems to be longer					
Rainfall seems to be less					
Average temperature seems to be higher					
Rainfall seems to be more variable					
Decrease and drying of water					
Weather seems to be unpredictable					
Loss of crops seem to be higher					
Fodder seems to be less					
Growing season seems to be shorter					
Pests and crop diseases have increased					
Declining and loss of wetlands					
Livestock diseases have increased					
Soil erosion is a bigger problem now					
Death of livestock have increased					
Rainfall seems to have increased					
Floods seems to be more frequent					

Note! *Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1*

b) Changes in farming practices

Statement	*Strongly agree*	*Agree*	*Not sure*	*Disagree*	*strongly disagree*
You have changed planting dates now					
You practise more conservation farming (zero tillage) now					
You practise more terrace farming now					
You use more manure now					
You retain more crop residuals and grass on the farm now					
You have more weed control now					
You practise more burning of the crop residuals and grass now					
You use more factory fertilisers now					
You use tractors more now					

Note! *Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1*

c) Adaptation strategies

Statement	*Strongly agree*	*Agree*	*Not sure*	*Disagree*	*Strongly disagree*
You practise mixed cropping more than past decades					
You grow more improved maize varieties now than past decades					
You cultivate fewer plots now than in past decades					
You grow more drought-resilient crops now than in past decades					
You depend more on remittances now than in past decades					
You cultivate more crops other than maize and beans now than in past decades					
You depend more on non-farm activities now than in past decades					
You keep more livestock now than in past decades					
You use more industrial insects and pesticides now than in past decades					

You depend more on traditional weather predictions now than in past decades					
You practise more irrigation now than in the past decades					

Note! *Strongly agree = 5; Agree = 4; Not sure = 3; Disagree = 2; Strongly disagree = 1*

d) Limitations on adaptation

Statement	*Strongly agree*	*Agree*	*Not sure*	*Disagree*	*Strongly disagree*
Climate variability (drought, increase in temperature and erratic rainfall)					
Insufficiency and untimely delivery of agricultural inputs					
Low financial capacity at different levels					
Top-down strategies					
Pests, crop diseases and vermin					
Unreliable weather forecast information					
Soil fertility					
Poor agronomic practises					
Lack of education on climate change adaptation mechanisms					
Increasing cases of human diseases (Malaria and HIV/AIDS)					
Emphasis on modern farming methods at the expense of traditional practices					
Migration of the youth to other areas					

Appendix 2

Survey of on-farm practices

No. of farm plot…………………..

1. Name of the village…………………………… Ward…………………….
   Division……………………………
2. Main crops grown………………………….……………………….…
3. Other crops ……………………………………………………………….
4. Observed environmental conditions (soil erosion in the farm): Tick as appropriate

Evidence	Observed	Not observed	Major	Minor
Gully erosion				
Rill erosion				
Surface erosion (sheet)				
Turbid water				
Others				

5. Rainfall distribution for adequate crops growth. Tick as appropriate

Distribution	Good	Bad	Very bad

6. Evidence of drought:

Evidence	Observed	Not observed	Major	Minor
Wilting of crops				
Soil cracks				
Crop failure				
Poor yield				
Stunted crop growth				
Extent of weeds on the farm				
Dried springs and streams				
Surface sheet erosion				
Dried wetlands and ponds				
Sedimentation				

7. List types of traditional farming practices observed: Tick as appropriate

Type of strategy	Scale of operation	
	Large	Small

8. Observed agronomic farming practices: Tick as appropriate

Evidence of agricultural practices	Observed	Not observed	Scale of operation	
			Large	***Small***

9. Soil fertility: Tick as appropriate

Good	Bad	Very bad

10. Presence of pests, diseases and vermin: Tick as appropriate

Types of pests and crops diseases	Observed	Not observed	Scale	
			Large	***Small***
Grasshoppers				
Maize bore				
Bean weevils				
White flies				
Aphids				
Blister beetles				
Vermin				

Appendix 3

Characteristics of the Respondents

Key informant

District level

Interviewee	Code
District crop officer	District official 01
District livestock officer	District official 02
District natural resources officer	District official 03
District development and planning officer	District official 04
District land use and planning officer	District official 05
District forest official	District official 06
District Sorghum coordinator	District official 07
Kisangara Sisal Estate Manager	Sisal estate informer

Ward Agricultural Extension officers (WAEO)

Ward	Code
Ward agricultural extension officers	Ward officer no. 01
Ward agricultural extension officers	Ward officer no. 02
Ward agricultural extension officers	Ward officer no. 03
Ward agricultural extension officers	Ward officer no. 04

Ward Executive Officer (WEO) = ward leader

Ward	Code
Ward executive officer 1	Ward leader 01
Ward executive officer 2	Ward leader 02
Ward executive officer 3	Ward leader 03
Ward executive officer 4	Ward leader 04

Village chairpersons = Village leader

Village Chairperson	Code
Village chairperson 1	Village leader 01
Village chairperson 2	Village leader 02
Village chairperson 3	Village leader 03
Village chairperson 4	Village leader 04
Village chairperson 5	Village leader 05

Focus group discussions

Location	Number of interviews	Code
Highland	02	HFG
Lowland	02	LFG

Oral history

Location	Number of interviewees	Code
Highland	06	HOH01
Lowland	06	LOH01

IN-DEPTH INTERVIEW

Highland – 45 interviewees

Division	Wards	Village name	code/ no.	Gender	Age	Farm ownership in lowland zones	Lowland farming status	Primary location
Kindoroko	Kilomeni	Sofe	sf01	M	91	No	N/A	Highland
			sf02	M	80	Yes	Abandoned	Highland
			sf03	M	42	No	N/A	Highland
			sf04	M	63	No	N/A	Highland
			sf05	M	87	Yes	Abandoned	Highland
			sf06	M	76	Yes	Abandoned	Highland
			sf07	F	72	Yes	Abandoned	Highland
			sf08	M	67	No	N/A	Highland
			sf09	M	37	No	N/A	Highland
			sf10	M	42	No	N/A	Highland
	Ngujini	Chanjale	ch11	F	45	Yes	Not cultivating	Highland
			ch12	M	68	yes	The last time I cultivated was 1992	Highland
			ch13	M	85	No	N/A	Highland
			ch14	F	46	Yes	Cultivating	Highland
			ch15	M	57	Yes	Abandoned	Highland
			ch16	M	64	Yes	Not cultivating	Highland
			ch17	F	56	No	N/A	Highland
			ch18	F	43	No	N/A	Highland
			ch19	M	44	No	N/A	Highland
			ch20	M	52	No	N/A	Highland

Highland – Interviewees

Division	Wards	Village name	code/ no.	Gender	Age	Farm ownership in lowland zones	Lowland Farming status	Primary location
Ugweno	Msangeni	Msangeni	ms21	M	64	No	N/A	Highland
			ms22	M	77	No	N/A	Highland
			ms23	F	46	No	N/A	Highland
			ms24	M	63	No	N/A	Highland
			ms25	M	74	No	N/A	Highland
			ms26	F	43	No	N/A	Highland
			ms27	M	45	No	N/A	Highland
			ms28	M	79	No	N/A	Highland
			ms29	F	61	No	N/A	Highland
			ms30	M	47	No	N/A	Highland
			ms31	F	43	No	N/A	Highland
			ms32	F	50	No	N/A	Highland
Usangi	Kirongwe	Lomwe	ml33	F	48	Yes	Not cultivating	Highland
			ml34	M	56	Yes	Not cultivating	Highland
			ml35	F	62	Yes	Not cultivating	Highland
			ml36	M	70	Yes	Not cultivating	Highland
			ml37	F	42	No	N/A	Highland
			ml38	M	64	No	N/A	Highland
			ml39	M	46	No	N/A	Highland
			ml40	M	48	Yes	Abandoned	Highland
			ml41	M	38	No	N/A	Highland
			ml42	F	52	No	N/A	Highland
			ml43	F	44	No	N/A	Highland
			ml44	M	52	No	N/A	Highland
			ml45	F	67	N o	N/A	Highland

Lowland Interviewees

Division	Wards	Village name	code/ no.	Gender	Age	Farm ownership in the highland zones	Farming status	Primary location
Lembeni	Lembeni	Kisangara	ks01	M	65	No	N/A	Lowland
			ks02	M	48	No	N/A	Lowland
			ks03	M	54	No	N/A	Lowland
			ks04	M	66	No	N/A	Lowland
			ks05	M	61	No	N/A	Lowland
			ks06	M	47	No	N/A	Lowland
			ks07	M	70	No	N/A	Lowland
			ks08	M	48	No	N/A	Lowland
			ks09	M	55	No	N/A	Lowland
			ks10	M	40	No	N/A	Lowland
			ks11	F	42	No	N/A	Lowland
			ks12	M	66	No	N/A	Lowland
		Mbambua	mb13	F	40	No	N/A	Lowland
			mb14	M	42	No	N/A	Lowland
			mb15	M	48	No	N/A	Lowland
			mb16	M	45	No	N/A	Lowland
			mb17	M	68	No	N/A	Lowland
			mb18	M	63	No	N/A	Lowland
			mb19	M	62	No	N/A	Lowland
			mb20	M	52	No	N/A	Lowland
			mb21	M	41	No	N/A	Lowland
			mb22	M	57	No	N/A	Lowland

Lowland – Interviewees

Division	Wards	Village name	code/ no.	Gender	Age	Farm ownership in the highland zones	Farming status	Primary location
Jipendea	Kwakoa	Kwakoa	kw23	M	53	No	N/A	Lowland
			kw24	F	50	No	N/A	Lowland
			kw25	M	52	No	N/A	Lowland
			kw26	M	46	No	N/A	Lowland
			kw27	M	52	No	N/A	Lowland
			kw28	M	50	No	N/A	Lowland
			kw29	F	46	No	N/A	Lowland
			Kw30	F	38	No	N/A	Lowland
			Kw31	M	48	No	N/A	Lowland
			Kw32	M	47	No	N/A	Lowland
			kw33	M	42	No	N/A	Lowland
			kw34	M	45	No	N/A	Lowland
Mgagao	Mgagao	Kiverenge	kv35	M	42	No	N/A	Lowland
			kv36	M	62	No	N/A	Lowland
			kv37	F	40	No	N/A	Lowland
			kv38	M	67	No	N/A	Lowland
			kv39	F	66	No	N/A	Lowland
			kv40	F	38	No	N/A	Lowland
			Kv41	M	52	No	N/A	Lowland
			kv42	M	48	No	N/A	Lowland
			kv43	M	56	No	N/A	Lowland
			kv44	M	56	No	N/A	Lowland
			kv45	M	77	No	N/A	Lowland

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