LIVING WITH CLIMATE VARIABILITY AND CHANGE: LESSONS FROM TANZANIA

Noah Makula Pauline

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DECLARATION

I declare that this Thesis is my own work, unaided work. It is being submitted for the Degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

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(Signature of the Candidate)

…………….day of………………2015

ABSTRACT

There is sufficient evidence supporting that climate change and variability are pervasive realities that are strongly impacting on smallholder farmers in the Great Ruaha River sub-Basin of Tanzania. This PhD study examines smallholder farmers' vulnerability, coping and adaptation strategies to climate change and variability (including non-climatic stresses), and investigates how such coping and adaptation may be constrained or enhanced given climate variability and change. Both quantitative and qualitative data collection methods were used when engaging with smallholder farmers and government officials. Primary data collection was undertaken in two phases, with phase one using participatory tools (e.g. focus group discussions, wealth ranking, community mapping and transect walk, and historical time lines). Data collected include climatic and non-climatic extreme events, farmers' perceptions, coping and adaptation strategies. Phase two involved detailed individual interviews (questionnaire surveys) and key informant interviews (case studies), so as to obtain in-depth information on issues of interest. Secondary data were collected from existing statistical sources, literature surveys in archives, libraries and documentation centres, and from governmental agencies (e.g. TMA). Demographic, agricultural production and livestock statistics, and rainfall and temperature records were collected. Results from selected meteorological stations and farmers' perceptions (74%) indicate that there has been an increase in average maximum temperatures, and both dry and wet years with varying magnitudes during the past four decades. Other climatic stresses include delayed onset and later cessation of the rain seasons. The agreement between farmers' perceptions and rainfall trends provides good evidence that the climate has become increasingly variable in the GRRB during the past four decades.

Achieving sustainable livelihoods is further compounded by non-climatic stresses such as access to markets and coordinating institutions. Results indicate that vulnerability is a complex phenomenon that entails two approaches (end-point and starting-point perspectives). The end-point perspective views vulnerability as the net projected climate change impacts after adaptation has taken place, whilst the starting-point perspective looks at both the current and future multiple stresses and places much emphasis in improving the adaptive capacity. In the study villages, such a nuanced picture highlighted areas for enhanced adaptation strategies. Farmers respond by using various strategies to deal with droughts, floods and other stresses when they occur. During droughts, they mostly use irrigation (canal, pumping and cans), or plant short-term maturing crops. During food shortages, farmers use strategies such as buying food, borrowing money, temporary migration, working in other people's farms for cash, and reducing consumption. Moreover, the farmers' choice of adaptation and coping strategies is influenced by factors such as location, access to resources, education levels and institutions. This calls for a whole system approach, which entails defining vulnerability of smallholder farmers to climatic and non-climatic stresses and thus designing appropriate response strategies. For example, mainstreaming adaptation to such stresses when considering development plans, projects, programmes and policies at all scales.

Keywords: Smallholder farmers, Great Ruaha River sub-Basin, Tanzania, stresses, Impacts, Vulnerability, Coping, Adaptation, Climate change, Climate variability.

DEDICATION

To my parents, my wife Rose and our beloved children Bernadetha-Mayeji, Benedict-Makula and Bertha-Butogwa

PREFACE AND ACKNOWLEDGEMENTS

My deepest appreciation goes to DANIDA through the CLIVET Project for funding this PhD study. This Thesis would not have been possible without the countless hours of discussion and steady commitment offered by my supervisors, Prof. Stefan Grab of the School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand and Prof. Coleen Vogel of the Global Change Sustainability Institute, University of the Witwatersrand. Indeed the support, assistance and professional input provided before and during the writing of this work remain a permanent asset for reporting other scientific works in future. Likewise, my appreciation goes to the CLIVET project partners and coordinators, specifically Prof. Torben Birch-Thomsen (University of Copenhagen, Denmark) and Dr. Emma Liwenga (University of Dar es Salaam, Tanzania) for their help during the formulation of the study. Their tireless guidance and contribution throughout the study enriched and helped to create the foundation of this study.

My research interests in smallholder farmers' vulnerability and adaptation to climate change and climate variability started when I was involved in the "*Dynamic Interactions among People, Livestock and Savannah Ecosystems under Climate Change*" project, which was undertaken in the agro-pastoralist areas of Tanzania and Kenya. The project focused on the assessment of the impacts of climate change on range-lands and livelihoods of agro-pastoralists. Being employed at the University of Dar es Salaam's Institute of Resource Assessment, I have also been involved in other climate change and agriculture related projects, which have contributed further to building my interest in this subject matter. Most importantly, my interest has been inculcated by the fact that I come from an agro-pastoralist family and have witnessed changes in rainfall pattern and its impacts to crop production back home for atleast the past twenty years. I have a deep feeling that broadening my knowledge in this subject will be a starting point for realizing my life-long desire to help improve the livelihoods of smallholder farmers of Tanzania in the face of climate change and variability.

My current understanding and input into this PhD study have also been shaped by two international conferences that I attended and presented papers at. Firstly, the Africa Climate

Conference 2013 (ACC2013), "*Advancing African Climate Science Research & Knowledge to Inform Adaptation Decision-Making in Africa*" which was held in Arusha, Tanzania, 15–18 October, 2013. The ACC2013 brought together stakeholders to draft an Africa-wide agenda for climate research and to explore climate research priorities, identify information needs for early warning and adaptation, enhance the networking of climate scientists, and support capacity development. The main recommendation was that climate information and services must be co-developed between producers and users of such information. This will ensure that the resulting information is action-oriented and used in an effective and timely manner. Moreover, the information must be used to transform policies, institutions and mind-sets of end-users for it to bring the impact that is expected on the ground. Secondly, the *International Conference on Regional Climate CORDEX 2013*, held in Brussels, Belgium, 4-7 November, 2013. The conference brought together the international community of regional climate scientists and stakeholders with a particular emphasis on the production, assessment and use of Regional Climate information. Participants recognized the need for a paradigm shift in which regional climate science operates by placing end-users' expectations and needs at the heart of the development of regional climate information through a change in perspective on the analysis and exploitation of climate model outputs, leading to new science-policy approaches. Furthermore, the need for training, capacity building and innovative information and knowledge transfer mechanisms would provide the necessary instruments for effective delivery of climate services contributing to the WMO-led UN Global Framework for Climate Services (GFCS) and the Future Earth (FE) initiative.

Two supervisors and two project coordinators have guided me through the process of this PhD study. Their diverse backgrounds (i.e. physical geography, human geography, climatology and social sciences) have enriched this study, and the current state of the PhD thesis is a reflection of these disciplines. I started the research with a general multiple stresses focus and then narrowed to vulnerability related to climate change and variability. In the process of analysis and writing, and inspired by past researchers (e.g. Kelly & Adger, 2000, Smit *et al*., 2000, O'Brien *et al*., 2004), I started to learn action-oriented thinking and adopted their approach to organize my thesis. The two conferences I attended also shaped the organization of this thesis and started to look at different contexts of vulnerability.

Therefore, I restructured my thesis to start with analysing climate stresses and farmers' perception, and then other non-climatic stresses.

Special thanks also go to the ACCFP Secretariat for the grant that provided additional funding to support the study. I am indebted to all government officials in the GRRB (from the regional to the village level) for the logistical support during data collection, to them I say *Asante Sana*. However, special thanks should go to Dr. Simon Stisen, the CLIVET project Leader and fellow PhD candidates (Ms. Sarah Osima and Ms. Madaka Tumbo), for providing positive cooperation and all necessary information I needed for this work. I would like to convey my heartfelt gratitude to Mr. Einhard Mwanyika, the retired agricultural extension officer, and Mr. Nico Malik for their assistance during data collection.

I am grateful to my parents the late Mr. Pauline Makula (R.I.P. Dad) and Ms. Bernadetha Fares Makula for laying down the foundation of my education. Special thanks goes to my brothers the late Simon Mashamba and the late Rev. Jacob Makula for their tireless support and inspiration, to them I say R.I.P. Last but not least, I am appreciative to my wife and our children, for their prayers and moral support. Thank you and God bless you.

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ACRONYMS

AFNE - Ate Food Normally don't Eat

AFPD - Ate Fewer Meals per Day

AIDS - Acquired Immunodeficiency Syndrome

APA – American Psychological Association

ASL - Above Sea Level

BCBF - Borrowed Cash to Buy Food

BF - Borrowed Food

CFR - Change in Frequency of Rainfall

CIR - Change in Intensity of Rainfall

CMI - Crop Moisture Index

CropSyst - Cropping System simulation model

CSS - Consumed Seed Stock

CUSUM - Cumulative Sum

DANIDA - Danish International Development Agency

DALDO – District Agricultural and Livestock Development Officer

DFID - Department for International Development

DNA - Designated National Authority

DoE - Division of Environment

DWDS - Days with Dry Spells

EAC - East African Community

EMA - Environmental Management Act

ENSO - *El Niño*–Southern Oscillation

FAO - Food and Agriculture Organization

FEWS - Famine Early Warning Systems

FINCA - Foundation for International Community Assistance

GCM - Global Circulation Model

GDP - Gross Domestic Product

GISS - Goddard Institute for Space Studies

GRRB - Great Ruaha River sub-Basin

HadCM3 - Hadley Centre Coupled Model

HIV - Human Immunodeficiency Virus

IPCC - Intercontinental Panel on Climate Change

IRI - International Research Institute for Climate Prediction

LFR - Looked for Relief

MARA/ARMA - Mapping Malaria Risk in Africa

MDGs - Millennium Development Goals

MIGR - Migration

NAFCO - National Agriculture and Food Cooperation

NAP - National Adaptation Plan

NAPA - National Adaptation Programmes of Action

NCCFP - National Climate Change Focal Point

NCCSC - National Climate Change Steering Committee

NCCTC - National Climate Change Technical Committee

NGOs - Non Governmental Organizations

NSGRP II - National Strategy for Growth and Reduction of Poverty II

PDSI - Palmer Drought Severity Index

PRA - Participatory Rural Appraisal

RAFE - Reduced Amount of Food Eaten

RDSU - Rural Development Support Unit

RNC - Rainfall Not Consistent

ROL - Rented Out Land

RSE - Rainfall Starts Earlier

RSL - Rainfall Starts Late

SCW - Significant Change in Weather

SDWFC - Sought Daily Work for Cash

SFW - Sold Firewood

SHA - Sold Household Assets

SMUWC - Sustainable Management of the Usangu Wetlands and its Catchment

SPI - Standardized Precipitation Index

SPSS - Statistical Package for Social Science

SRES - Special Report on Emissions Scenarios

SREX - Special Report on Managing the Risks of Extreme Events and Disasters to advance climate change adaptation

STD - Sexually Transmitted Diseases

STI - Standardized Temperature Index

SWSI - Surface Water Supply Index

TMA - Tanzania Meteorological Agency

TNBC - Tanzania National Business Council

UN - United Nations

UNFCCC - United Nations Framework Convention on Climate Change

URT - United Republic of Tanzania

USAID - United States Agency for International Development

VPO - Vice President's Office

WMO - World Meteorological Organization

WPFF - Worked in other Peoples Farms for Food

CHAPTER 1: BACKGROUND TO THE STUDY

1.1 INTRODUCTION

In this first chapter, the general background to the study, information on the study area and context of vulnerability to climate change and climate variability are presented. A brief discussion on the impacts of climate change on the agricultural sector is presented, as this is the main focus of the study. The research proposition, aim and objectives are presented in the final section of this chapter. This PhD study adopts the evolution of climate change research (four eras) as shown by the IPCC assessment reports (IPCC, 1990, 1995, 2001, 2007, 2013, Niang *et al*., 2014).

1.2 STUDY CONTEXT

Climate change and variability is a widespread contemporary reality that is strongly impacting development on the African continent (IPCC, 2007, 2013; Niang *et al*., 2014). According to climate data available since 1950, evidence suggests that some climatic indices have changed on the continent during at least the last century (Shongwe *et al*, 2011; IPCC, 2012, 2013). The African continent is considered to be particularly vulnerable to such events, a situation amplified by the interaction with other stresses and its low capacity to adapt (Boko *et al*., 2007; Niang *et al*., 2014). Climate variability and change may be additional challenges for future development on the continent; as agriculture, which is the main economic activity, is inherently sensitive to such stresses.

Some studies have reported differential vulnerability to climate change between developed and developing countries (e.g. Darwin & Kennedy, 2000; Reilly *et al*., 2001; Parry *et al*., 2004), with major vulnerabilities (i.e. recurrent food shortages, loss of natural resources and poverty) occurring in low-latitude regions (e.g. the African continent). Thus, substantial pressure is expected to be exerted on the developmental sectors of Africa (i.e. agricultural, health and water sectors). However, regional scale impacts are likely to be variable, with some regions benefiting from an altered climate whilst others are adversely affected (Boko *et al*., 2007; Malley *et al*., 2009; Rowhani *et al*., 2011; Niang *et al*., 2014).

Sources of livelihoods for Tanzanian farmers, particularly the agricultural sector, are already suffering the adverse impacts of climatic stresses. For example, poor rainfall distribution (patchiness), periods of drought, intra- and inter-seasonal dry spells, delayed onset and early cessation of the rain seasons, and poor water management, have been amplifying the problem of soil moisture stress (Paavola, 2003; Tillya & Mhita, 2006). Such climate stresses may have placed between 20 to 30% of the Tanzanian population living in semi-arid areas at risk (DFID, 2001). An analysis by Hatibu *et al*. (2000) and Morris *et al*. (2003), for example, revealed that more than 33% of disasters in Tanzania over the last ca. 100 year period were related to drought. Empirical analysis showed that Tanzania had recorded 37 occurrences of drought between 1872 and 1990 (URT, 1998). In 2006, a major drought triggered serious food and power crises in the country. Such a situation has increased the vulnerability of smallholder farmers to such stresses. To this end, the current PhD study focuses on assessing the vulnerability of smallholder farmers to such stresses and the subsequent adaptation strategies.

The field of vulnerability and adaptation to climate change research has progressed over time. Four paradigm shifts or eras have been observed since the first IPCC assessment report in 1990 (Global Climate Partnership Fund, 2012). During the first assessment report (first era), assessments were based on future climate change scenarios and quantification of impacts using models. In this era, much of the focus on a vulnerability perspective was on 'end-point vulnerability assessment'[1] where vulnerability was seen as the outcome or product of a climate impact after adaptation has taken place. The second era of climate change research comprised of the second and third IPCC assessment reports (1995 and 2001 respectively). The importance of current vulnerability to observed impacts of climate change started to be recognized. Within this era, vulnerability is viewed as the 'starting-point' when undertaking climate change assessments. Here the end-point is still included but a strong focus shifts to examining some of the underlying 'structural' and other socio-economic, socio-cultural and justice dimensions that may shape vulnerability to climate risks including climate change (O'Brien *et al*., 2004; Füssel & Klein, 2006). The focus of much climate change efforts were noticeable in what may be called the 'third era', wherein

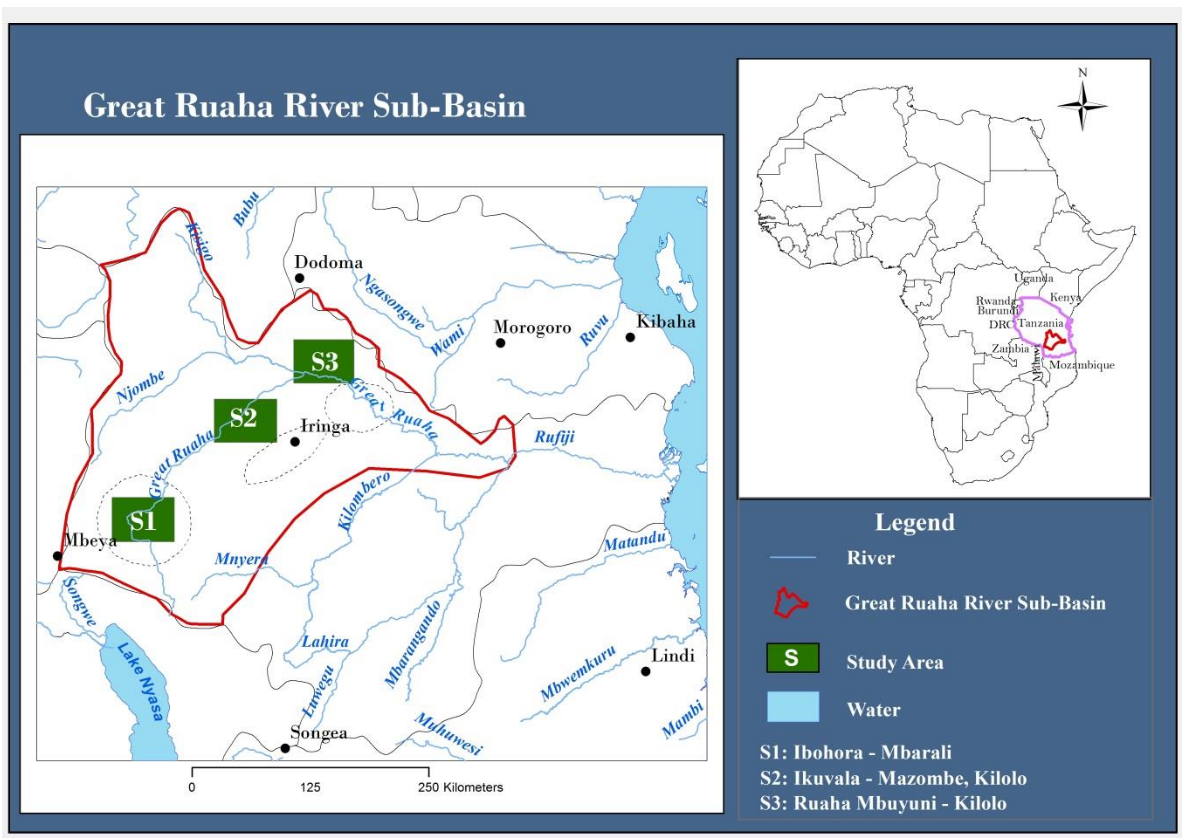
[1] Distinguishing between starting-point and end-point vulnerability is essential and key in this work. See further details on approaches in the remainder of this chapter.

the IPCC fourth assessment report (2007) and climate change assessments started to link vulnerability and adaptation planning to climate change. This means that understanding the underlying causes of present-day vulnerability provides an opportunity to plan for adaptation strategies, for both the current and future impacts of climate change. The IPCC 5th assessment reports, Working Group I (IPCC, 2013) and Working Group II the Africa chapter (Niang *et al*., 2014), highlight some key issues suggesting that climate change research is now shifting to a fourth era. In this era, a focus on climate resilient pathways and transformation is expressed (Global Climate Partnership, 2012). Moreover, trans-disciplinary approaches that involve users of climate information in transforming existing policies, institutions and people's behaviour with a focus on current vulnerability to the impacts of climate change is encouraged (WMO, http://www.gfcs-climate.org/ accessed on 21st October, 2014).

As is evident from this brief overview through time, highlighting shifts in discourse and focus on climate change, indeed a multidisciplinary approach is required for vulnerability assessments. To this end, there is need for an elaborate and common understanding by all disciplines involved in vulnerability assessments (O'Brien *et al*., 2004). It was not until after the first three IPCC reports (IPCC, 1990, 1995, 2001), when 'vulnerability' began to be recognized as a term in climate change, and various disciplines started to find ways of assessing vulnerability at different levels, ranging from regions, sectors, ecosystems and social groups. Notwithstanding the word, vulnerability in the climate change literature needs to be clearly defined because it hosts two different interpretations, and two different purposes for using it (O'Brien *et al*., 2004). By using such nuanced understanding of vulnerability, a greater understanding of how the impacts of climate change will be distributed, will be achieved, and targeted areas for vulnerability reduction interventions identified. A focus on prior damage, referred to by Kelly and Adger (2000:328) as the "wounded soldier" approach, claims that addressing present-day vulnerability will reduce vulnerability under future climate conditions. Therefore, the focus of this approach is to devise policies or measures that reduce current vulnerability, increase adaptive capacity, or illuminate adaptation options and constraints (Burton *et al*., 2002).

Much recent research in Tanzania has focused on the end-point approach by analyzing climate change impacts on the agricultural, water and health sectors (e.g. Paavola, 2003; Eriksen *et al*., 2005; Tilya & Mhita, 2006; Yanda *et al*., 2006; Mongi *et al*., 2010; Rowhani *et al*., 2011). This perspective also tends to dominate the current policies and plans in Tanzania. For example, the NAPA and Climate change strategy are more focused at addressing future impacts of climate change. In this PhD study, vulnerability is assessed in both dimensions (i.e. starting-point and end-point). Climate variability and change, together with other stresses as causes of vulnerability, will thus be assessed together with the impacts and drivers of change. With such a nuanced approach, the full sense of vulnerability to climate stress and change is hopefully captured. The study also adopted a strong focus on local case studies in order to uncover the details of the underlying causes of the past, as well as the current vulnerability in the study area.

Figure 1.1: Map showing the study area



Source: GIS Lab, University of Dar es Salaam, 2014

This PhD study was undertaken in the Great Ruaha River sub-Basin (GRRB), where three villages were selected for data collection (Figure 1.1). Details outlining the methods and approaches chosen for selection of cases is outlined in chapter Three (see section 3.4). In this thesis, vulnerability and adaptation to climate change and variability on rural spaces, particularly in the context of food security, is explored. Both quantitative and qualitative data collection methods were used when engaging with smallholder farmers and government officials. Primary data were collected using focus group discussions and household questionnaire surveys, whilst secondary data were collected from records held by government institutions. Before starting with field work, the ethical guidelines outlined in the APA Ethics code (2002) was considered and included in this study (see details in chapter Four).

1.3 PROPOSITION

The working proposition for this thesis is that smallholder farmers are vulnerable to and are aware of climate change and variability and other stresses, and are actively engaged in coping and adapting to such changes.

1.4 AIM AND OBJECTIVES

1.4.1 Aim

The aim of this study is to examine smallholder farmers' vulnerability, coping and adaptation strategies to climate change (including climate variability) and other stresses, and to investigate how such coping and adaptation may be constrained or enhanced.

1.4.2 Specific objectives

i. To identify and understand past climate variability and extreme events through both (a) instrumental records (e.g. existing climatic station data) and (b) through social and anthropological methods that capture detailed lived experiences, perceptions and accounts from local people.

ii. To generate a baseline of climatic and non-climatic stresses that smallholder farmers have and are currently facing, against which one can begin to determine any vulnerabilities to climate variability and change.

iii. To better understand the coping options and adaptation strategies to both the sudden-onset of extreme events and the more pervasive climatic change/variability.

iv. Finally, to determine how coping and adaptation may be constrained or enhanced given climate variability and change.

CHAPTER 2: THE LITERATURE REVIEW

2.1 INTRODUCTION

Detailed information on vulnerability, impacts and response strategies to climate change and variability are reviewed within this chapter. The vulnerability concept is key in climate change study, due the fact that it helps to understand the past and current impacts, thus helping to improve the adaptive capacity of an individual or community to future impacts. The primary and secondary impacts of climate change and variability on agriculture (the main focus of this PhD study), from the global to the local perspectives is outlined. Finally, examples of some of the response strategies, where notions of coping and adaptation strategies are used are also explored in this chapter, with a view to learning from one another's experiences.

2.2 THE VULNERABILITY CONCEPT

Vulnerability assessment of a system (e.g. socio-ecological) is one of the approaches used to understand the ability of that system to respond to stresses such as climate variability and change (Folke *et al*., 2002). Different scholars have used different definitions when referring to vulnerability. Vulnerability is a term referring to the total exposure to risk, in this case those risks associated with climate change and variability [Disaster risk = Function (Hazard, Exposure, Vulnerability)] (Kelly & Adger 2000; Folke *et al*., 2002). Similarly, vulnerability may be defined as the level of capability to which a system, community or an individual is able to respond to the impacts of climate change (Eakin & Luers, 2006). Additionally, vulnerability is also defined as a function of assets and options that households possess (Agrawal, 2010). These three definitions present different focuses when referring to vulnerability. For example, the first definition focuses on the nature of the hazard, in this case a drought or flood, whilst the third definition looks at the assets possessed by the household, which determines the options available (room for manoeuvre) for the household to survive the hazard when it occurs. This PhD study uses the third definition that is also elaborated more under the livelihood framework section in chapter Four.

The concept of vulnerability has been used by many researchers in environmental and social research (e.g. McCarthy *et al*., 2001; Eakin & Luers, 2006; Füssel, 2006), in assessing changes and trends in socio-ecological systems. As previously described in chapter One, vulnerability assessment is viewed in two perspectives (i.e. end-point and starting-point). These perspectives host two definitions which lead to two different meanings for using them. Firstly, it is viewed as an end-point that is a residual of climate change impacts after adaptation has taken place (Kelly & Adger, 2000). Under this perspective, vulnerability represents the net impacts of climate change and serves as a means to defining the extent of the climate problem (Kelly & Adger, 2000; O'Brien *et al*., 2004). This approach to vulnerability assessment focuses on estimating the projected impacts of climate change rather than attempting to reduce them (Füssel & Klein, 2006). Secondly, vulnerability is also referred to as a starting-point situation, where vulnerability is a state generated by multiple stresses, and only exacerbated by climate change (Kelly & Adger, 2000; O'Brien *et al*., 2004). Other researchers have concluded that addressing the current vulnerability may help to improve the adaptive capacity of a community to future impacts of climate change (Kelly & Adger, 2000; Smit *et al*., 2000). In this PhD study, a shift to viewing vulnerability in both dimensions as described here is emphasized so as to establish a full sense of the stresses farmers are facing.

As earlier stated in this section, dealing with current vulnerability to climate change helps to improve the adaptive capacity of an individual or community to future impacts. Adaptive capacity is defined as the capability of a system (e.g. region, ecosystem or community) to react and cope to changes (Tubiello & Rosenzweig, 2008; Sivell *et al*., 2008). The adaptive process involves various major and minor alterations of practices and sometimes institutional structures. The whole concept of adaptive capacity explains the ability of an individual or community to change so as to address present threats to survival at the same time enhancing its ability to cope with future stresses (Yohe & Tol, 2002). Thus, factors such as institutional structures, flexibilities in policies and resource distribution, are closely linked to the adaptive process (Scoones, 1998; Ellis, 2000; Eakin & Luers, 2006; Sivell *et al*., 2008).

Factors that influence adaptive capacity can be classified into two categories. These categories include generic and specific determinants related to climatic stresses such as flood and drought. Examples of generic determinants are such as income, education and health, whilst institutions, knowledge and technology are specific determinants (Downing & Patwardhan, 2003; Brooks *et al.*, 2005a; Tol & Yohe, 2007; Yohe *et al.*, 2007). Other scholars have presented a different categorisation of determinants, including population characteristics, agricultural practices, access to resources and institutional settings (e.g. Adger *et al.*, 2003; Reid & Vogel, 2006). The current study is also committed to the analysis of factors influencing farmers' adaptive capacity in the Great Ruaha River sub-Basin in Tanzania. Moreover, it attempts to assess farmers' vulnerability to climate variability and change, and the subsequent coping and adaptation strategies.

2.3 IMPACTS OF CLIMATE VARIABILITY AND CHANGE ON AGRICULTURE

According to the recent IPCC reports (IPCC, 2013, Niang *et al*., 2014), there has been an increase in observed temperature trends by 0.5°C or more over most parts of Africa during the last 50 – 100 years (e.g. Grab & Craparo, 2011; Hoffman *et al.*, 2011; Mohamed, 2011; Stern *et al.* 2011; Funk *et al*., 2012; Nicholson *et al.*, 2013). Similarly, the mean temperature increase over the African continent is projected to exceed 2°C towards the end of the 21st Century (e.g. Christensen *et al*., 2007; Joshi *et al.* 2011; Sanderson *et al.*, 2011; James & Washington, 2013). Observed trends of rainfall for the Sahel region show a general reduction during the 20th Century (e.g. Nicholson *et al.*, 2000; Lebel & Ali, 2009; Ackerley *et al.,* 2011; Mohamed, 2011; Biasutti, 2013). However, observed trends of precipitation over eastern Africa show a high degree of spatio-temporal variability during the 20th Century (Rosell & Holmer, 2007; Hession & Moore, 2011), with an observed general decrease in rainfall over the last three decades (Funk *et al.*, 2008; Williams & Funk, 2011). The eastern Africa region has also experienced a high frequency of droughts and floods during the past 30 – 60 years (Funk *et al.*, 2008; Williams & Funk, 2011; Shongwe *et al.*, 2011; Lyon & DeWitt, 2012). A general reduction in rainfall over southern Africa is also observed predominantly during the second half of the 20th Century (Hoerling *et al.*, 2006; New *et al*., 2006). Precipitation projections in many CMIP-3 and CMIP-5 models suggest that towards the end of the 21st Century, west and eastern Africa will experience wetter rain seasons (Moise & Hudson, 2008; Shongwe *et al.*, 2011; Biasutti, 2013). However, the CMIP3 GCM projections for southern Africa indicate a reduction in rainfall (Moise & Hudson, 2008; James & Washington, 2013; Orlowsky & Seneviratne, 2012).

The projected climate changes are expected to bring both positive and negative impacts across scales (Kurukulasuriya & Mendelsohn, 2006; Boko *et al*., 2007; Niang *et al*., 2014). These differential impacts are likely to be caused by variations in vulnerability among social groups, ecosystems or sectors at different levels (O'Brien & Leichenko, 2000). For example, global warming is expected to be beneficial by extending cropping seasons in middle and higher latitudes (Rosenzweig & Hillel, 1995; Yang *et al.*, 2007). In contrast, some low latitude regions (i.e. sub-Saharan Africa), which are currently highly vulnerable, are likely to be negatively impacted by projected climate changes (Parry, 1990; IPCC, 2001; Schwartz & Randall, 2003).

The projected changes are expected to impact negatively on the agricultural sector in many countries in sub-Saharan Africa (Boko *et al*., 2007; Niang *et al*., 2014), where agriculture (the main economic activity) is 98% rain-fed (FAO, 2002). According to UNFCCC (2007), about one third of the African population experience droughts in their areas and an estimated 220 million individuals are vulnerable to drought each year. It is estimated that by 2100, agricultural losses may reach between 2 and 7% for the Sahara region, 2 and 4% for central African countries and 0.4 to 1.3% for northern and southern Africa (Mendelsohn *et al.*, 2000; Eriksen *et al*., 2008). Marginal areas with low input farming practices in the sub-Saharan Africa may be impacted significantly as they have low capacity to adapt to climatic stresses (Rosenzweig & Parry, 1994; Reilly & Schimmelpfennig, 1999; Kates, 2000; McGuigan *et al*., 2002; Thornton *et al*., 2006; Niang *et al*., 2014). With exception to eastern Africa where maize production may benefit to the increased warming (Thornton *et al*., 2009), the rest of sub-Saharan Africa is expected to experience negative impacts on major cereal crop yields (Thornton *et al*., 2009; Lobell *et al*., 2011; Roudier *et al*., 2011; Berg *et al*., 2013).

Using two global circulation models (GISS and HadCM3 coupled to a cropping system simulation model [CropSyst]), a study in Mali shows that impacts of climatic stresses may lead to reduced crop yields, thus resulting to risks of food shortage and a decrease in the economy (Butt *et al.,* 2005). Results from the projections suggest that the sensitivity of maize to changing weather conditions is relatively small (generally less than 10% change) under both dry and wet scenarios by 2030 and 2060. White (Irish) potatoes, the primary cash crop, are the most sensitive to changing weather conditions, with yields decreasing under both dry and wet conditions; yields could decrease by about 25% by 2060. The SREX report shows that severe droughts occurred in East Africa during the 2010/2011, rain season, resulted to 50,000 fatalities (directly and indirectly) and affected about 13.3 million people (IPCC, 2012).

Secondary impacts of climate change on agriculture include increases in food prices as a consequence of declining food production (Ahmed *et al*., 2009). Cereal crops are expected to face higher market prices (between 39% and 43% depending on the SRES scenario) (Calzadilla *et al*., 2013). Increasing global food prices may have led to the deaths of 30,000 to 50,000 more children in sub-Saharan Africa due to poor nutrition in 2009 (Friedman & Schady, 2009). Climate variability and change is expected to aggravate this situation in future (Yabi & Afouda, 2012). A study using current climate scenarios (e.g. dry and wet scenarios in 2030 and 2060) on 11 African countries found falling farm revenues (Kurukulasuriya *et al.,* 2006). Moreover, the GDPs for some countries are reported to be impacted by climate variability. For example, climate variability reduces Zambia's GDP growth rate by 0.4% per year, which amounts to a loss of US$4.3 billion over a ten-year period (Thurlow *et al*., 2009, Mubaya, 2010). Malley *et al*. (2009) reported noticeable declines in crop productivity in the Great Ruaha River sub-Basin due to frequent past droughts. Details of climate change impacts for Tanzania and the study area in particular, are provided in chapter Three.

2.4 RESPONSE STRATEGIES TO IMPACTS OF CLIMATE CHANGE AND VARIABILITY

Linked to approaches that make use of vulnerability and resilience, much recent attention has also focussed on how an individual responds given his/her resilience or vulnerability to change. Here notions of adaptation and coping have been used. Given the past and current climate variability and change in the study area, the need to understand how farmers perceive and adapt to climate change is very important. Some studies have indicated that climate is changing and farmers have been responding to reduce the negative impacts of such changes in sub-Saharan Africa (e.g. Thomas *et al.,* 2007; Ishaya & Abaje, 2008; Mertz *et al.,* 2009).

2.4.1 Coping strategies

The concept of coping strategies to climatic stresses has been defined differently by various scholars. Davies (1996) defined coping strategies as short-term measures employed by a farmer, pastoralist or fisherfolk in response to food shortages. Similarly, Ellis (1998) defined coping strategies as measures taken in response to a decline in normal sources of food or survival. Additionally, coping may be defined as utilisation of assets possessed by an individual in response to a food crisis (Adams *et al*., 1998; Vincent *et al*., 2013). Some studies in Tanzania have also highlighted climate-related coping strategies (e.g. Paavola, 2008; Mongi *et al*., 2010; Kangalawe, 2011, 2012; Yanda & Mubaya, 2011). These include migration, receiving food aid and selling of household assets (Phillips, 2007). Others include ddiversification into various sources of livelihoods, remittances and aid, and reducing consumption rate (Ellis, 2000).

Coping strategies may be classified as a short-term response to a crisis (e.g. Vincent *et al*., 2013) or both long-term and short-term responses (e.g. Corbett, 1998). The summary of these classifications and their characteristics are provided in Table 2.1.

Table 2.1: Classification of coping strategies

Category of coping strategies	**Characteristics**
Short-term	• Highly vulnerable strategies • Calls for the sale of assets • Threaten future livelihoods • High risk, but have low return • Erosive strategies that may lead into poverty (De Waal, 2003).
Long-term	• Low risk, but have high return. • Sustains for a relatively longer period of time.

Source: after Davies, 1996: In Mubaya, 2010

All definitions provided in this section explain a similar context of coping strategies and are all adopted in this PhD study. Moreover, the categorisation presented in Table 2.1 also enables a critical examination and analysis of coping strategies in the study area context. Coping strategies vary according to the biophysical context; therefore, evaluating coping strategies by using the context approach enables a clear understanding of the concept (Mubaya, 2010). To this end, three study villages representing different biophysical contexts within a sub-basin are selected in order to examine coping strategies (see details in Chapter Three).

2.4.2 Adaptation strategies

Adaptation strategies may be defined as the range of interventions taken in response to climatic stresses (IPCC, 2001; Smit *et al.*, 2000). These measures aim at managing losses or taking advantage of the opportunities presented by such changes. Adaptation to climate change occurs in two steps; firstly, farmers have to perceive the change, and secondly, they take actions in response to such changes through adaptation (Maddison, 2006). This definition is applicable to this PhD study, thus it is used in the discussions of adaptation strategies. This PhD study seeks to understand how farmers adapt to the impacts of climate change in the study area.

Adaptation is characterised by adjusting the entire system in a sustainable manner rather than dealing with few components of the system that are affected. Therefore, for the adaptation process to be effective, there should be flexibility in the entire livelihood system that provides food and income to farmers (Schipper, 2007). There are two categorisations of adaptation strategies to climate change (Table 2.2), such as autonomous and planned actions (Howden *et al.*, 2007; Tubiello & Rosenzweig, 2008).

Agrawal (2010: 182) presents five different categories of adaptation strategies as follows:

- “Mobility: the distribution of risk across space.
- Storage: the distribution of risk across time.
- Diversification: the distribution of risk across asset classes.
- Communal pooling: the distribution of risk across households.

- Market exchange: the purchase and sale of risk via contracts. In the case of market access, this category may substitute for any of the other four categories (Halstead & O'Shea, 1989)".

Table 2.2: Categories of adaptation strategies

Approach	Definition	Operation
Autonomous	Actions taken independently by households or communities.	•Shifting planting and input schedules. • Switching crops. • Change management practices
Planned	Actions that require combined action from various actors across scales (e.g. using policies)	• Irrigation infrastructure. •Water allocation. • Efficient water use technologies. •Accessible, efficient markets for products and inputs

Source: after Tubiello & Rosenzweig, 2008

The effectiveness of these categories of adaptation strategies and those presented in Table 2.2 depend partly on the biophysical and political setting in which they are practised. Furthermore, the fivefold classification of adaptation strategies presented above can be applied to both coping and adaptation because both are responses to climatic stresses (Agrawal, 2010). Therefore, this classification diminishes the difference between coping and adaptation, which basically depends on the duration (short-term or long-term) of effects produced on adaptive capacity. The distinction between coping and adaptation breaks down when climatic extreme events happen repeatedly (Campbell, 1990; Young & Jaspars, 1995; Agrawal, 2010). For example, the study by Mertz *et al.* (2009) reported that the coping and adaptation strategies of farmers in the Sahel can be categorised as diversification of crops and livelihoods, and migration. This study grouped all response strategies (short-term coping and long-term adaptation strategies) without any distinction.

Diversification of livelihoods as a category of adaptation strategies (e.g. Agrawal, 2010) is defined as a process whereby households construct their livelihoods from a range of activities and assets in response to a climatic stress (Ellis, 2000). These include diversification within farm activities (across crops) or from farm activities to non-farm activities (across sectors). Although diversification within farm activities is used by most households all over rural Africa (Reenberg & Fog, 1995; Reenberg *et al*., 1998; Ponte, 2001; Lacy *et al*., 2006; Yaro, 2006; Thomas *et al*. 2007; Bryan *et al*., 2009; Mertz *et al.*, 2010; Trærup & Mertz, 2011), diversification to non-farm activities is also becoming widely used in the rural spaces (Ellis, 1998, 2000; Barret *et al*., 2001; Roncoli *et al*., 2001; Bah *et al*., 2003; Rasquez & Lambin, 2006). It is important to note that the basis for diversification is to create a range of livelihood sources so as to improve the adaptive capacity (Reardon & Vosti, 1995).

One of the adaptation strategies that has proved to be efficient and has potential to improve crop production to smallholder farmers is irrigation farming (both by gravity and motor pumps). This farming practice helps farmers to supplement moisture, especially when prolonged droughts occurs (Baethgen *et al*., 2003; Orindi & Eriksen, 2005). It is important to note that climate change also impacts sources of irrigation water. Therefore, farmers ought to use other crop management practices in conjunction with irrigation practices so as to preserve moisture (Loë *et al*., 2001). It is also important to note that some of the adaptation strategies may lead to maladaptation practices (Vincent *et al*., 2013). Maladaptation is a situation whereby the adaptation strategy used may increase risks to other systems that are sensitive to climate change (Scheraga & Grambsch, 1998; Vincent *et al*., 2013). For example, use of motor pump irrigation practices to grow vegetables, tomatoes and onions, in the GRRB may be an adaptation, but if removing water from the river adversely affects others downstream, then at a larger scale, and in the long-term, this strategy is a maladaptation. Moreover, adaptation can be affected by different factors. These include access to crop markets, financial capital, inputs and climate services (Bradshaw *et al*., 2004; Nhemachena & Hassan, 2007; Hassan & Nhemachena, 2008; Kurukulasuriya & Mendelsohn, 2008; Deressa *et al.*, 2009; Mertz *et al.,* 2009).

The current study tries to partly combine and apply both categorisations/classifications of adaptation strategies as previously presented in this section. To this end, this PhD study examines both coping and adaptation strategies to climate change and variability, and tries to separate coping and adaptation strategies to such changes. The main differences between coping and adaptation strategies that are used in this study are as summarized in Table 2.3.

Table 2.3: Summary of differences between coping and adaptation strategies

Particulars	**Coping strategies**	**Adaptation strategies**
Duration	Short-term	Long-term
Context	-Response measures to a sudden-onset crisis (e.g. food shortage, drought and flood). -Deals with few components that have been impacted by climatic stresses (e.g. agriculture)	-Total adjustment of the entire system: policies, structures, institutions, farming practices, behaviour and livelihood activities. -Takes advantage of the opportunities presented by climatic stresses (e.g. diversification into non-farm activities, i.e. business enterprises)

Moreover, the study attempts to investigate to whether smallholder farmers in the GRRB are coping more frequently or adapting. The detailed profile of the study area is presented in the next chapter.

CHAPTER 3: THE STUDY AREA

3.1 INTRODUCTION

Context matters in vulnerability assessments, and thus the need to explore in detail the context of the case studies in this chapter. A more localized background to the study sites and the broader context of the country are provided in this chapter. The general country context is profiled in the first part. In the second part, the description of the study districts and specific villages is presented. The description focuses on the location, the physical environment and the socioeconomic context of the study villages and districts. A detailed characterization (livelihoods, change and vulnerability context) of the study villages is discussed in Chapter Five. The aim is to highlight the similarities and differences between the study sites.

3.2 THE COUNTRY CONTEXT

The United Republic of Tanzania is located in East Africa between 1° S and 12° S latitude and 30° E and 40° E longitude. The country covers a total area of 945,087 Km^2 (URT, 2003). It borders Kenya and Uganda in the North, Rwanda, Burundi and the Democratic Republic of Congo in the West, Zambia and Malawi in the South-West and Mozambique in the South (Figure 1). The primary economic sector in the country is agriculture (including livestock), providing livelihood income and employment to over 80% of the population. The sector also accounts for the production of raw materials for industries and the generation of foreign exchange. The three most important crops are maize, coffee and cotton, with maize being a major staple food and coffee a major cash crop grown in large plantations (World Bank, 2002; URT, 2007).

Tanzania is not in isolation with regard to climate change impacts. The SREX and recent 5th IPCC reports project changes in temperature and rainfall levels in East Africa and Tanzania in particular (IPCC, 2012, 2013). According to the National Adaptation Programme of Action (NAPA) report of 2007, frequent and severe droughts in many parts of the country are reported to impact on food production (URT, 2007). For example, famine resulting from either floods or drought and severe food price shocks has become increasingly common since the mid-1990s (URT, 2003).

Projections reveal that a 20% decrease in precipitation and 2°C increase in temperature are likely to impact on cereal yields in Tanzania by 2050 (Rowhani *et al*., 2011). The model shows that an increase of 2°C relative to the mean 1992–2005 rain season will reduce yields of cereal crops by 18.6±5.2% (maize), 12.6±5.3% (sorghum) and 16.3±6.0% (rice) in Tanzania (Rowhani *et al*., 2011). In contrast, a 20% increase in rainfall will lead to an increase in maize and sorghum yields by 6.7±1.7% and 5.7±1.7% respectively (Rowhani *et al*., 2011). These results suggest that climate change may significantly influence future maize yields in Tanzania, which is the staple food to most Tanzanians (Agrawala *et al*., 2003).

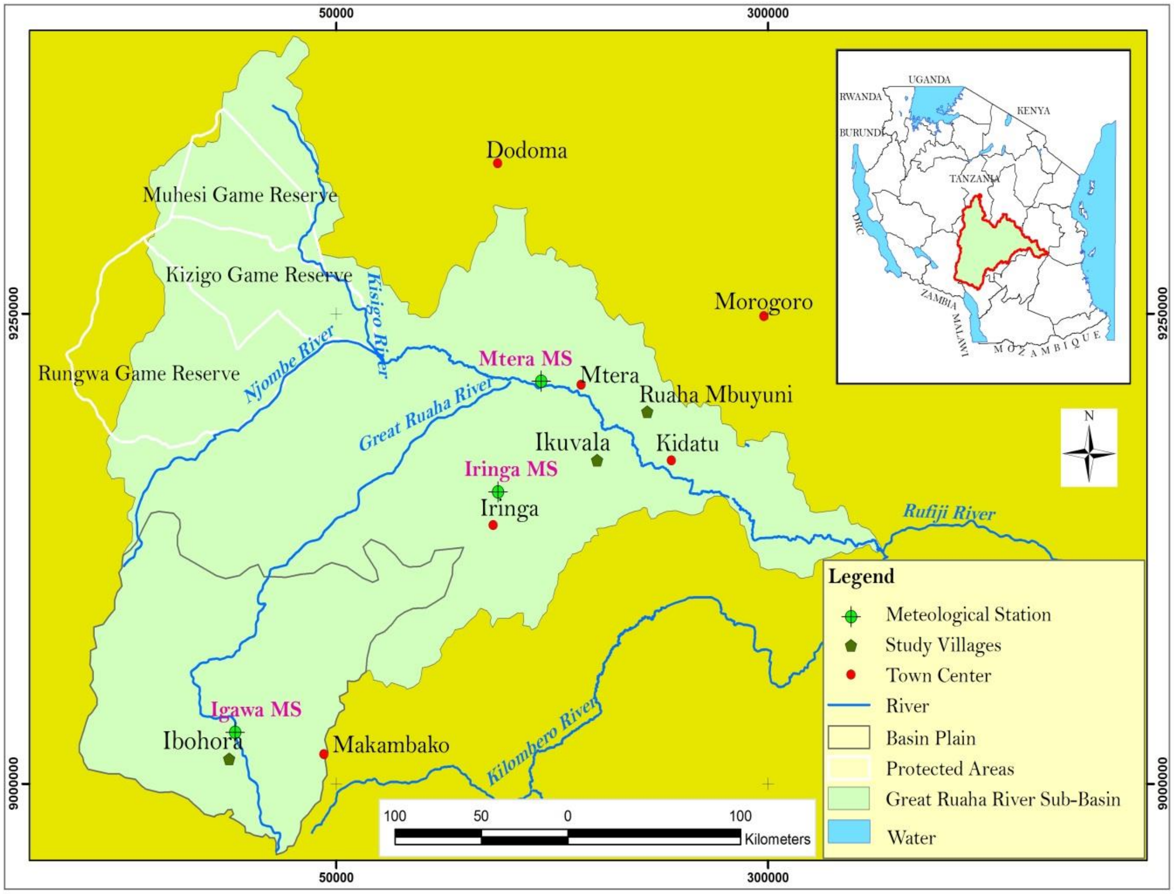
In semi-arid areas, specifically Tabora and Dodoma in central Tanzania, increasing temperature and decreasing rainfall is estimated to reduce maize yields by between 80% and 90%, and therefore threaten the main source of food for peasants (Jones & Kiniry, 1986; Mwandosya *et al*., 1998). While food shortages may be owing to other factors such as prices and seasonal outbreaks of diseases (USAID, 2006), climate change seems to have the strongest influence on food shortages for Tabora region in 2002/2003 growing season. Being part of the semi-arid regions of Tanzania, the GRRB has been recording a noticeable decline in crop production due to frequent droughts (Malley *et al*., 2009). Therefore, this PhD study aims at investigating differences in smallholder farmers' vulnerability, coping and adaptation to climate change and variability in this semi-arid region context.

3.3 THE GREAT RUAHA RIVER SUB-BASIN

The Great Ruaha River sub-Basin (GRRB) is located in south-western Tanzania and covers 83,979 Km^2 (Figure 3.1). The sub-basin is situated between longitudes 34° and 36° E and latitudes 6° and 9° S. It is a sub-basin of the Rufiji River Basin (177,000 km^2), which is the largest basin in Tanzania, occupying 25% of the land area of Tanzania. The Great Ruaha River is the main river draining through the whole sub-basin. It originates from a number of large and small streams on the slopes to the southeast, which receives high rainfall

(SMUWC, 2001). The GRRB is divided into three distinct river systems: the Great Ruaha, the Little Ruaha and Kisigo (Figure 3.1).

Figure 3.1: Map showing the Great Ruaha River sub-Basin



Source: GIS Lab, University of Dar es Salaam, 2013

The climatic conditions that exist in the basin vary widely. Rainfall is strongly seasonal, highly localised and spatially varied in GRRB (SMUWC, 2001). There are only two seasons, one rain season (November to May) and one dry season (June to October). Mean annual rainfall in the GRRB from the lowlands to highlands varies from 500 mm to 1600 mm respectively (*ibid*). The area north of the sub-basin experience semi-arid conditions, with a mean annual rainfall of about 500 mm. Rainfall increases southwards, with up to 1,800 mm of rainfall measured in some areas. The rainfall pattern is such that there is one rain season (mid-November to May). There is a tendency for the dry season to set in earlier in the GRRB than for example, the Kilombero sub-Basin. Runoff patterns in the GRRB are closely related to the rainfall pattern. Most rivers start rising in December, with a peak in March to April (SMUWC, 2001).

The Great Ruaha River sub-Basin is very important for supplying water to different upstream and downstream users. The major users of river water include:

- Mtera and Kidatu hydropower plants that depend on the waters of the Great Ruaha River to supply over half of the country's electricity.
- Rural and urban domestic water supply.
- Agriculture (i.e. irrigated). Valley bottom cultivation (Vinyungu) is widely practiced during the dry season in meeting the livelihood needs of the rural poor. Crops grown include paddy, maize, millet, cassava, sweet & Irish potatoes, beans, sugarcane, fruits and vegetables (SMUWC, 2001; Fieldwork observation, 2010).

3.4 SELECTION OF THE STUDY AREA

Three villages located in three agro-ecological areas in the GRRB, south-western Tanzania, make up the sites for this PhD study (Figure 3.1). The sites were purposively selected based on available information from past studies (e.g. Birch-Thomsen *et al*., 2001), which thus permits building on existing knowledge and making comparisons. The study sites were also selected based on the major crops grown in the GRRB. The first village (Ibohora) is in the upstream of the sub-basin (Usangu plains) where rice farming is predominant; the second village (Ikuvala) is located in the midlands region of the river (highlands) where maize and tomatoes are priority crops, and the third village (Ruaha Mbuyuni) is in the downstream region of the sub-basin where mostly onions and rice are cultivated (Table 3.1). The three agro-ecological areas provide a useful range in land-use types from which to address issues including different levels of vulnerability, different/or similar perceptions and experiences, coping and adaptation strategies to climatic extreme events, and different livelihood activities.

Accessibility to all villages by road during all seasons was taken as an important criterion for village selection, given that research was carried out during both dry and wetter seasons.

The population of farmers in the villages and other demographic factors were also considered, assuming that people would be attracted to live in areas that offer suitable living conditions. Production systems (commercial or subsistence) and methods of irrigation were considered as criteria for selection so as to capture adaptation options taken by both commercial and subsistence farmers in the GRRB when extreme climatic conditions occur. Precipitation or availability of irrigation water between areas was one of the key factors considered during the selection of study villages. Moreover, land use patterns during the rain and dry seasons as criteria for selection of the study villages were considered so as to capture temporal dimensions of coping and adaptation strategies.

The study villages were selected after a pilot study in the regions, covering the study area where agricultural officers from regional to district levels were interviewed using the aforementioned criteria. Three agro-ecological areas were then selected within the GRRB, with one village selected from each area (Table. 3.1). These agro-ecological areas represent areas that grow different crops grown, thus permitting comparison between sites.

Table 3.1: Study villages

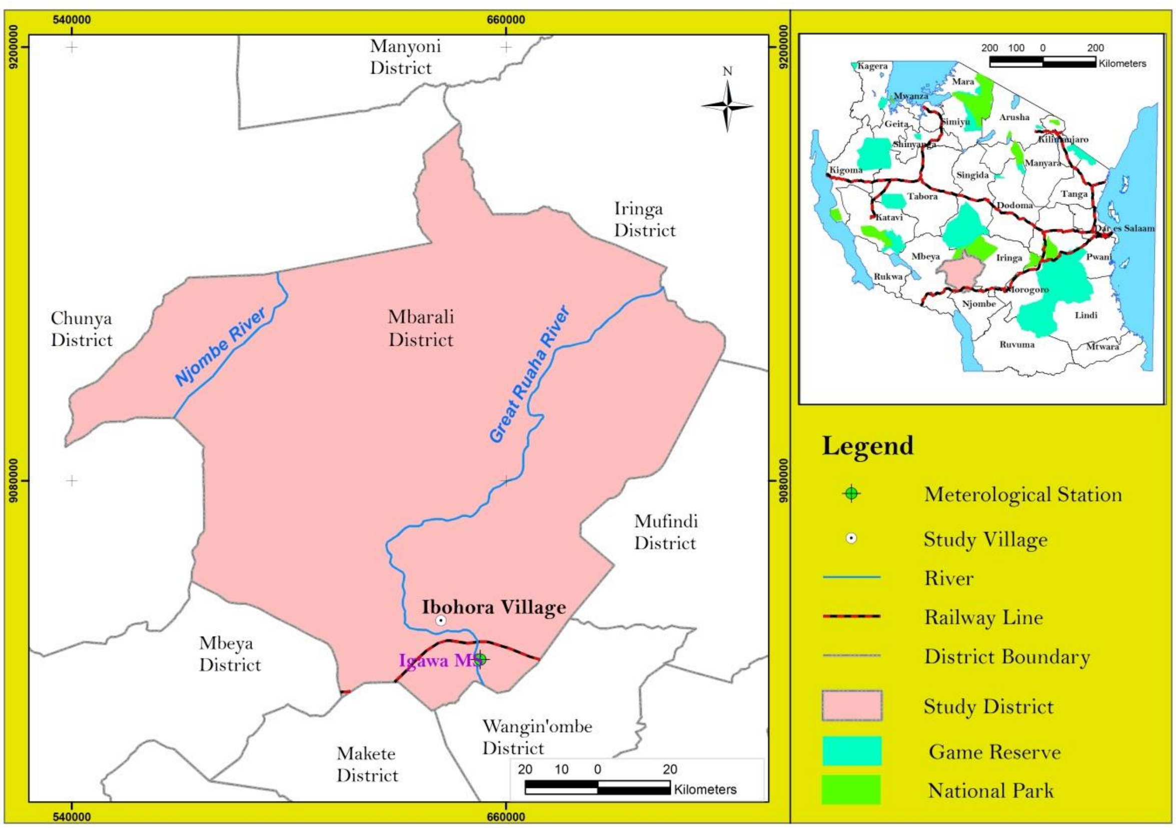
District	Ward	Village	Selection criteria
Mbarali	Ubaruku	Ibohora	Upstream, plain, swampy area, humid, semi-arid, predominantly irrigated rice farming, low populated.
Kilolo	Nyalumbo	Ikuvala	Mid-stream, highland, wet area, predominantly rain-fed tomato and maize farming, valley bottom farming, medium populated
Kilolo	Ruaha-Mbuyuni	Ruaha-Mbuyuni	Downstream, lowland, predominantly dry, irrigated onion farming. More use of motorised pump irrigation farming, highly populated with a business centre.

3.5 MBARALI DISTRICT

3.5.1 Location, climate and population

Mbarali district is among the seven districts in the Mbeya region (Figure 3.2). The district lies between latitude 70° and 90° S and between longitude 33° and 35° E. The District is at an altitude ranging from 1000 to 1800 m a.s.l. The average annual temperatures range between 25°C and 30°C, whilst the mean annual rainfall is about 450 to 650 mm. The district is bordered by the Iringa district to the north-east, the Mbeya district to the west, and the Njombe and Mufindi districts to the east. To the north, it borders the Mbozi district and Ruaha National Park, while to the south it borders the Makete district and Mpanga Kipengere Game Reserve (Mbarali District Council, 2010).

Figure 3.2: The Mbarali district indicating the study area (Ibohora village)



Source: GIS Lab, University of Dar es Salaam, 2013

The 2002 population census indicates that the Mbarali district population stood at about 282,911, with 140,385 males and 142,526 females (Mbarali District Council, 2010). Administratively, the district is divided into two divisions, namely Ilongo and Rujewa, with a total of 10 Wards, 93 registered villages, 731 hamlets and 55,374 households. Seven villages and three sub-villages were eliminated in order to expand the Ruaha National Park in 2008 (Mbarali District Council, 2010). The major ethnic groups of the Mbarali district are Sangu, Hehe and Bena. In addition, there are other small tribal groups including Sukuma, Wanji, Barbeig, Masai, Kinga, Nyakyusa and Gogo (Mbarali District Council, 2010).

3.5.2 Land use pattern and farming practices

Mbarali district had a total area of 15,560 km^2, before the expansion of the Ruaha National Park in 2008. By then, half of the land area was covered by forest and savannah woodlands. The remaining area was made up of flood plains, which were used for paddy production and wetlands for grazing. However, only 5,000 km^2 remained after the expansion of the Ruaha National Park. Table 3.2 indicates the land use patterns before the expansion of Ruaha National Park (Mbarali District Council, 2010). The primary economic activity for Mbarali district is agriculture. It is estimated that over 83% of the population is engaged in agriculture and livestock farming. The predominant food and cash crop grown in the district is paddy, other crops include maize, sweet potatoes, sorghum, sunflower, onions, cassava, beans, groundnuts and vegetables (Mbarali District Council, 2010).

Table 3.2: Classification of land use patterns in the Mbarali district before the expansion of Ruaha National Park

Classification	Area in Km^2	% Area
Arable land	1,960	12.2
Game reserve	5,200	32.5
Forest reserve	172	1.1
Settlement	6,078	38.0
Swamps, Hills, etc.	2,590	16.2
Total	16,000	100

Source: Mbarali district council, 2002

The Usangu plains form a large part of swamps and large rice irrigation schemes in Mbarali district. Land in the Usangu plains is mainly used for grazing and cultivation (Mbyopyo, 1992). Since the 1950s, there has been a tremendous increase in the livestock population in the area, which is mainly due to the influx of pastoralists into the plains. The plains had been attractive because of the availability of pastures and water (Charnley, 1994). Smallholder farming is practiced by individual farmers, whereas large scale farming is carried out in state farms which are now privatised. Main crops grown in the plains are maize, rice, sorghum and cotton (Table 3.3). Both rain-fed and irrigated agriculture are practiced in the plains, with irrigation canals being fed by major rivers in Usangu (Kikula *et al*., 1996).

Table 3.3: Trends in crop production for the periods 2007/8 and 2008/9

Crop	2007/2008			2008/2009		
	Production (ha)	**Harvest (tons)**	**Production per ha**	**Production (ha)**	**Harvest (tons)**	**Production per ha**
Rice	33,500	117,250	3.5	32,400	106,920	3.3
Maize	33,000	85,800	2.6	28,800	43,200	1.5
Millet	8,000	9,600	1.2	9,200	7,360	0.8
Cassava	3,000	27,000	9.0	1,200	9,600	8.0
Sweet potatoes	4,000	34,000	8.5	1,500	12,750	8.5
Ground nuts	20,500	20,500	1.0	14,800	14,800	1.0
Sunflower	1,500	1,050	0.7	1,200	1,080	0.9
Onions	1,200	11,400	9.5	1,200	11,400	9.5
Beans	21,000	21,000	1.0	12,000	9,600	0.8
Tomatoes	1,050	10,500	10.0	1,500	11,250	7.5
Sugarcane	700	10,500	15.0	700	7,000	10.0

Source: DALDO's Office 2009

Mbarali district consist of three categories of irrigation schemes, these include traditional (57 schemes), improved (17 schemes) and modern (4 schemes) (Mbarali District Council, 2010). Traditional irrigation schemes have been practiced for about 50 years now across the district. Improved irrigation schemes include Madibira, Igomelo, Ipatagwa, Ruanda Majenje, Kimani, Mbuyuni and Uturo, whilst modern irrigation systems are found in the Mbarali Highland Estates Company and Export Trading Company LTD area (Mbarali District Council, 2010).

3.5.3 Ibohora village

Ibohora is a Bena word that means an area with wet soils (*Unyevunyevu*). The area was previously wet due to abundant rain, thus influencing the relocation of villagers; this led to the development of the Ubaruku village. Later, people started to settle back in Ibohora and the village was re-established and registered in 1976 after the villagization program. Ibohora village has 385 households and a population of 708 residents, among them 355 households were male headed and approximately 30 households were female headed (Ibohora village register, 2010). The major ethnic groups are Bena, Hehe and Sukuma. The village is easily accessible by a gravel road throughout the year and has constructed irrigation canals that receive water supply from the Mbarali Rice Farm's main canal. The main socio-economic activities include agriculture, livestock keeping and small businesses. The village is composed of both large scale and small-scale irrigators (commercial rice farming). The large scale irrigator is an investor who owns an average of 3000 ha (Mbararli Rice Farm), whilst small scale irrigators own an average of 800 ha which is sub-divided among owners (Field observation, 2010).

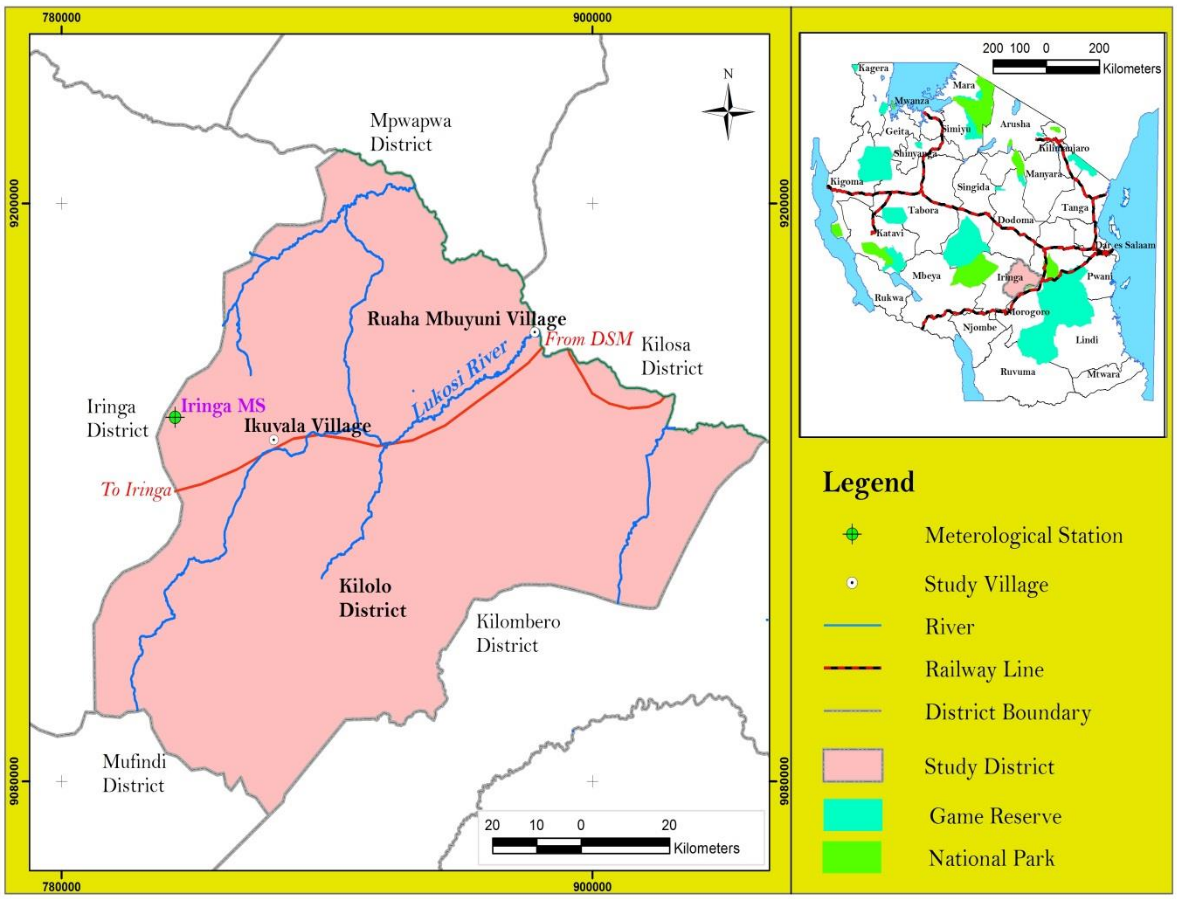
3.6 KILOLO DISTRICT

3.6.1 Location, climate and population

Kilolo district is one of the districts of the Iringa region and occupies an area of 7,881 km^2, of which 6,803.2 km^2 are habitable, whilst national parks, forests, rocky mountains and water occupy the remaining area (Figure 3.3). The district is located between latitude 7° and 8° S and longitude 34° and 37° E. The district had a population of 205,081 counted by the 2002 census, with only 45,337 households. The district has an average household size of 4.5 (Kilolo District Council, 2010).

The topography varies significantly within the district, ranging from highlands to lowlands and valleys. Rainfall in the district is fairly typical of the tropical region and is largely uni-modal with rains starting from November to May, with a peak in March. The average rainfall generally varies between 500 – 2700 mm per annum. Mean temperatures in the higher areas are typically 15°C, and extremes in June and July may vary from below 15°C to 30°C in the lowlands. There are numerous streams which together form major rivers that drain into the Great Ruaha River. The rivers/tributaries include the Little Ruaha, Great Ruaha, Lukosi, Mgombezi, Mgambalenga, Mdahila, Magana, Hasi, Lwipa, Mngeta, Mtitu, Kihansi, Mlawi, Lungu and Mbingwa (Kilolo District Council, 2010).

Figure 3.3: The Kilolo district indicating the study area (Ikuvala and Ruaha Mbuyuni villages)



Source: GIS Lab, University of Dar es Salaam, 2013

3.6.2 Land use pattern and farming practices

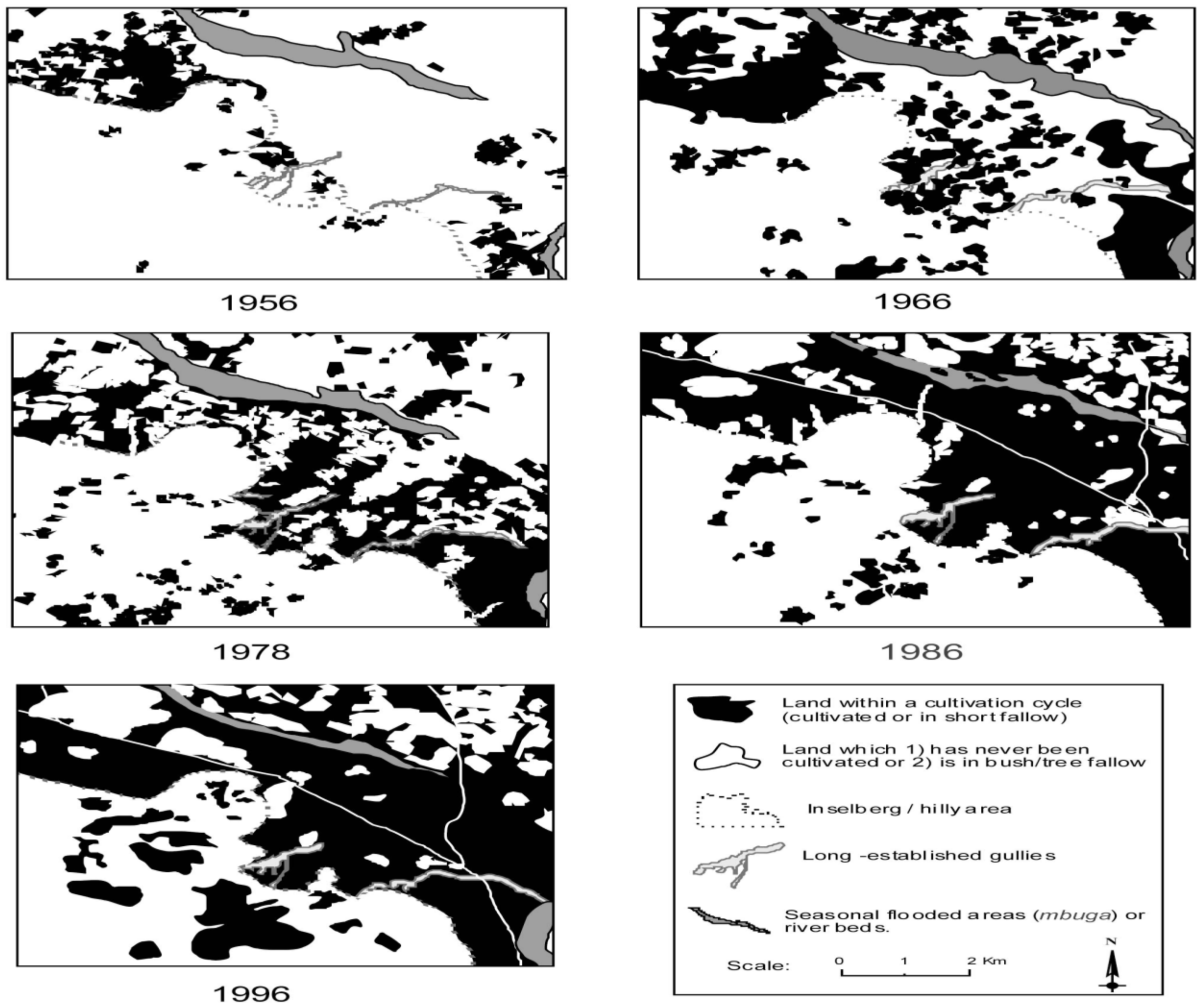
The major economic activities in the Kilolo district are crop and livestock production. The district has 4,735 ha of land suitable for irrigation. There are seven irrigation schemes in the district that utilize 2,035 ha of land; these include: Irindi, Nyanzwa, Mgambalenga, Msosa, Ruaha Mbuyuni, Ukumbi and Ihimbo. Food crops grown in both irrigated and rain-fed farms include maize, paddy, wheat, Irish and sweet potatoes, peas, bananas, yams, fruits and vegetables. Cash crops grown include tomatoes, onions, tobacco, tea, coffee, pyrethrum, a variety of fruits and timber. There are approximately 2,700 ha under fruit and vegetable production. The district produces approximately 200,000 tons of tomatoes per year. The Ilula area (including Ikuvala village) is a centre for tomato production and business in the district. The district also has 58,800 ha of land that is used for free-range livestock grazing. Livestock kept in the district include traditional and dairy cattle, sheep, dairy goats, pigs and poultry (Kilolo District Council, 2010).

Over the last fifty years, land use in the Kilolo district has significantly changed owing to the increase in population and socio-economic conditions. Major changes have been recorded in the semi-arid areas of the district (i.e. the Mazombe division). According to Birch-Thomsen *et al.* (2001), settlements were sparse and located in the foot hills during the 1950s (Figure 3.4). A relatively dense settlement was located close to the main road to Dar es Salaam. Farming activities generally took place around the settlements and along rivers. Furthermore, the study indicates that natural forest dominated the semi-arid area in 1955 (Figure 3.4). Later, expansion of settlements and agricultural land were seen around small Inselbergs (Birch-Thomsen *et al.*, 2001). Upland tomato farming on rain-fed fields started in the 1970s as part of the production system. As a result some households also started farming tomatoes in irrigated gardens leading to further expansion of cultivated land in the area. The crop later spread rapidly and became an alternative to maize as a cash crop (Birch-Thomsen *et al.*, 2001).

3.6.3 Ikuvala and Ruaha Mbuyuni villages

Ikuvala was a sub-village of Ilula Mwaya village until 2010 when it was registered as an independent village. Ikuvala village has 301 households and a population of 1,205 residents, among them 261 households are male headed and 40 households are female headed. The major ethnic groups are Hehe, Bena and Kinga.

Figure 3.4: Land use changes in Ikuvala sub-village: 1956–1996



Source: 1956 aerial photography; 1966 declassified satellite photography; 1978 aerial photography; 1986 SPOT-image; 1996 TM image (after Birch-Thomsen *et al.*, 2001)

The social services available in the village include a primary school, five churches, one pump well for drinking water and a gravel road. The main socio-economic activities include agriculture (rain-fed), livestock keeping and small business enterprises (i.e. shops, selling tomatoes and sunflower, tea rooms and local bars selling *Ulanzi*) (Field observation, 2010).

Ruaha Mbuyuni is a growing business centre compared to Ibohora and Ikuvala villages. Ruaha-Mbuyuni village was registered in 1976 after the villagization programme was introduced. The village has 974 households and a population of 4,226 villagers, among them 2,094 are males and 2,132 are females. During fieldwork the village had been divided into three villages, leaving an approximate of just over 300 households for Ruaha Mbuyuni village. Other villages include Mtandika A and Mtandika B. The major ethnic groups are Sagara, Gogo and Kinga. Recently, the village has experienced accelerated population increases due to immigration of people from nearby villages in search of irrigation water, small business and job opportunities. The main socio-economic activities are agriculture (both irrigated and rain-fed), livestock keeping and small businesses (i.e. shops, selling onions and tomatoes, hotel, tea rooms and local bars). Residents of Ruaha Mbuyuni village depend on the Ruaha and Lukosi rivers for irrigation water through both constructed canals and pumps. They use pumps to irrigate both food and horticultural crops at a small scale level (Field observation, 2010).

Table 3.4: Main characteristics of the three villages

Village	**Main characteristics**			
	Altitude (m a.s.l)	**Average rainfall (mm)**	**Main crops**	**Type of farming**
Ibohora	1050	450-650	Rice and maize	Both rain-fed and irrigated, but mostly irrigated farming of rice (gravity through canals and using motorised pumps)
Ikuvala	1444	500-1000	Tomatoes, maize and sunflower	Rain-fed farming in uplands and valley bottom farming on hired land in neighbouring villages
Ruaha Mbuyuni	550	350-500	Onions, rice and maize	Mainly irrigated farming (both canal and motorised pumps).

CHAPTER 4: ANALYTICAL FRAMEWORK AND METHODOLOGY

4.1 INTRODUCTION

In this chapter two key sections are presented, these include the analytical framework and specific methods used in this study. The analytical framework that was used to explore relevant issues is divided into two sections. The Sustainable Livelihoods Approach and its relevance to this study is highlighted in the first part so as to give a general picture of issues covered. The analytical framework for understanding linkages between perceptions of farmers and climate change and variability, impacts and associated coping and adaptation, is presented in the second part. The methodological approaches that formed the basis of this study are presented in this chapter. The research strategy, data requirements and sampling procedures, data collection methods and analysis techniques are highlighted. Moreover, the limitations of the study are reflected in this chapter.

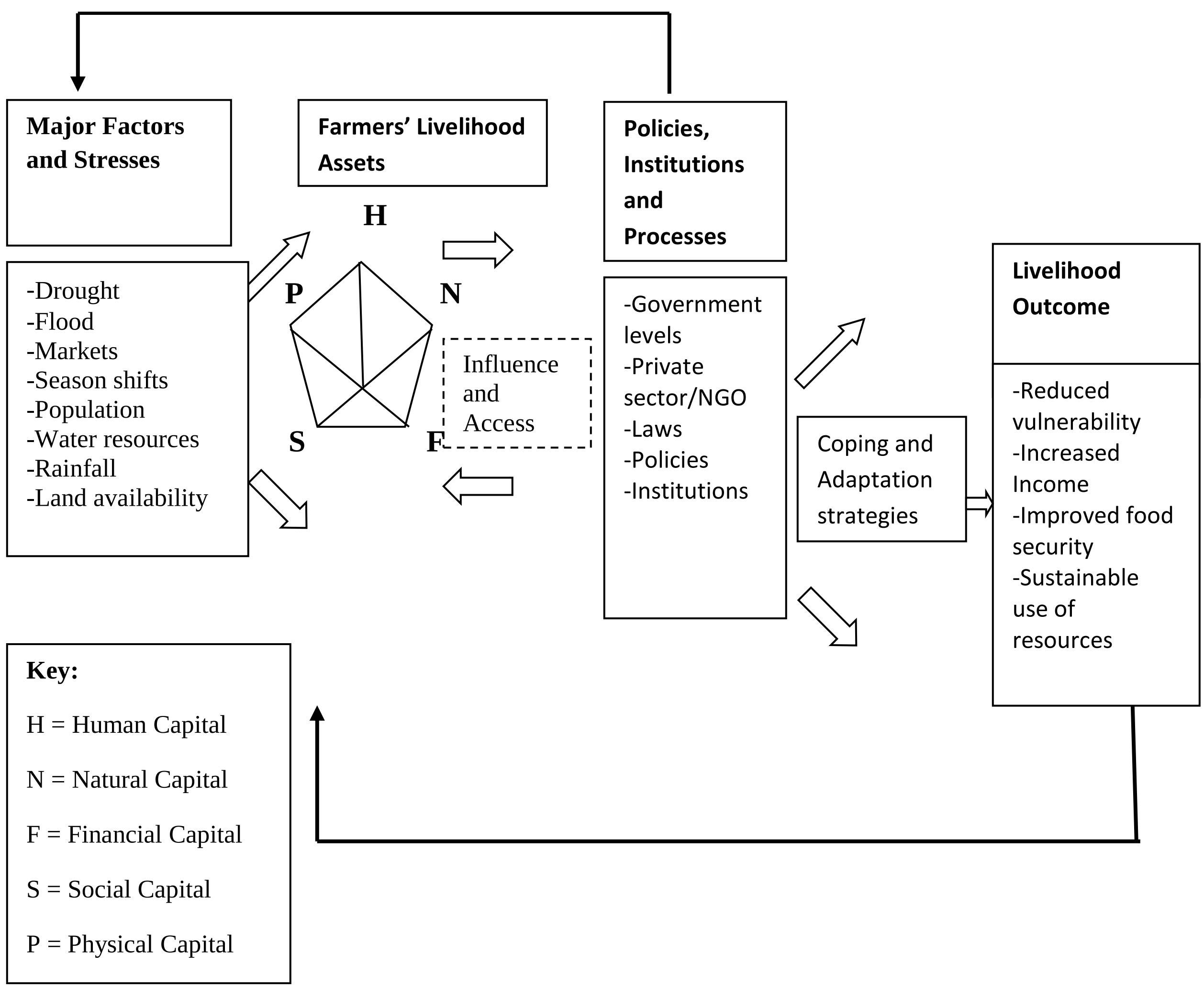
4.2 CONCEPTUAL FRAMEWORK

4.2.1 The sustainable livelihoods approach

The Sustainable Livelihoods Framework tries to link different aspects (i.e. vulnerability context, livelihood assets, institutions, networks, adaptation strategies and livelihood outcomes). It is a conceptual framework that takes an asset/vulnerability approach to establish the livelihoods of poor people. It defines five types of asset: human capital (health, labour capacity, education, skills), social capital (the ability to draw on support through membership of social groups, networks), natural capital (land, water, access to natural resources), physical capital (water supply, quality housing, communication, energy, irrigation schemes), and financial capital (savings, pensions, wages, access to credits) (Figure 4.1). It also provides a framework for addressing policy issues relevant to the poor (Ashley & Carney, 1999)**.**

Some studies (e.g. Scoones, 1998; Batterbury, 2001; Porro, 2005; Eakin *et al.*, 2006) used the livelihood framework approach as a tool in understanding rural community responses to environmental and social stresses. The livelihood approach shows how social and environmental changes are closely connected to local level decision making processes. The approach also introduces adaptation and vulnerability contexts that shape the human-environment interactions and influence the change process in rural communities. In this PhD study, the concept of adaptation is given special attention because it links livelihood assets, transforming structures and the resultant livelihood outcomes (see details in Chapter Two).

Figure 4.1: The Sustainable Livelihood Framework



Source: after Ashley & Carney, 1999.

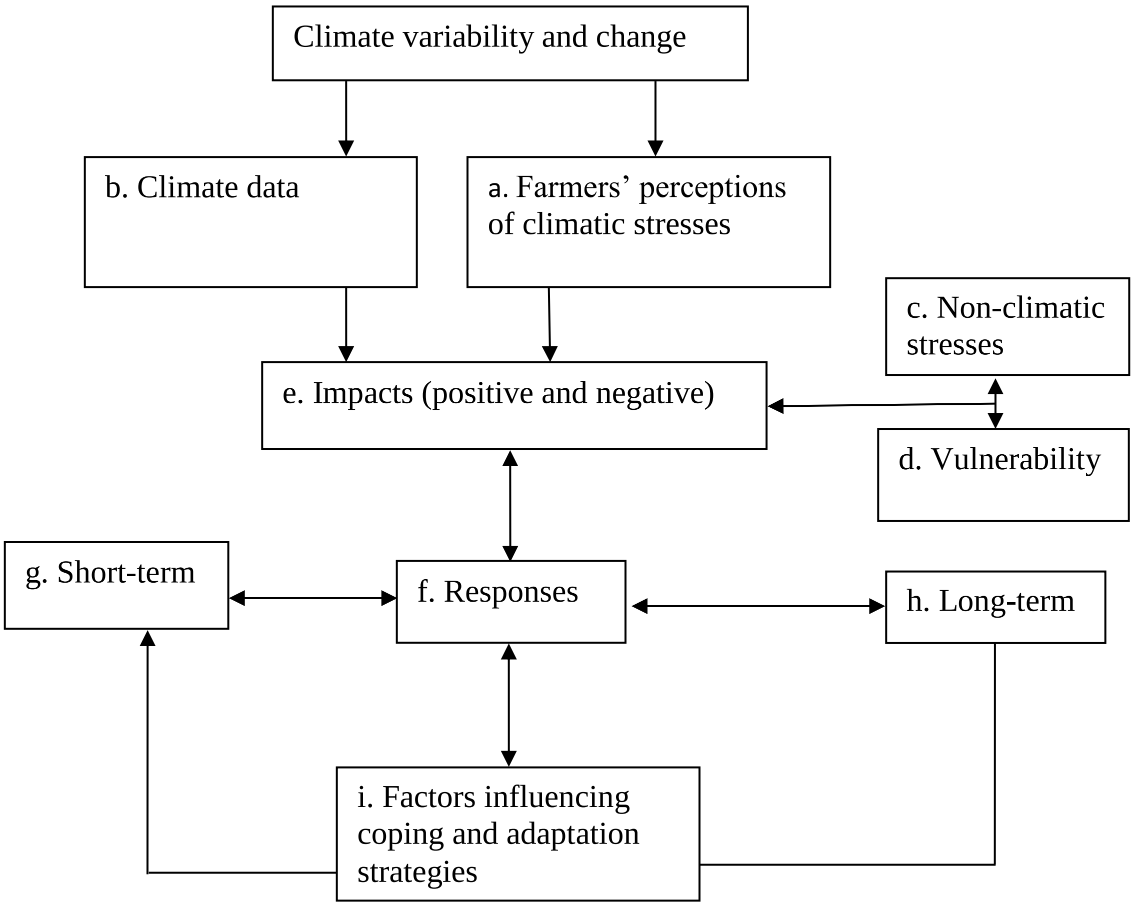
The framework summarises issues that were addressed by this study (Figure 4.1). It was used to characterise farmers according to the livelihood assets they possessed (see Chapter Five section 5.2). Perceptions and experiences of extreme events (e.g. floods, droughts) were gauged from different categories of farmers with access or possession of a certain set of livelihood assets (e.g. poor and rich). This helped to analyse the differential vulnerability to climatic stresses between wealth groups. Therefore, this study focused on the following components of the framework: major factors and stresses (the vulnerability context), farmers' assets/capitals, adaptation strategies and livelihood outcomes.

4.2.2 The relationship between farmers' perceptions, coping and adaptation strategies

The details regarding perceptions, coping and adaptation concepts have been provided in Chapter Two. In this section, the contextual linkage between these concepts is provided. The linkage informs data collection and discussions in Chapter Five. Therefore, the analysis of data and synthesis of this study is guided by the analytical framework highlighted in Figure 4.2. The constructed framework indicates the linkages between perceptions, impacts and responses strategies to climate change.

A thorough understanding of local perceptions on climatic stresses is important as they are related to and guide response strategies to such changes (Eyob, 1999; Legesse, 2006). This formed the first part of data collection. Farmers were asked about their perceptions on the climatic stresses, such as rain season patterns, variability in rainfall and temperature, dry spells and droughts/floods. The study took into account the differentiated perceptions among various household categories, such as socio-economic, cultural and environmental settings (Mubaya, 2010). Climatic data from three meteorological stations in the sub-basin were collected and analysed (see details later in this chapter). The aim was to corroborate farmers' perceptions with observed rainfall records. Apart from climatic stresses, the study also sought to investigate non-climatic stresses in the study area. It is important to note that farmers' livelihoods are impacted by both climatic and non-climatic stresses. Some of the non-climatic stresses investigated include market changes, access to financial facilities, access to farm inputs and implements, infrastructure and government support. This analysis is covered in detail in Chapter Five.

Figure 4.2 An analytical framework for analysing results in this thesis.



After analysing farmers' perceptions to both climatic and non-climatic stresses, the focus turned toward investigating the impacts of such changes on smallholder farmer livelihoods. Mubaya (2010) noted that farmers' perception of climatic stresses needs to be studied in the context of impacts of such stresses. Therefore, both positive and negative impacts were investigated in the study area. The vulnerability of smallholder farmer livelihoods to the impacts of such changes was analysed. Both the starting-point and end-point perspectives of the vulnerability concept (see details in Chapters One and Two) were investigated and analysed.

After detailing the impacts of both climatic and non-climatic stresses to the livelihoods of smallholder farmers, the focus turned to investigating the responses employed by farmers in times of stress. In this study, responses were categorised into short-term coping strategies and long-term adaptation strategies (see details in Chapter Two). Response strategies were investigated at both the household and community levels (see details later in this chapter). As noted earlier in this section, the perceptions of farmers on climatic and non-climatic changes is the pre-requisite to both coping and adaptation strategies. This means, farmers start responding once they perceive a change. However, other researchers claim that perception of climatic stresses does not necessarily lead to adaptation to such stresses (e.g. Mapfumo *et al*., 2008). As noted later on in section 4.9 in this research, the assessment of perception is not always simple due to poor recall by respondents. However, the use of both farmers' recounts and rainfall station data helped to overcome this shortfall (Figure 4.2: a, b boxes).

Moreover, different factors influencing the choice of response strategies by farmers are worth considering in this study. Some of these factors include demographic characteristics of the household (e.g. age, sex and marital status of the household head), access to information (e.g. extension and climate services), location and wealth status of the household. These were analysed to show how they influence farmers' choice of response strategies when stress occurs (see details in Chapter Five).

4.3 STUDY DESIGN

This PhD study is part of a broader capacity building project titled "Impacts of Climate Change on Water Resources and Agriculture - and adaptation strategies in Tanzania (CLIVET)" funded by the Danish International Development Agency (DANIDA). The overall objective of the project is to contribute to the development of capabilities of Tanzania to encounter the impacts of climate change on the water and agricultural sectors, and develop best strategies to adapt to these changes. By providing increased local research capacity within climate change and adaptation in agriculture, the project enhances the national competences to confront pressing issues of climate change, both more generally in terms of capabilities to projected climate changes, as well as to assess the potential impacts on water resources and agricultural production and develop adaptation measures.

The overall project was divided into three work packages:

- **Work package 1:** Projecting and assessing climate change in the GRRB in Tanzania (in short: **Climate**)
- **Work package 2:** Projecting and analysing impacts of climate change and adaptation measures on hydrology and water resources within agriculture in the GRRB in Tanzania (in short: **Water resources**)
- **Work package 3:** Analysing climate change impacts and devising adaptation strategies in the Tanzanian agricultural sector (in short: **Adaptation**).

The work associated with work package three was key to this PhD study. The research focused on examining farmers' vulnerability, coping and adaptation strategies to climate change and variability, particularly in the agricultural and water sectors. Both qualitative and quantitative data were collected so as to adequately address the specific objectives of work package three.

4.4 MANAGEMENT OF FIELDWORK

Fieldwork for this PhD study was undertaken in two phases. The first phase involved the collection of qualitative information, whilst the second phase entailed the collection of quantitative information and in-depth discussions with a variety of stakeholders (e.g. with representatives from local case studies and with district officials). The research began with a familiarisation visit to the regions covering the Great Ruaha River sub-Basin, with the aim of selecting study villages and obtaining study permits. This exercise was done in consultation with local authorities and other team members in the wider CLIVET project. After obtaining research permits for the study villages, the researcher undertook a preliminary field visit so as to gather general information and meet local leaders in the respective villages. Information collected includes regional and village profiles (number of households and various land use activities) (Table 4.1). Ultimately, this formed the basis for establishing suitable sample sizes, and informed the methods to be considered during data collection.

Table 4.1: Information collected during the preliminary fieldwork.

Method	Information collected
Key informant interviews (Regional and District Agriculture officers and District Executive Directors)	Regional and district profiles
Key informant interviews (Village leaders)	Village profiles and land use history

4.5 RESEARCH METHODOLOGY

Both qualitative and quantitative approaches were used in this study. These approaches are complementary and they provide different perspectives trying to answer various questions (RDSU, 2003). The research undertaken adopted a multi-method design, which included various techniques (e.g. questionnaire and PRA) (Flick, 1998; Denzin & Lincoln, 2000). According to RDSU (2003), using both qualitative and quantitative methods help to triangulate and validate research findings. Another advantage of qualitative methods is that they are effective in identifying intangible factors, such as social norms, socioeconomic status and gender roles. Moreover, when used along with quantitative methods, qualitative methods help to interpret and better understand the complex responses and the implications of quantitative data (Strauss & Corbin, 1990; Liwenga, 2003).

The above techniques were used in order to collect information and build a detailed picture of coping and adaptation strategies across households and communalities at each site. Other studies from different regions across the world used similar approaches and methods. For example, studies in Africa, Belona Island, Latin America and Asia used methods such as researcher's observation, a questionnaire survey, focus group discussions, and historical timelines (Eakin, 2005; Paavola, 2008; Reenberg *et al*., 2008; Eriksen & Silva, 2009, Mertz *et al*., 2009; Nielsen & Reenberg, 2010; Mubaya *et al*., 2010; Deressa *et al.*, 2011; Habiba *et al*., 2012).

4.6 DATA COLLECTION METHODS AND HOUSEHOLD SAMPLING

a. Data sources

Data collection included both the collection of primary and secondary data sources (Table 4.2). The secondary data sources included documentation from various sources such as those locally available in the study area, government offices such as the Tanzania Meteorological Agency (TMA) and the National Archive of Tanzania.

Table 4.2: Primary and secondary sources of data and information collected.

Source of data	Information collected
Secondary data sources	
a. TMA.	Climatic parameters, e.g. rainfall and temperature data.
b. The National Archive of Tanzania.	Old records (last ca. 100 years) of climatic variability, rainfall data and narrations of long time weather changes in the study regions.
Primary data sources	
a. Focus group discussion: Farmers: mixed gender and age	Historical timelines and multiple stresses, crops grown, livestock, livelihood, farming practices, coping and adaptation strategies, weather trends and water use management.
b. Questionnaire survey: Household heads (90 surveys).	Household characteristics, perceptions of climate change, impacts, vulnerability to climate variability and strategies to respond to climatic stresses
c. In-depth case studies: Individual men and women from both female and male-headed households.	General household characteristics, perceptions on climate change, impacts of climate change and response strategies.
d. Key informants: District and village officials.	The role of the government during food shortage and climatic extreme events, such as droughts and flooding.

The source of primary data was mostly from the local communities and district officials, including individual household members, farmer groups and district officials (e.g. Agriculture officers, Community Development officers and Natural Resources officers).

b. Sampling

Sampling of households to be included in this study was preceded by defining what constitutes a household. A household is the basic unit of production and consumption in the villages; hence it was used as a unit of analysis, preferably with the heads of the households as informants. According to Mung'ong'o (1995), the definition of 'household' has been a contentious argument that has led to a voluminous body of literature. It is difficult to find a universal definition applicable to all households, since it is not easy to know what constitutes a household in different communities.

In addition, the definition of household may depend on the nature of the study to which the household is referred. According to Vedeld & Øygard (1981) the definition of household membership may be based on the following criteria: (i) *Residence:* the household members live in the same unit of hut/house cluster, (ii) *Production or working unit*: the household members work together on common fields as well as in other activities, (iii) *Consumption unit*: the household members pool their income together. The three definitions were presented to the village leaders in the study area and agreed collectively that the first one matches their household types. The definition of a household in this study therefore, is based on the residence; thus, a household is referred to a husband and/or a wife (wives) including children and other dependants living under the same roof or a cluster of several huts/houses around a single compound, answerable to the same head and sharing common sources of income and livelihood. The definition also includes the child headed households (e.g. orphans). A husband with more than one wife but not living in the same residential place is considered as a separate household.

Based on the definition above, village register books containing the names of all households in each village were used to select the households for interview. Village leaders in each village were asked to check whether all their heads of households are listed in the villagers' register book. In each village, respective sampling units were then randomly selected using random numbers. The study placed emphasis on the random selection of sample units to ensure that the sample selected reflects a true representation of the studied population. However, in some cases purposive sampling was used to ensure that particular knowledgeable people are selected for group interview (e.g. in developing the time line of extreme events).

c. Sample size

There are different opinions on the ideal sample size to be selected for study. Boyd *et al*. (1981) have suggested that under certain conditions, such as time and resource limitations, a sample size of 5% is satisfactory. However, Clarke (1986) suggested that for a sample to be representative enough for statistical analysis, a sample size of at least 10% of the total population in the study is recommended. The three selected villages have different numbers of households (385 for Ibohora village, 301 for Ikuvala village and about 350 for Ruaha Mbuyuni village after the village was divided into three villages), hence for comparison purposes, it was decided to select an equal number of households per village. Therefore, 30 households (between 5 to 10% households) in each of the study villages were selected for the questionnaire survey, resulting in a total of 90 surveys. Two groups in each village were selected for in-depth study (focus group discussions), one group for women only and another of mixed men and women (6−12 individuals in each group). The focus group discussions were done several times in each village according to the type of data needed at different phases (i.e. reconnaissance survey, phase one and two of data collection).

4.6.1 Primary data collection

As stated earlier in this chapter, both qualitative and quantitative sampling methods (Chambers, 1992; Kothari, 2004) were used in primary data collection to provide both historical and current information on multiple stresses, including climatic extreme events, perception on climate change and adaptation strategies, land use changes, household socio-economic characteristics and agricultural production. Such methods included participatory rural appraisals such as in-depth interviews, focus group discussions and participant observations (qualitative methods), and questionnaire surveys (quantitative methods).

Primary data collection was undertaken in two phases, with phase one using participatory tools (e.g. group meetings, wealth ranking, community mapping and transect walk, and historical time lines). These tools were used to gather information such as multiple stresses that farmers face (e.g. past climatic extreme events), farmers' perceptions, adaptation strategies and experiences to these stresses using focus group discussions (group meetings). Phase two involved detailed individual interviews (questionnaire surveys) and key informant interviews (case studies), so as to obtain in-depth information on issues of interest.

4.6.1.1 *Phase one of data collection: Focus group discussions*

This phase used qualitative techniques of data collection. These PRA techniques include focus group discussion with key informants, historical timelines, wealth rankings and transect walks (Chambers, 1992; Poffenberger *et al*., 1992; Pratt & Lozois, 1992; Mikkelsen, 1995; Reenberg *et al*., 2008). Such techniques have the advantage of soliciting more information from local people, since they encourage participation and dialogue between local people and researchers, as well as among local people themselves. The emphasis to local peoples' participation in research is the argument that local people have experience, knowledge and the ability to conduct their own analysis (Chambers & Jiggins, 1986).

Based on the various PRA techniques described, focus was on group discussions that were held on separate occasions with some of the villagers in small groups. Groups of key informants of mixed age and gender were also involved in recounting historical climatic extreme events, establishing different drivers of socio-economic and land use changes, and determining wealth rankings.

Focus group discussions involved intensive discussions and interviewing of small groups of people with different wealth status, age and gender profiles (Plate 4.1). The researcher decided to have an interview with a group of women only after discovering that they were not free to express themselves when mixed with men. Another reason is that women are likely to be a highly vulnerable group to climatic stresses in the community studied, because they are responsible for the daily domestic and farm activities of the households. The study by Le Gal (2003) in South Africa revealed that women make up 91% of the household workforce (i.e. share in family workforce). The aim was to avoid biased responses between age and gender groups. These groups were selected for discussion so as to understand circumstances, coping and adaptation perspectives, and experiences from favoured and vulnerable groups in the community. These groups discussed issues of perceptions, time lines of past extreme events, vulnerability, past experiences of extreme events, access to resources, growing seasons, local patterns of coping and adaptation strategies.

Plate 4.1: A group of farmers in a focus group discussion

Source: Fieldwork, 2010

a. Wealth ranking

The wealth ranking technique was used to establish the ways in which people define poverty and identify measurable indicators of wealth. Household differentiation into different socio-economic groups in the study villages was based on the concept of wealth and poverty, as understood by villagers. The underlying idea was that not all farmers are affected equally by the impacts of climate variability/change; and there was a need to differentiate by using factors such as wealth. The wealth ranking approach has been widely used in socio-economic studies of rural communities in several countries including Tanzania (e.g. Boesen & Ravnborg, 1993; Mung'ong'o, 1995; Birch-Thomsen *et al*., 2001; Larson, 2001; Gregersen, 2003, Liwenga, 2003). The primary assumption is that local people know themselves better than the researcher (outsider) and can place themselves into different wealth groups based on their own perceptions of wealth. Moreover, Scoones (1995) argues that wealth ranking using local people is vital in understanding the nature of rural differentiation in a community.

The randomly selected households were ranked according to their wealth status. Indicators for wealth ranking were identified in collaboration between the villagers. Every village established its own agreed wealth indicators, such as ownership of livestock, ox-plough, tractor, bicycle, and house roofed with iron sheets, and other valuable domestic assets. Larsson (2001) and Gregersen (2003) argue that the wealth ranking exercise is subjective, as what is considered as a wealthy household in one village may not be the same in another village.

b. Historical timeline of extreme events

The historical timeline constructed by a group of farmers in collaboration with the researcher, enabled analysis of different stresses/drivers; including past rainfall and temperature patterns, past extreme weather events such as drought and floods, their impacts, and how farmers and herders have responded (short- and long-term strategies) to such events during the past 40 years. Thirty years is usually the minimum period if one wants to make any claims about climate change (Hulme, 2005; Lovejoy & Hannah, 2005). In each of the study villages, the number of people who were selected to participate in the discussions, represented an equal proportion of participants based on their economic activities, gender and wealth groups. One key informant was selected during pre-testing of the tool, from whom the general information about the village was obtained. Farmers were then required to provide a history of extreme events in their locality.

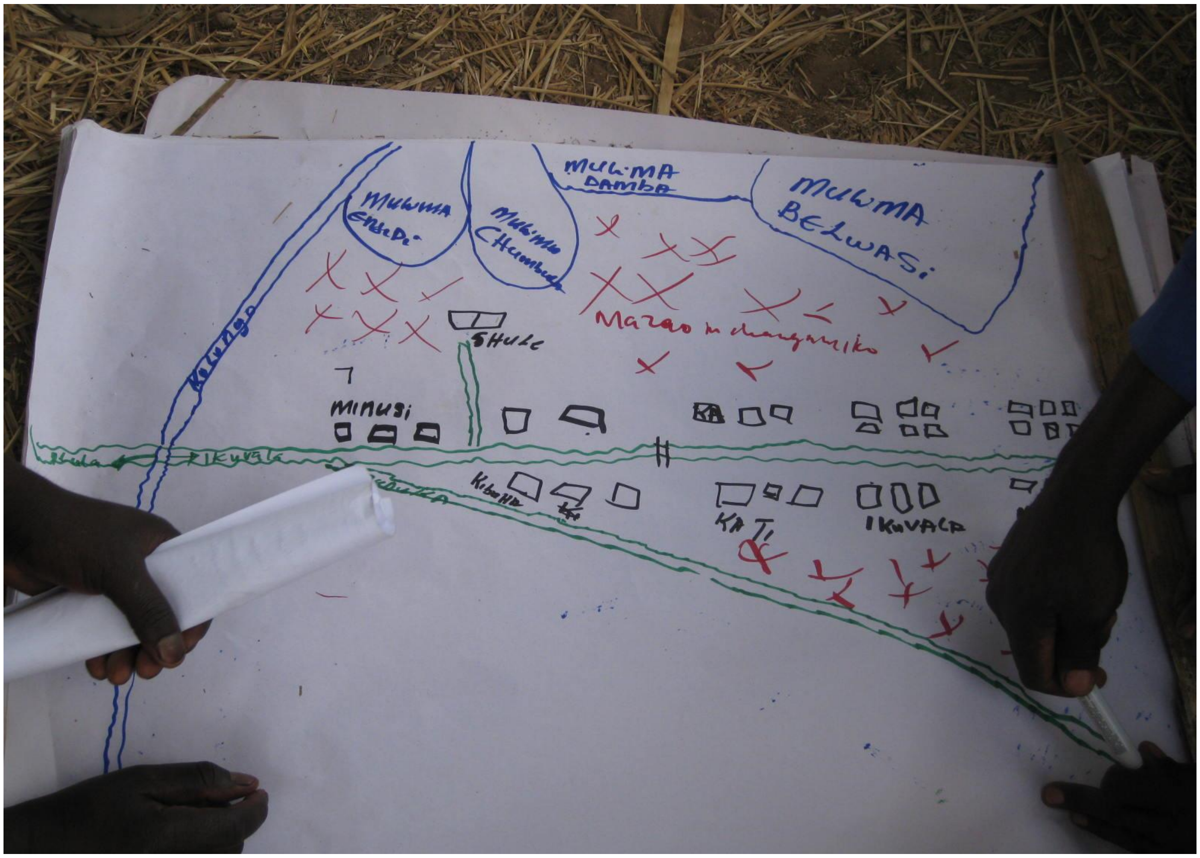
When the historical accounts of extreme events were presented by participants, the researcher would further probe when so required (when, what, how etc.), while plotting the timeline on a flip chart. The time line captured different stresses/drivers of socio-economic and environmental changes (main drivers), including extreme weather events, the year during which the event occurred and impacts. The exercise included primary responses from farmers, showing when there were major changes in their daily life activities over the past 40 years. The exercise was also used to identify important dates for comparison, and compare changes in seasonal dimensions of food productivity and impact of climate variability.

c. Community mapping and transect walk

Participants were asked to draw a village map, indicating the distribution of different ecological zones and their uses (land uses) (Plate 4.2). Other things that they were to show on the map included areas affected by soil erosion, areas with poor soil fertility and those with fertile soils. Reasons for land use changes over time, soil erosion and for poor soil fertility were discussed when the process of drawing maps was underway. Accordingly, some probing questions were asked such as 'when, what, how' etc., with discussions and responses noted.

After a map had been drawn, participants (two villagers and the researcher) walked diagonally across the village (transect walk). The transect walk had been chosen to validate information indicated in the community/village map, such as land use patterns, economic activities carried out in different ecological zones, types of vegetation cover, physical features, land access and/or ownership and land degradation (e.g. Chambers, 1992; Birch-Thomsen *et al*., 2001).

Plate 4.2 Villagers drawing a land use map



Source: Fieldwork, 2010.

4.6.1.2 *Phase two of data collection*

Phase two of data collection involved the use of both qualitative and quantitative methods. The quantitative method used includes the household survey using a semi-structured questionnaire, whilst the qualitative method used involved the in-depth study using key informants.

a. Household questionnaire surveys

Household interviews were conducted using structured questionnaires in order to obtain quantitative information, which could be subjected to statistical analysis, so as to compliment and triangulate the more qualitative information from PRA and documentary data sources. This technique was used to obtain information about household characteristics, household farm size and crops cultivated, farm labour, access to- and ownership of land, land use management, major sources of income, farmers experiences with the past climate variability and changes, farm outputs, sources of food and income during droughts and floods, changes in farming practices, irrigation and livestock fodder. It also asked about perceptions of climate change, indigenous predictions of rain seasons, access to extension services, socio-economic characteristics, and coping and adaptation strategies.

b. *Key informant interviews (case studies)*

Key-informant interviews were conducted with selected representatives of farmers. The researcher approached the village chairman and explained the criteria for selecting the key informants (i.e. wealth rank or economic status, gender and age/farming experience), so as to ensure true representation of the studied communities. The village chairman thereafter helped to select the right respondents for the key informant interviews. Six farmers were purposively selected in each village for in-depth discussions on (a) farmers' experiences regarding the past climate variability and changes (past impacts of climate change) and (b) response measures concerning impacts of climate variability and change (coping and adaptation strategies). District officials and village leaders were interviewed so as to gather information about the role of government during climatic extreme events such floods and droughts.

4.6.2 Secondary data collection methods

District council annual and quarterly reports provided general information on major land use practices over time and irrigation water management (including water use rights). Village annual reports provided information on major crops produced, the estimates of other assets/capital and land use systems. Village annual reports also provided village demographic data, agricultural production and livestock statistics. Daily rainfall data over a 52-year period (1960 to 2012) for the Igawa, Iringa and Mtera meteorological stations in the GRRB were obtained from the Tanzania Meteorological Agency (TMA). Igawa meteorological station was used for the Ibohora village and it is about 10 km from the village. Iringa meteorological station which is about 50 km from Ikuvala village was used for this village. Mtera meteorological station was used for Ruaha Mbuyuni village and it about 50 km from the village.

4.7 DATA PROCESSING AND ANALYSIS

4.7.1 Questionnaire survey data

4.7.1.1 *SPSS and Excel software*

Data from questionnaire survey/household interviews were coded and processed using Statistical Package for Social Science (SPSS) computer software version 16 and Microsoft Excel. The results from this analysis are presented in the form of frequency tables, percentages and cross tabulation distribution to compare different variables within and across the villages. Moreover, qualitative data were grouped into themes and included in the discussion to triangulate the quantitative data. Direct quotes were used to strengthen the analysis.

4.7.1.2 *Logistic regression analysis*

A logistic regression analysis was undertaken so as to determine factors that influence smallholder farmers' perceptions and choice of response measures during dry years. Four groups of factors were tested: (i) demographic characteristics (ii) access to information/education level (iii) location and (iv) wealth rank of the household (Table 4.3).

The dependent variable, which is Y, is either an adaptation or a coping strategy for food shortage presented in Table 4.3. The general model is:

$$Y=b0 + bX1 + bX2+\ldots\ldots\ldots\ldots +bXn$$

Y= either 0 or 1 where 0 means no use of a strategy and 1 represents use of a strategy.

Table 4.3: Definition of variables influencing adaptation and choice of farming practices.

Demographic	
X1- Age of household head	Age of household head in years
X2- Sex of household head	Sex of household head 0=Male, 1=Female
X3 -Marital status	Marital status of household head 0=Single (single, divorce, widowed), 1=Married (married, polygamist)
Access to information and technologies	
X4 – Education level of household head	Education level of household head 0=No formal education, 1=Have primary, secondary or tertiary education
X5 – Access to weather information	Household access to climate/weather services 0=No, 1=Yes
X6 – Change in weather pattern	Observed weather or climate changes by household in the past years 0=No, 1=Yes
Location	
X7- Village	Name of village
Wealth rank	
X8- Wealth	Household level of poverty 0=Poor, 1=Medium or Rich

Selected strategies for responding to food shortage and how they are influenced by different factors include, amongst others: selling livestock (S. livestock), selling household assets (SHA), consuming seed stock (CSS), eating food that is not normally eaten (AFNE), reducing amount of food eaten (RAFE), eating fewer meals per day (AFPD), seeking daily work for cash outside farm (SDWFC), migrating (MIGR), borrowing cash to buy food (BCBF), borrowing food (BF), working in other peoples farms for food (WPFF), selling firewood (SFW), renting out land (ROL), and looking for relief (e.g. government food aid and remittances) (LFR). In contrast, selected farming practices in climate variability or weather changes are such as ripping, use of crop residue, using chemical weed control, tied ridging, ox-plough, pump irrigation, growing drought tolerant varieties, changing crops, mulching and intercropping.

4.7.2 Rainfall data

4.7.2.1 INSTAT software

INSTAT™ software developed by the Statistical Services Centre, University of Reading, United Kingdom, was used to explore the evidence for climate change/variability in terms of the onset and termination of rain, and dry spells during the rain season from 1960 to 2012 (according to data availability in each of the selected meteorological stations) (Stern & Knock, 1998). The analyses were aimed at investigating the possible effects on the length of the rainy seasons and establish whether there is a change in the patterns of rainfall seasons over time in the GRRB. The standardized precipitation index was computed to determine dry and wet years.

Quality control of missing climate data was made to a few data sets using any of the several methods available for filling missing values, as suggested by Mutai (2000). To achieve the outlined objective of the study, the characteristics of daily rainfall data for the study area were explored using a superior software INSTAT to investigate evidence of climate change/variability. Exploration, therefore, concentrated on using daily rainfall records for the preliminary analysis of the specified events, including the start of rains, end of the rain season and the frequency of occurrences of the dry spells during the wet seasons, as outlined by Barrow (2004).

a. Determination of start/onset of rains

The rain event may be defined in different ways for different purposes, and several methods to approach this are in place. In this regard, a day is defined as rainy if it receives a rainfall amount of more than 1mm. This seemingly arbitrary value is to avoid any complications at sites that may be inconsistent in their recording of very small rainfall amounts, and also to avoid possible complications in the use of inches and mm in the recordings. For this study, the start of the rain season was taken as the first date from 1st November receiving more than 20 mm over 1 or 2 consecutive days and not followed by a period of more than 10 consecutive dry days in the following 30 days (Stern *et al*., 2003). This criterion was selected basing on the fact that the rain season in the study area starts in November. This was statistically determined using INSTAT software (Stern & Knock, 1998).

b. Determination of the end of the season (Cessation)

The end of the rain/growing season was determined using INSTAT software based on water balance. The rain season in the study area normally ends in late April or early May. Stern and Knock (1998) determined the end of the rain season using the simple water balance equation as derived below:

The amount of water in the soil on day i+1 is: $W_{i+1}=W_i + P_i - E$

Where Pi is the daily rainfall and E is the daily evapo-transpiration taken as 5.0 mm per day throughout the season. W_i is the amount of water in the soil on a day i. Maximum water storage capacity of the soil was taken to be 100 mm. The end of the season was defined as the first day that W_i becomes zero and remains at zero for more than 5 days.

c. Determination of the length of the growing season

Complete rain/growing season duration (length) was determined based on the method used by Segele and Lamb (2003) where the effective length of the season is the period between rainfall onset and cessation dates. The cessation dates derived from the water balance technique takes into consideration the dry spells that occur during the season.

d. Determination of the mid-season dry spells of 10 or more days

A dry spell occurs whenever sequences of wet days are preceded and followed by dry days. For the purpose of this study, a dry spell is one which receives rainfall amounts of less than 1mm per day. This was determined using INSTAT software (Stern & Knock, 1998). The risk of dry spells was determined by counting the number of dry days of 10 or more days from the start of the rain season. This period was selected because it can affect the growing of crops, especially, maize which is the staple food in the study area (Sawa & Adebayo, 2011).

e. *Determination of drought/flood using the Standardized Precipitation Index (SPI)*

The standardized precipitation index (SPI) developed by McKee *et al*. (1993) was employed to determine wet and dry years. The aim of this analysis is to investigate the drought and wet categories, and frequency at one time step (annually or 12 months) for the past 50 years/growing seasons in the selected study sites within the GRRB. These time scales reflect the impact of drought and excessive rain on agriculture. The time period selected for this PhD study was the rain/growing season that is Nov/October to April/May.

The SPI is defined theoretically as the sub-areas under a normal (Gaussian) probability distribution function. It has many advantages over other drought indices, which require more than two variables, such as the Palmer approach. It considers only two parameters, the arithmetic mean and the standard deviation. For this reason, the current study chose to use SPI as an indicator to determine dry and wet growing seasons.

McKee *et al.* (1993) used a classification system that is normalized so that wetter and drier climates can be represented in the same way (Table 4.4). The SPI is simply the standardization of a given time series, X, as X1, X2, Xn.

$$\mathrm{SPI} = \frac{(x - xi)}{\sigma}$$

Where (x – xi) is the mean and σ is the standard deviation.

Table 4.4: Drought categories defined for SPI values

SPI Values	Drought and wet category
0 to -0.99	Mild drought
-1.00 to -1.49	Moderate drought
-1.50 to -1.99	Severe drought
≤ -2.0	Extreme drought
1.00 to 1.49	Moderately wet
1.50 to 1.99	Severely wet
2.00 and above	Extremely wet

Source: after McKee *et al*., 1993

The SPI is a dimensionless index where negative values indicate drought and positive values wet conditions (McKee *et al.*, 1993). This means that positive SPI values indicate greater than median precipitation, while negative values indicate less than median precipitation. This PhD study adopted the definition of a drought event as defined by McKee *et al*. (1993).

4.7.2.2 Trend and change detection analysis

Point rainfall data were used in order to determine the trend and change in the length of the rain season in the GRRB. The Mann Kendall method and Sen's estimator of slope were used to determine the presence of trends in the time series. The Mann-Kendall test and Sen's slope estimates were used to determine whether there is a significant linear trend in annual precipitation or not. The Mann-Kendall method is a non-parametric test which seeks to determine trends through the existence or non-existence of slope which is then related or transformed to statistical parameters of evaluation. Sen's test on the other hand estimates the magnitude of the slope and the confidence interval for the slope. The Mann-Kendall test can be stated most generally as a test for whether Y values tend to increase or decrease with T (monotonic change).

H0: Prob [$Y_j > Y_i$] = 0.5, where time $T_j > T_i$.

H1: Prob [$Y_j > Y_i$] $\neq$ 0.5 (2-sided test).

The step change detection was analysed using the distribution-free Cumulative Sum (CUSUM) test. Whereby, the change in direction of slope represents a change in time series. The upper and lower confidence limit bands were presented on the graph, where, values that went beyond the normal line indicate that a shift have occurred in the rainfall time series.

4.8 ETHICAL CONSIDERATIONS

Before starting with field work, the researcher sought an ethics certificate from the University of Witwatersrand Ethics Committee (Appendix D), and an introduction letter from the Vice Chancellor of the University of Dar es Salaam, which introduced the study and researchers to the regional authorities where the study was to be undertaken. The ethical guidelines outlined in the APA Ethics code (2002) was considered and included in this study. Each participant was given a participant information sheet before they participated in an interview. The information sheets and consent forms were available in an appropriate language version in order to cater for farmers whose first language is not English. In the information sheets, the nature of the research was explained and it was clearly stated that participation in the research is completely voluntary, and there will be no penalties should they refuse to participate. The information sheet also provided participants with the expected time it will take to complete the interviews. Participants were informed that they may withdraw from the study at any time, and that there are no adverse consequences of withdrawing from the study. Participants were also ensured that the information they gave would be kept both confidential, in that their identities will not be revealed by the researcher or the translator; and remain anonymous (i.e. that the names of the participants will not be attached to the transcribed data).

4.9 LIMITATIONS OF THE STUDY

This PhD study encountered some limitations during the period of data collection and analysis/synthesis of the report. One of the limitations of the study was the difficulty of distinguishing between the impacts of climatic and non-climatic stresses (e.g. demographic, socio-economic and other environmental changes) to the livelihoods of smallholder farmers. Also, there were difficulties in using farmer perceptions of climate change during the past 40 years, due to poor recall. As noted earlier in section 4.2.2 in this research, the assessment of perception is not always simple. Issues of age and memory "golden-age effect" can cloud observations and the ability to recall specific periods of droughts and or flood events and periods. Other researchers also have encountered a similar challenge (e.g. Mendelsohn & Dinah, 2005, Mubaya, 2010). As in the cited studies, this PhD study used a multi-method approach and tried as much to separate the impacts of climatic and non-climatic stresses. Such methods include historical recounts and analysis of rainfall historical records. Therefore, specific perceptions on climatic impacts were related to a specific climatic index, such as delayed onset of rainy season, drought and excessive rainfall/flood. Another limitation was the coarse spatial distribution of meteorological stations across the study area, which made it difficult to obtain actual climate data in close proximity to the study villages. These data were needed for comparing the perceptions of farmers. The researcher had to rely on meteorological stations that were as far as 50 km away from the study villages.

CHAPTER 5: FINDINGS AND DISCUSSION

5.1 INTRODUCTION

Results from this PhD study and a detailed discussion are presented within this chapter. The livelihoods characteristics and vulnerability of smallholder farmers are presented at the beginning of the chapter and linked to the sustainable livelihood framework. The four main parts reflect the four specific objectives of this study and the analytical framework presented in Chapter Four. These parts include *livelihoods characteristics (e.g. livelihoods and vulnerability, and agricultural practices), observed climate variability and farmers' perceptions, response measures* and *factors constraining smallholder farmers' adaptation to climatic stresses*. Similarities and differences across villages concerning climatic non-climatic stresses, and response strategies are detailed.

5.2 LIVELIHOODS CHARACTERISTICS AND VULNERABILITY

In this section, the demographic characteristics, sources of livelihoods and the vulnerability context of the study villages are profiled. Linked to the asset part of the livelihood framework (see details in Chapter Four), household ownership and access to assets and resources are described in this section. Other issues such as education levels and type of farming practiced by households are profiled. This helps to analyse differences and similarities within and across villages.

5.2.1 Household characteristics

Household demographic characteristics are important for assessing vulnerability and coping strategies. Survey results indicate that there is a significant difference in the number of male- and female-headed households interviewed in all study villages (P = 0.006). More male-headed households were sampled in Ruaha Mbuyuni (72.7%) and Ikuvala (69.7%) than in Ibohora village (36.4%). More female-headed households were sampled in Ibohora village (63.6%); this may be due to the fact that most males had both permanently and temporarily migrated to nearby urban centres in search of casual jobs and business opportunities (Table 5.1). Among the migrated males, youths return to the village only during the farming season and leave after harvesting and selling their produce. They were mainly linked to farming for commercial purposes, hence leaving their elders struggling with a workforce deficit. Consequently, recurrent food shortages are experienced in Ibohora village where the available workforce (elders) could only manage to cultivate small tracts of land, which, together with unpredictable rainfall, results in low yields that could not sustain their families until the next harvest.

The overall survey results indicate that most household heads interviewed were within the age group of 16−45 years (38%), followed by 33% (46−60 years) and 28% above 60 years. Few household heads (1%) within the age group of 1−15 years were interviewed because these included orphans only (child-headed households). Results show that more household heads of the age above 60 years were interviewed in Ibohora village, compared to the other two villages (Table 5.1). This may be due to the fact that more youth have been migrating to nearby urban centres.

Table 5.1: Table showing characteristics of the household heads in the study villages

Variable	Categories	Percentage of respondents			Total average N=90	X^2 P-Value
		Ibohora n=30	R.Mbuyuni n=30	Ikuvala n=30		
		%	%	%	%	
Sex	Male	36.4	72.7	69.7	60	10.278
	Female	63.6	27.3	30.3	40	0.006**
Age	1-15	0	0	3	1	7.330
	16-45	27.3	45.5	42.4	38	0.501
	46-60	33.3	33.3	33.3	33	
	>60	39.4	21.2	21.3	28	
Marital status	Married	48.5	75.7	74.6	67	13.235
	Single	51.5	24.3	25.4	33	0.104
Wealth rank	Poor	66.7	36.4	33.3	46	9.556
	Medium	30.3	48.5	57.6	44	0.049**
	Rich	3	15.1	9.1	10	
Education level	None	48.5	27.3	27.3	34	5.768
	Primary	51.5	66.7	72.7	64	0.217
	Secondary	0	6	0	2	

** Significant at 5%

When household heads were asked to rank the wealth category of their households during the questionnaire survey, most of them (46%) identified themselves as being in the poor category, followed by the medium wealth category (44%). A small number of respondents (10%) ranked themselves as rich (Table 5.1). This is justified by results that show a significant difference (P = 0.049) between the wealth ranks of household heads sampled (Table 5.1). Farmers reported during focus group discussions that households within the medium and rich income categories were better placed to respond to the impacts of climatic extreme events. These families could afford to purchase farm inputs and implements such as improved seeds, tractors, fertilizers and pumps for irrigation near rivers. Most importantly, these families had reserves in terms of livestock, food and cash to be used during years with a low crop harvest. This is concurrent with other studies (e.g. Scoones, 1998; Ellis, 2000) which had similar findings. These studies reported that ownership of assets and access to resources (e.g. land and farm implements) increases a household's adaptive capacity to climatic stresses.

Most household heads in all the study villages were married (67%), followed by 33% who reported to be single (Table 5.1). There was a perception in all villages that female-headed households are more susceptible to the impacts of climate variability and change, due to shortages of man-power and lack of material possessions, such as financial capital, land and livestock. Therefore, the marital status of a household head was linked to the way in which they are able to respond to climatic stresses, according to available options or resources. In a study in Zimbabwe and Zambia, Mubaya (2010) found that there was a likelihood of female-headed households to be poor, a situation which can reduce the response options of a family when climatic stresses occur.

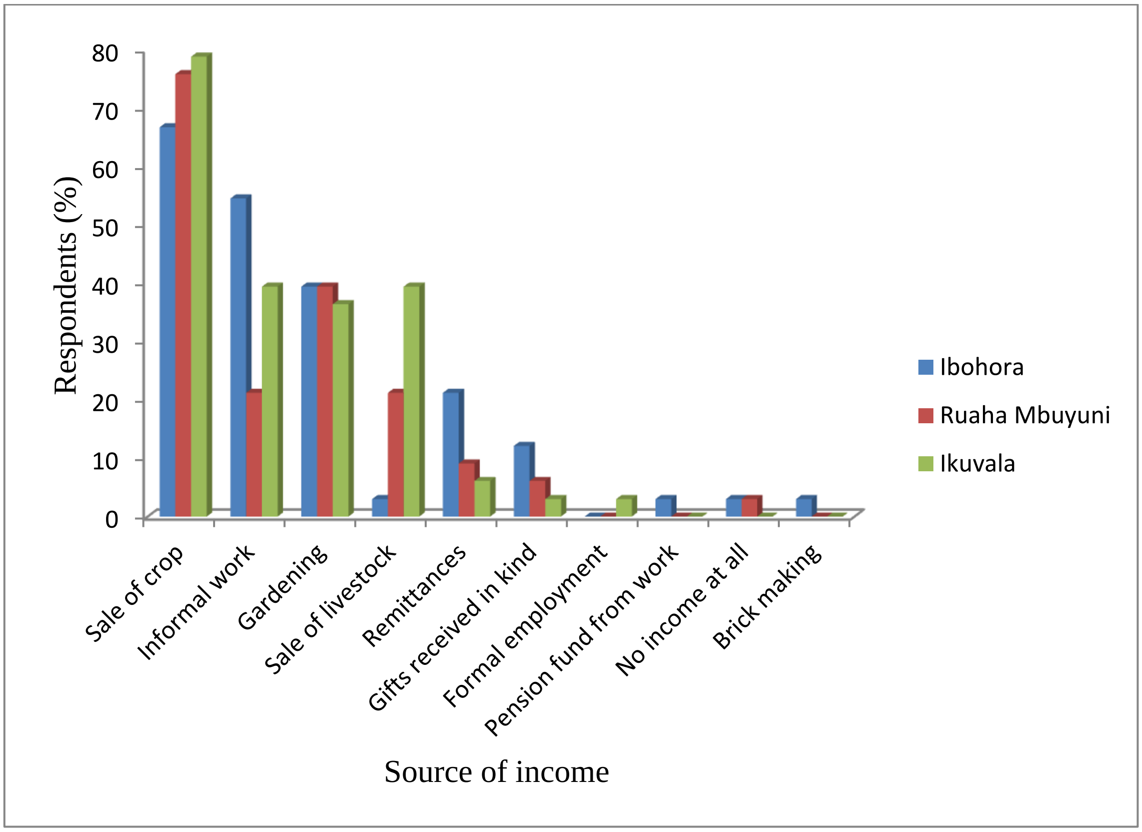
Results show that most household heads in all the study villages attained primary education (64%), followed by 34% who did not attain formal education. Only 2% of household heads had attained secondary school education (Table 5.1). Therefore, the average literacy level of household heads is moderate. The level of education is a very important factor since household heads are decision makers for their families, particularly when it comes to issues of understanding weather forecasting, and adoption of suitable farm inputs and implements (Shultz, 1975).

5.2.2 Household sources of income

The household income source provides an indication of potential vulnerability and coping options (the room for manoeuvre) that the household has when climate related stresses occur. Most households from the study villages (67.7% Ibohora, 75.8% Ruaha-Mbuyuni and 78.8% Ikuvala) accrue their income from selling crops (Figure 5.1). These results reveal that the income of farmers in the study area is closely linked to agriculture, which is a climate sensitive sector. This is in line with past studies showing similar findings (e.g. Agrawala *et al*., 2003; URT, 2003, 2007; Rowhani *et al*., 2011). Furthermore, farmers sell both food and cash crops in order to generate their financial income. Vegetable and spice farming in gardens, together with informal work, ranked second in the list of income sources (39% and 38% respectively). Vegetable garden farming and involvement in informal work were used by farmers as coping strategies during the drought years. Vegetable garden farming was reported to be increasing in all study villages because it involves farming of short-term maturing crops. The advantage of these crops is that they use little water and mature quickly. Therefore, farmers could generate quick cash to use during the poor crop production years and supplement the little income they got from selling traditional cash and food crops.

Selling of livestock is another source of income as reported by heads of households during the focus group discussions. More farmers from Ikuvala village (39.4%) sell livestock as a source of income than those from Ruaha Mbuyuni (21.2%) and Ibohora (3%) villages, which depend on selling livestock as their source of income (Figure 5.1). During focus group discussions, farmers highlighted that livestock are kept for many purposes such as prestige, workforce (ox-plough), food and cash. Farmers normally purchase livestock during the good crop production years and save for selling during poor crop production years. Few farmers reported dependence on gifts (8%) and remittances (12%) received from relatives and friends as their source of income (Figure 5.1). Remittance was reported by farmers as not being a common practice in the study villages because very few households had their relatives employed or doing business elsewhere and sending money back to their families.

Figure 5.1: Household sources of income



5.2.3 Household livestock and asset ownership

Livestock and other household assets are important in providing a coping option as they are used as a saving. Survey results show that more farmers from Ikuvala village (52%) own livestock (cattle, goats, donkeys, poultry and pigs) than those in Ibohora (9%) and Ruaha Mbuyuni (3%) villages (Table 5.2). Results indicate that Ruaha Mbuyuni and Ibohora farmers own more small livestock, such as poultry (33% and 30% respectively), than other types of livestock. Poultry keeping is a way of saving, and farmers could easily sell chicken and purchase food in times of food shortage or exchange poultry for food. Furthermore, livestock are kept equally for cash and food in times of need. Farmers reported that keepers of large livestock (e.g. cattle) own them mostly for wealth and asset accumulation purposes.

Results indicate that more famers from Ikuvala village own ox-drawn ploughs (55%) and ox-cats (27%) than those from Ibohora and Ruaha Mbuyuni villages (Table 5.2). This is due to the fact that more farmers from Ikuvala own livestock and engage mostly in rain-fed cultivation within large agricultural plots of maize and tomato.

Table 5.2: Household livestock and asset ownership

Variable	Percentage of respondents			X 2 P-Value
	Ibohora n=30	R.Mbuyuni n=30	Ikuvala n=30	
Livestock				
	%	%	%	
Own Cattle	9	3	52	24.343 0.000**
Goat/Sheep	3	21	52	19.159 0.001**
Poultry	30	33	55	4.503 0.050**
Donkey	0	3	21	14.616 0.006**
Pigs	3	0	36	23.594 0.000**
Agricultural implements				
Ox-drawn plough	12	6	55	26.545 0.000**
Ox-cat	0	6	27	16.554 0.002**
Irrigation Pump	3	24	0	15.525 0.004**
Sprayer	0	39	27	18.847 0.001**
Hand hoe	100	94	91	6.165 0.187
Home assets				
Radio	55	70	58	5.895 0.207
Mobile phone	39	55	61	6.997 0.136
Sewing Machine	0	3	6	4.286 0.369
Bicycle	58	64	67	5.438 0.245

** Significant at 5%

More farmers from Ruaha Mbuyuni own irrigation pumps (24%) than those from Ibohora (3%) and Ikuvala (0%) villages. Ruaha Mbuyuni village is within the dry-land belt and hence receives insufficient rain to support growing crops. Therefore, most of the farmers use pumps for irrigation to support rice and onion farming. Furthermore, results indicate more ownership of pesticide sprayers by farmers from Ruaha Mbuyuni (39%) and Ikuvala

(27%) than those in Ibohora village where none of respondents own a sprayer. This is not surprising because sprayers are mostly used in large scale farming of tomatoes (main cash crop for Ikuvala) and onions (main cash crop for Ruaha Mbuyuni) where there were more crop pests and diseases.

Hand hoes are owned by almost every household in the study villages, with 100% of farmers in Ibohora village, 94% in Ruaha Mbuyuni and 91% in Ibohora. These results suggest that farmers still rely on hand hoes as the primary means of tillage. About 70% of Tanzania's cropped area is cultivated by hand hoes, 20% by ox-ploughs, and only 10% by tractors (TNBC, 2009; URT 2009; URT, 2010).

With the reported trends of delayed onsets of rainfall and mid-season dry spells in the study area (see section 5.4), it is very difficult for a farmer using a hand hoe to adequately time farming activities. Notwithstanding such observations, soil fertility was reported to be very low in all villages, which means that farmers require large plots of land to harvest enough food and produce cash crops. This may be one of the factors that has contributed to increased levels of poverty and reduced resilience for some of the farmers in these regions.

Most households in all villages reported owning radios (58%), mobile phones (61%) and bicycles (67%) (Table 5.2). Farmers reported that mobile phones and radios are very important tools in providing market and sometimes weather related information. Farmers could easily reach customers from town centres who provided a competitive price for their cash crops. Bicycles are used as a means of transport and for transportation of agricultural crops from farms to markets. According to Brooks *et al*. (2005b), household's access to resources and other assets stimulate economic growth. Therefore, farm implements and inputs, livestock, household assets such as radios and mobile phones, are important assets to help increase household agricultural productivity and improve farmers' resilience to shocks emanating from climatic extreme events.

5.3 AGRICULTURAL PRODUCTION AND IRRIGATION PRACTICES

5.3.1 Land ownership and size of land cultivated

Land is a very important resource to farmers because they depend on it for their survival. Almost every resident in the study villages is engaged in farming. Another observation was that most farms close to rivers, where motorised pump irrigation is practiced, are rented by rich people, and most of them come from nearby urban centres.

Table 5.3: Land ownership and cultivation

Variable	Categories	Percentage of respondents			Total average N=90	χ^2 P-Value
		Ibohora n=30	R.Mbuyuni n=30	Ikuvala n=30		
		%	%	%	%	
Land owned (acres)	<1	9.1	9.1	0	7	16.943 0.259
	1-4	57.6	39.4	30.3	42	
	5-10	18.2	9.1	27.3	18	
	>10	9.1	21.2	21.2	17	
	NA	6.0	21.2	21.2	16	
Land cultivated (acres)	<1	9.1	9.1	0.0	6.1	25.901 0.027**
	1-4	69.7	48.5	42.4	53.5	
	5-10	12.1	15.2	24.2	17.2	
	>10	3.0	3.0	12.1	6	
	NA	6.1	24.2	21.2	17.2	
Land irrigated (acres)	<1	6.1	6.1	12.1	9	41.022 0.000**
	1-4	3.0	45.5	0.0	16	
	5-10	0.0	6.1	3.0	3	
	>10	0.0	9.1	0.0	3	
	NA	90.9	33.3	84.8	69	

** Significant at 5%

Most farmers from Ibohora (56.7%), Ruaha Mbuyuni (39.4%) and Ikuvala (30.3%) own between 1−4 acres of land (Table 5.3). There was thus no significant difference between the size of land owned by farmers in all the study villages (P = 0.259).

Most farmers in the study villages cultivate small plots, this is attributed to poor tillage tools (hand hoes), inadequate workforce and capital to manage large plots. Unpredictable weather was another key factor that forced farmers to cultivate small plots because most of them missed the timing of the rain season. Most farmers (53.5%) from all villages cultivate between 1−4 acres, followed by those who cultivate 5−10 (17.2%) acres (Table 5.3). A small percentage of farmers (6%) cultivate more than 10 acres, and most of these were from Ikuvala village where large-scale rain-fed cultivation of maize and tomato is undertaken. The agricultural sector in Tanzania is dominated by smallholder farmers cultivating an average farm size of between 0.9 ha and 3.0 ha (TNBC, 2009; URT, 2009; URT, 2010).

Irrigation farming was reported by farmers to be the only immediate solution to unpredictable rainfall patterns in the study villages. Irrigation was possible in Ibohora and Ruaha Mbuyuni villages due to available water sources (rivers). There was no source of irrigation water in Ikuvala village and farmers were thinking of the possibility of using ground water for irrigation. Ruaha Mbuyuni village was reported to depend mostly on irrigation because the village is located in the dry-lands. Survey results show that 6.1% of farmers are engaged in irrigation farming of small tracts of land (>1 acre) in Ibohora village. Most farmers (45.5%) who practice irrigation farming in Ruaha Mbuyuni village cultivate between 1−4 acres of land (Table 5.3). Few farmers (12.1%) from Ikuvala village practice valley bottom farming in plots hired in nearby villages. Both canal and pump irrigation methods are used in Ibohora and Ruaha Mbuyuni villages. Practically, there was no irrigation agriculture in Ikuvala; farmers hire land in nearby villages during the dry season or extreme dry years and practice valley bottom farming of tomatoes and vegetables. All irrigators are registered by the Rufiji Basin Water office (RBWO) as Water Users, and they pay for irrigation services (TSHs 35,000/year ~ US$ 22).

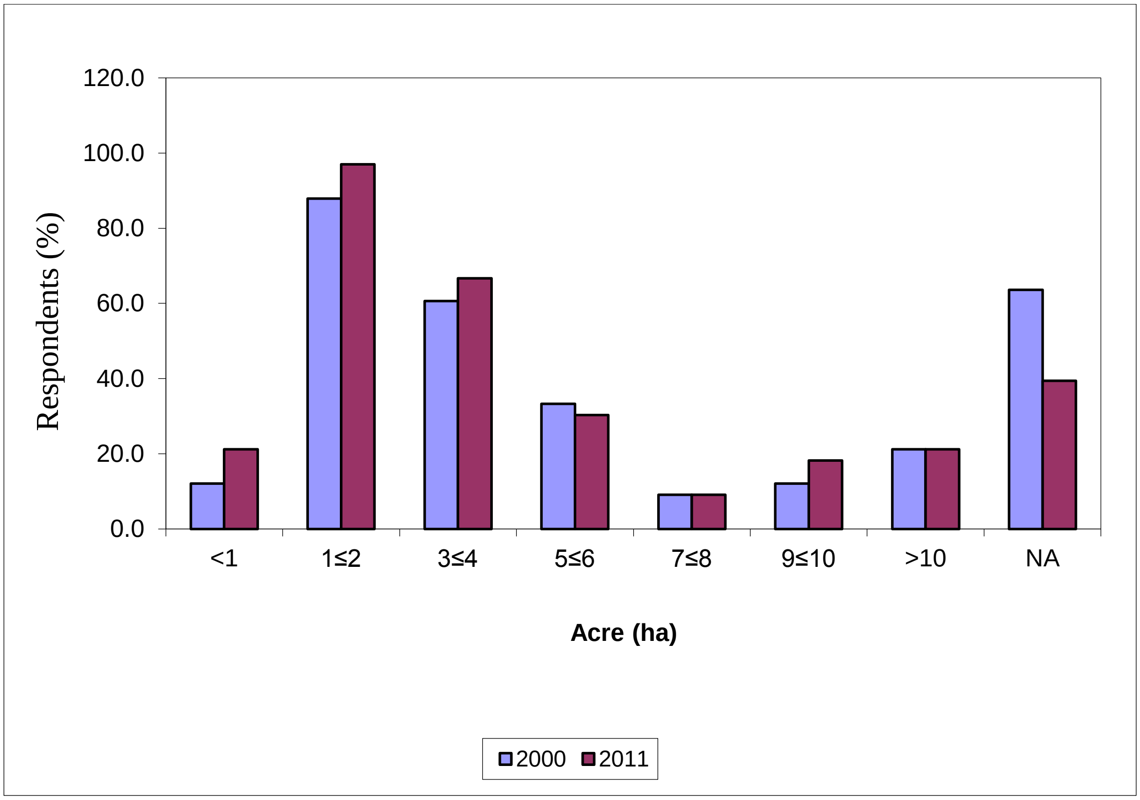
Depending solely on rivers as the source of irrigation water is at times a challenge to farmers in the study area, and was particularly so during the 1990s when major rivers dried up completely due to drought. According to Fox (2004), the Great Ruaha River used to be perennial, but since 1993 there have been increasingly long dry periods during which it has dried up completely. Farmers suggested alternative sources of water for irrigation, such as the harvesting of rain water and groundwater wells.

5.3.2 Past 10 years and contemporary land cultivation

This section highlights changes that have happened within the past ten years with regards the size of land cultivated and drivers for these changes. Survey results show that farmers in the study villages generally cultivated more land during 2011 than in 2000 (Figure 5.2). Ninety seven percent of farmers in all villages cultivated $1 \leq 2$ acres of land in 2011 and 87.9% of farmers cultivated a similar size of land in 2000 (Figure 5.2). The increase was observed by farmers on short-term maturing cash crops such as onions, tomatoes and vegetables. These crops were mostly cultivated in small plots such as near water sources, valley bottoms and lowland areas. Furthermore, more farmers cultivated on plots of $3 \leq 4$ acres (66.7% in 2011 and 60.6% in 2000). Few farmers (18.2% and 12.1%) in 2011 and 2000 respectively cultivated on plots sizes of $9 \leq 10$ acres (Figure 5.2).

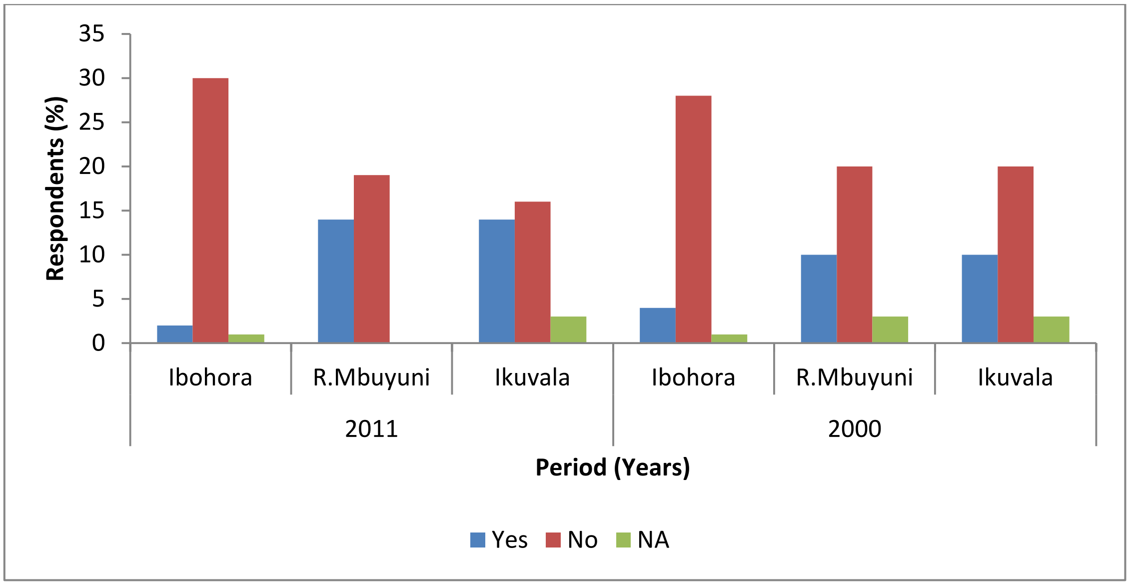
Generally, most farmers in the study villages cultivate between 1 and 4 acres and very few cultivated between 9 to 10 acres of land during 2000 and 2011 (Figure 5.2). Farmers reported that this trend may be owing to multiple factors or challenges that have recently increased in magnitude and frequency, and hence have led to a decrease in the size of farms cultivated. These factors or challenges include a shortage of rainfall, poor timing of the growing season, decline of manpower, inadequate funds to manage farms, lack of access to pump irrigation, recurrent crop failures due to dry spells, increased crop pests and diseases, and access to markets. Such challenges may have demoralized farmers from investing more in cultivation, and thus have diversified to other non-farm livelihood activities, such as small businesses.

Figure 5.2: Land cultivated during the year 2000 and 2011 (estimated percentage)



More farmers hired additional land during the 2011 (14% in Ruaha Mbuyuni and Ikuvala, and 2% in Ibohora) than in the 2000 (10% in Ruaha Mbuyuni and Ikuvala, and 4% in Ibohora) growing seasons (Figure 5.3). Farmers from Ruaha Mbuyuni and Ikuvala villages reported that hiring additional land was becoming common practice. They hire farms in lowlands and valleys that could hold moisture for long periods (four months of the dry season) and hence support growing crops. Hiring of additional land was reported to be driven by many factors, such as the increased demand for tomatoes, onions and vegetables, which are the main cash crops. The decrease in soil fertility also forces farmers to hire additional land to increase productivity. Recurrent droughts and erratic rainfall tendencies are other reasons reported to contribute to the increased hiring of additional land during 2011, compared to 2000. Access to water that could enable pump irrigation farming also contributed to an increasing number of farmers hiring more land during 2011. Moreover, farmers reported hiring additional land in areas which had a year round supply of water for irrigation, and which can thus be cultivated more than once a year.

Figure 5.3: Additional land hired during 2000 and 2011



Similar assessments carried out in different contexts in sub-Saharan Africa came up with related findings (e.g. Eriksen & Silva, 2009; Mertz *et al*., 2009; Nielsen & Reenberg, 2010; Deressa *et al*., 2011). For example, a study in Mozambique by Eriksen and Silva (2009) compared two villages in their analysis. The villages (Matidze and Massavasse) are located in the Limpopo river valley. On the one hand, cultivation in Matidze village takes place mainly in terms of small-scale rain-fed farming, although there are a few smaller pump irrigated farms. In terms of market access, there is a long distance to large markets and limited transportation. On the other hand, Massavasse village is set within an irrigation scheme and is comprised of small, medium, and large-scale farms. The village is close to large markets and has good transportation. Results indicate that during the 2002−2003 drought, Massavasse villagers engaged in pump irrigation and received a good yield; unlike Matidze villagers who had limited access to irrigation farming.

5.4 OBSERVED CHANGES AND FARMERS' PERCEPTIONS

In this section, a focus on describing the nature of the hazard is presented. Here the focus is on interrogating the nature of the hazard, how the variables underlying climate change and climate variability are configured; and whether this configuration of climate is matched with the farmer observations/perceptions. Factors probed here include observed onset, cessation and length of the rain season, droughts/wetness and mid-season dry spells as described in the local meteorological data. This section links to the first objective, which seeks to understand past climate variability and extreme events through both instrumental records and social and anthropological methods that capture detailed lived experiences, perceptions and accounts from local people. This section is also linked to the vulnerability context of the livelihood framework (see Chapter Four). The focus in this section is on observed climatic variability as one of stresses compounding the livelihoods of smallholder farmers. Examinations of projected and observed meteorological and climatological data are presented in the next section.

5.4.1 Climate variability and change: Observed data

The focus for analysing climatic factors (i.e. observed onset, cessation, mid-season dry spells, droughts/wetness and length of the rain season) was at meteorological stations close to the study villages (see Chapter Four). Results for each village are presented in the following sections. The analysis is only based on rainfall variability due to the lack of long-term temperature records from the selected meteorological stations.

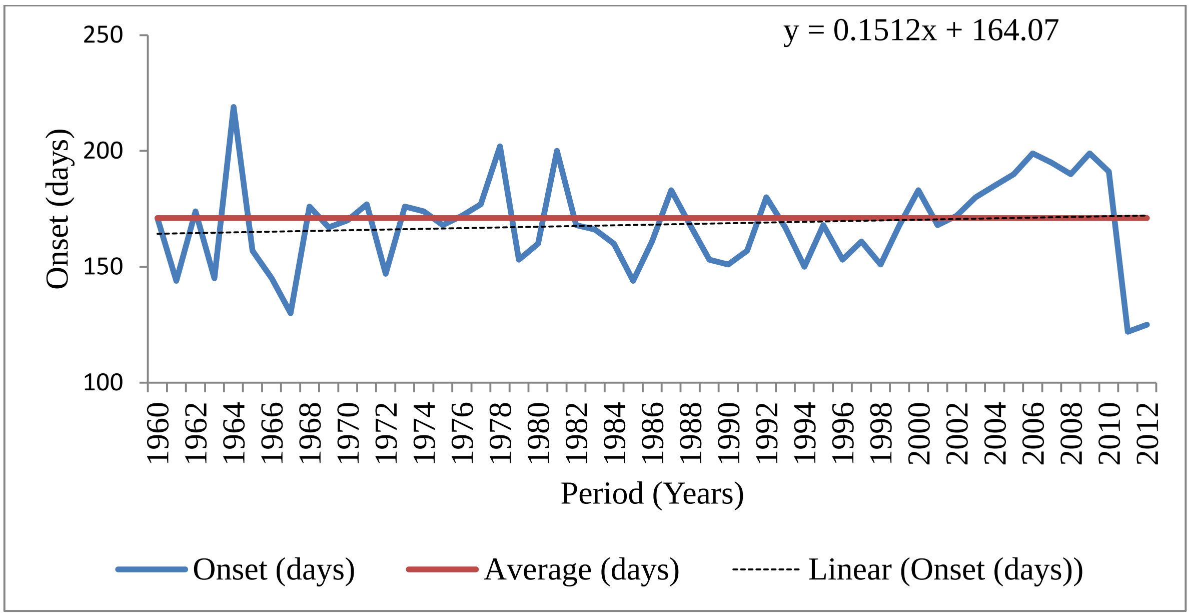
5.4.1.1 *Onset of the rain season*

a. Ibohora village

Results indicate higher than average inter-annual variability of onset dates during the 1960s and early 1980s (Figure 5.4). The average onset date for Igawa meteorological station is day 171 (20^{th} December). Forty four percent (23 of the 52 years reviewed) of the years had later than average onset dates; among them 11 occurred during the last decade. In contrast, 56% of the years reviewed have earlier than average onset dates, and most of them occurred before 1990. Years with the most delayed onsets of the rain season are 1971 (24^{th} December), 1978 (18^{th} January), 1981 (16^{th} January), 2005 (6^{th} January), 2006 (15^{th} January), 2007 (11^{th} January), 2008 (6^{th} January) and 2009 (15^{th} January). Moreover, results indicate delayed onsets for consecutive years during the most recent decade (i.e.

from 1998 to 2011) (Figure 5.4). The linear trend and trendline equation for the onset dates of the rain season in the study area are shown in Figure 5.4. This figure indicates an increasing trend towards later onset dates (y = 0.1512x + 164.07), at a rate of 1.5 days/decade. This implies that rainfall progressively starts later during recent years in the area.

Figure 5.4: Rainfall onsets at Igawa meteorological station

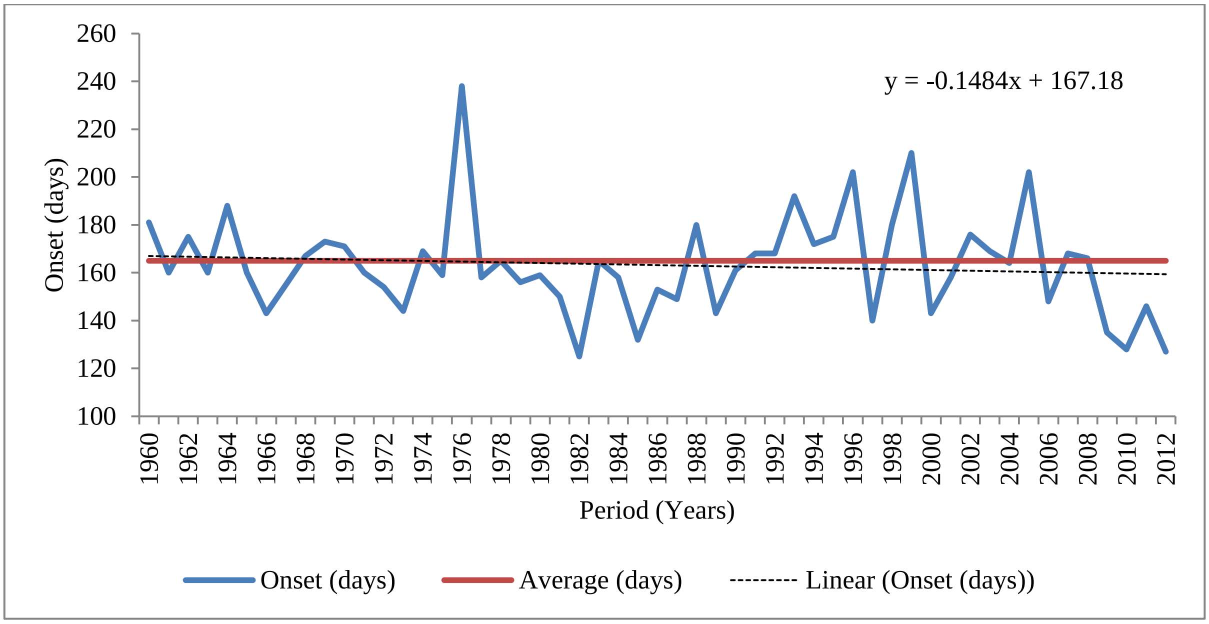


b. Ikuvala village

Daily data from the Iringa meteorological station were analysed to determine the onset dates for the past 52 years (1960-2012). There is higher than average inter-annual variability starting from the early 1990s (Figure 5.5). The average onset date is 12th December (day 165). Twenty one of the 52 years analysed have their onset dates later than average (13 of them occurred during the past two decades). This indicates that more than 50% of the years had early onsets of the rain season. Years with the most delayed onsets are 1976 (23rd February), 1996 (18th January), 2005 (18th January) and 2008 (26th January); years with the earliest onset dates are 1982 (2nd November), 1985 (9th November) and 2009 (12th November). Furthermore, the consecutive delayed onset date of the rain season from the early 1990s to 2012, with exceptions in 1997, 2000, 2009 and 2012, is shown.

Moreover, the trendline equation is negative (y = -0.1484x + 167.18) (Figure 5.5), which means that rainfall progressively starts earlier at a rate of 1.4 days/decade.

Figure 5.5: Rainfall onsets at Iringa meteorological station

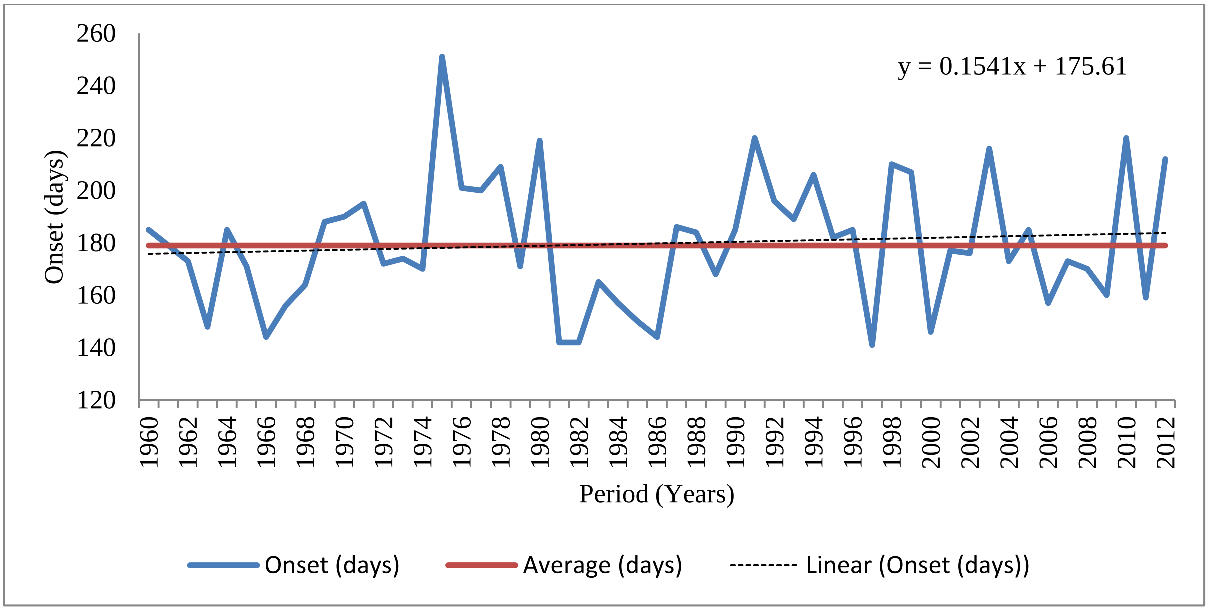


c. Ruaha Mbuyuni village

Generally, there has been higher than average inter-annual variability in the onset dates of the rain seasons during this time period (Figure 5.6). The average onset date is day 179 (28th December), which indicates that 46% of the years had their onset date later than average. Starting from the mid to late 1970s, and then early and late 1990s, the area has been experiencing delayed onsets of rains (Figure 5.6). These years include 1975 (7th March), 1976 (17th January), 1977 (16th January), 1978 (25th January), 1980 (4th February), 1991 (5th February), 1992 (12th January), 1994 (22nd January), 1998 (26th January), 1999 (23rd January), 2003 (1st February), 2010 (2nd February) and 2012 (28th January). Furthermore, years with the earliest onset dates are the mid-1960s and early 1980s. Moreover, the trendline equation for rainfall data at Mtera meteorological station is positive (y = 0.1541x + 175.61) (Figure 5.6). This means that rains are on average being delayed by 1.5

days/decade; however, early rainfall onsets for consecutive years from the mid-2000s had been recorded.

Figure 5.6: Rainfall onsets at Mtera meteorological station

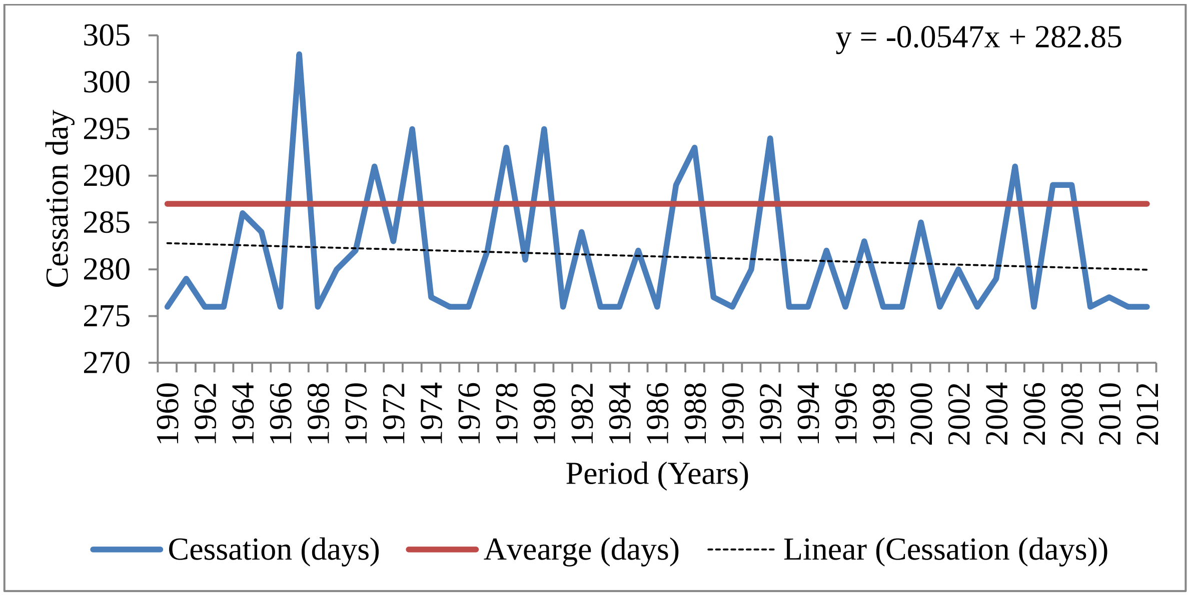


5.4.1.2 *Cessation of the rain season*

a. *Ibohora village*

There is higher than average inter-annual variability in cessation dates at the Igawa meteorological station from the mid-1960s to early 1990s, than mid-1990s to 2000s which show a consecutive early cessation dates (Figure 5.7). The average cessation day is 286 (11th April), which indicates that only 15 years (28.8% of years) had their cessation dates later than average. The remaining years, which are mostly within the last three decades, have had their cessation dates earlier than average. The linear trendline equation for cessation dates of the rain season is negative (y = -0.0547x + 282.85). This indicates that the rains progressively end at a rate of 0.5 days/decade earlier during recent decades (Figure 5.7).

Figure 5.7: Rainfall cessations at Igawa meteorological station



b. Ikuvala village

Results clearly indicate the existence of inter-annual variability in cessation dates over the past 52 years at Iringa meteorological station. However, there is a decrease in inter-annual variability for two consecutive decades after the 1990s. The average cessation date is 9th April (day 285), which indicates that 33 of the 52 years analysed had their cessation dates earlier than average. The linear trendline equation is negative (y = -0.0597x + 285.56), indicating that rain seasons are progressively ending earlier at a rate of 0.5 days/decade (Figure 5.8).

c. Ruaha Mbuyuni village

Results from the Mtera meteorological station indicate that there is a lower than average inter-annual variability in cessation dates (from the average of 8th April), except for the year 1996, which was much later than average (12th June). The rainfall data at Mtera meteorological station show a delayed trend in cessation dates at a rate of 0.2 days/decade (y = 0.0879x + 279.23) (Figure 5.9). Therefore, the higher inter-annual variability of the onset dates impact on the cessation of the rain season.

Figure 5.8: Rainfall cessations at Iringa meteorological station

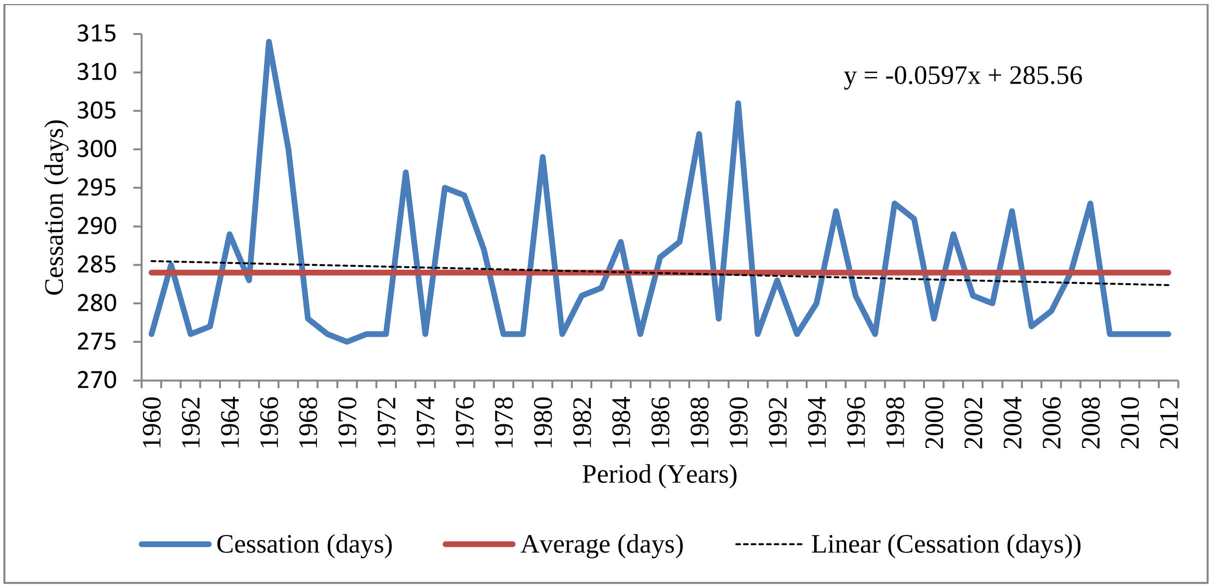
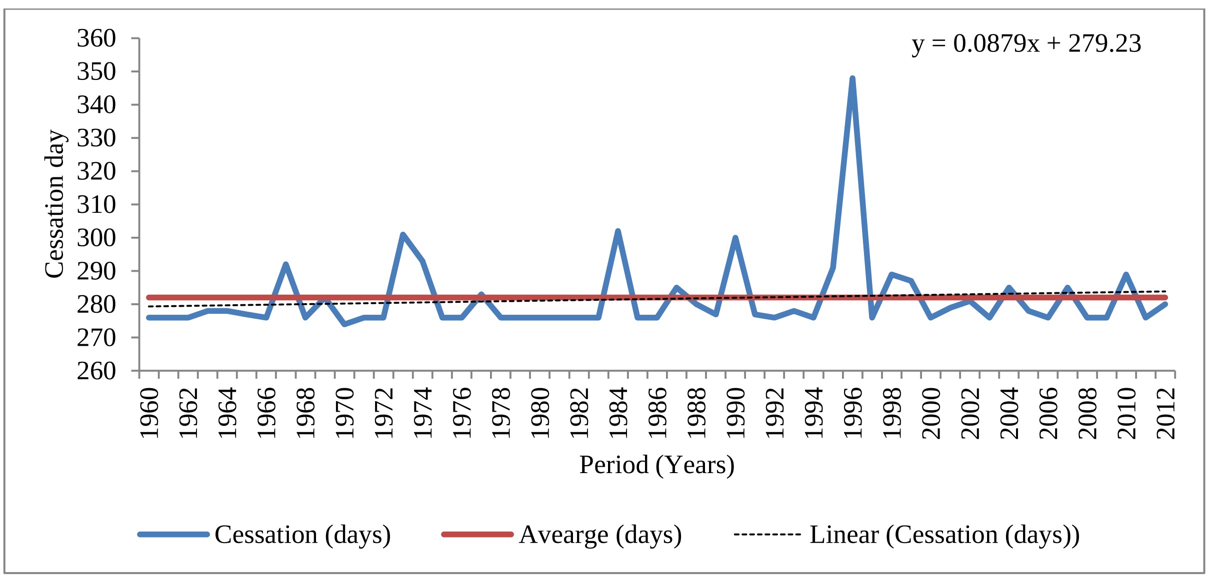


Figure 5.9: Rainfall cessations at Mtera meteorological station

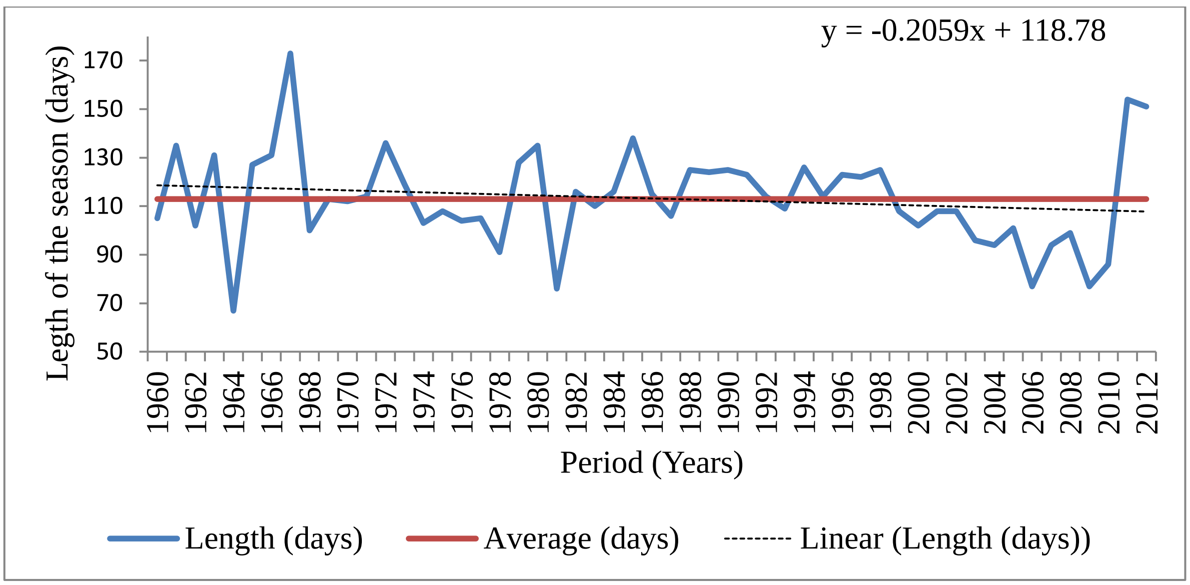


5.4.1.3 *Length of the rain season*

a. *Ibohora village*

The length of the rain seasons for Igawa meteorological station indicates more than average inter-annual variability (Figure 5.10). This trend has been influenced by late onsets and early cessation dates as mentioned. The average length of the season is 113 days, which indicates that more than half of the 52 years analysed have their season lengths shorter than average. The linear trend for the length of the season for the study area is shown in Figure 5.10. The graph shows a decreasing trend in the length of the rain season. The negative trendline equation (y = -0.2059x + 118.78) implies that the length of rain seasons is progressively declining during the recent decades (i.e. by 2.0 days/decade for the Usangu plains).

Figure 5.10: Length of the rain season at Igawa meteorological station



There is a statistically significant decreasing trend of the length of the rain seasons (at a < 0.05) (Table 5.4). There is a statistically significant step jump (at a < 0.05), whereby the season length in earlier years (1972−1999) is longer than that of later years (1999−2009) (Table 5.4). This means that the season lengths are decreasing progressively during the recent two decades. For example, the season length was only 77 days during the rain season of 2009. The length of the growing season was too short to support most crops grown in Ibohora village, such as maize and rice.

Table 5.4: Kendall and CUSUM tests for rain season lengths at Igawa meteorological station

Test statistic	Z statistic	Critical values			Results
		a = 0.1	a = 0.05	a = 0.01	
Mann-Kendall	-2.175	1.645	1.96	2.576	S(0.05)
CUSUM	10	7.521	8.384	10.048	S(0.05)

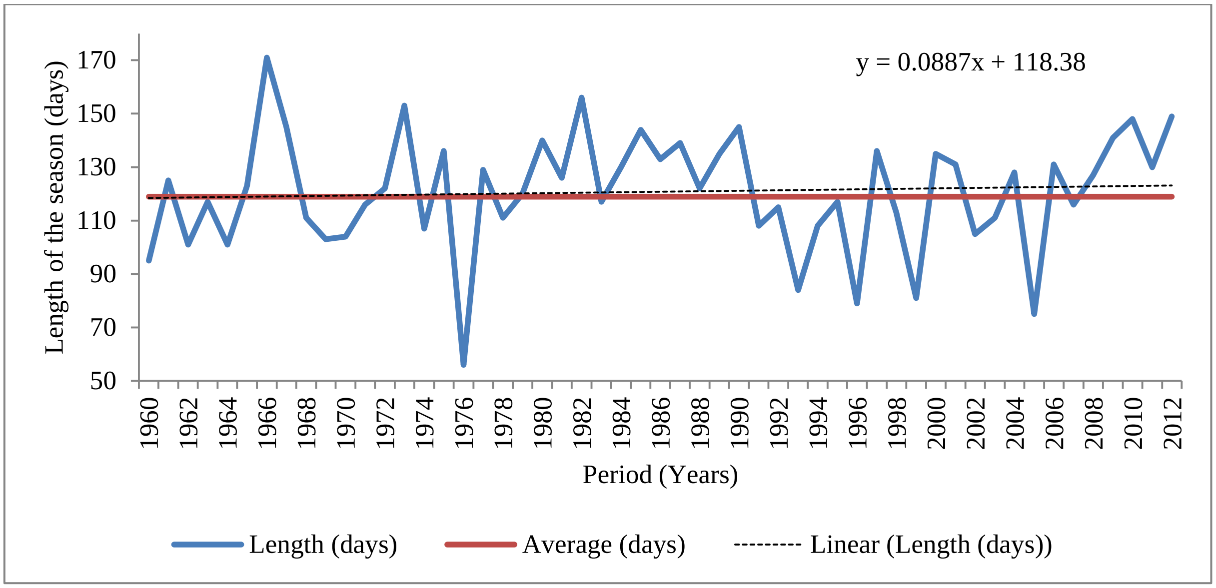
b. Ikuvala village

Onset and cessation dates of rain seasons at Iringa meteorological station indicate that the season lengths have been varying over the past five decades (Figure 5.11). The mean season length is 119 days, which implies that more than 50% of the years have experienced shorter than average season lengths. The graph indicates a consecutive decline in the length of rain seasons, starting from the early 1990s to 2008. Moreover, the trendline equation is positive, indicating an increasing trend of rain season length during recent years ($y = 0.0887x + 118.38$). This implies that the length of the rain season is increasing at a rate of 0.8 days/decade for the Iringa region (Figure 5.11). There is no statistically significant trend (at a = 0.1) for the data. Furthermore, there is no statistically significant step jump (at a = 0.1), in which the season length in earlier years (1971-1989) is not different to that of later years (1989-2008) (Table 5.5).

Table 5.5: Kendall and CUSUM tests for rain season lengths at Iringa meteorological station

Test statistic	Z statistic	Critical values			Results
		a = 0.1	a = 0.05	a = 0.01	
Mann-Kendall	-0.993	1.645	1.96	2.576	NS
CUSUM	5	7.521	8.384	10.048	NS

Figure 5.11: Length of the rain season at Iringa meteorological station



c. *Ruaha Mbuyuni village*

Results from Mtera meteorological station indicate that the mid-1970s, early-1990s and most of the 2000s experienced the shortest rain season lengths; in contrast, the mid- 1960s, 1980s and 1990s experienced the longest rain season lengths. The linear trend and trendline equation for the rain season lengths in the study area are shown in Figure 5.12. The graph shows a negative trendline equation (y = -0.0662x + 103.62), which implies that the length of the rain seasons is slightly decreasing in the area by 0.6 days/decade. The graph shows that the length of the rain season started to decrease in the early 1990s (Figure 5.12).

There is no statistically significant trend in the length of the rain season (at a = 0.1) (Table 5.6). Results further show that there is no statistically significant step jump in the length of the rain season (at a = 0.1), with the length of earlier years (1971−1990) not being different from that of later years (1990−2009) (Table 5.6). This suggests that there has been variability in the season length during the past five decades, with extremes in some seasons, such as in 1996, which was the longest rain season during the 52 year record (197 days).

Figure 5.12: Length of the rain season at Mtera meteorological station

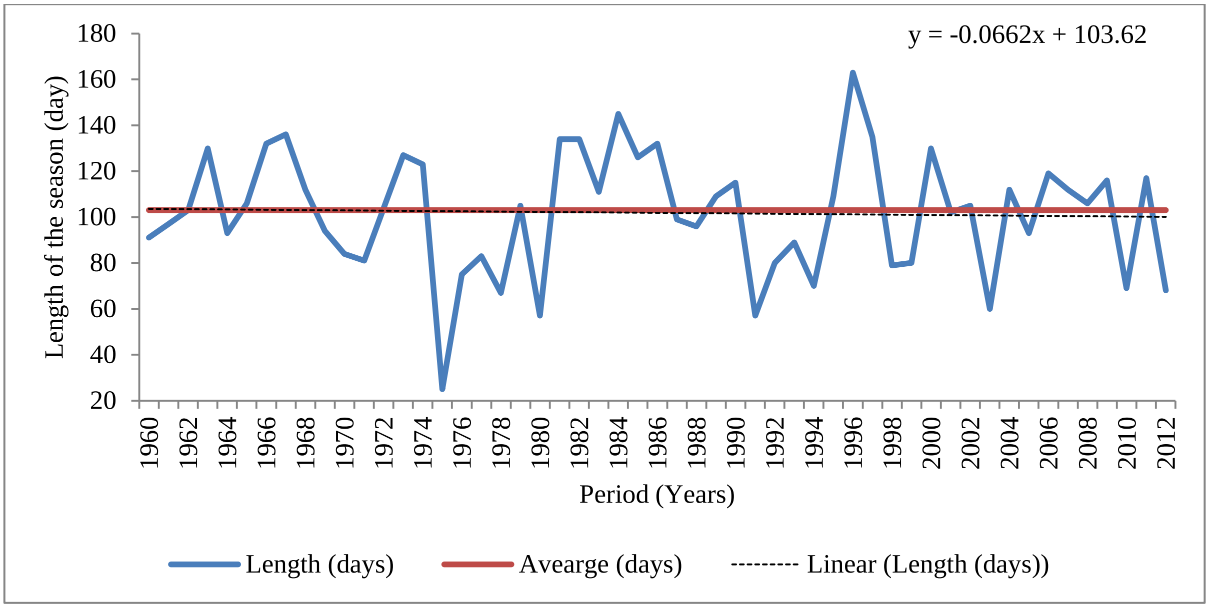


Table 5.6: Kendall and CUSUM tests for rainy season lengths at Mtera meteorological station

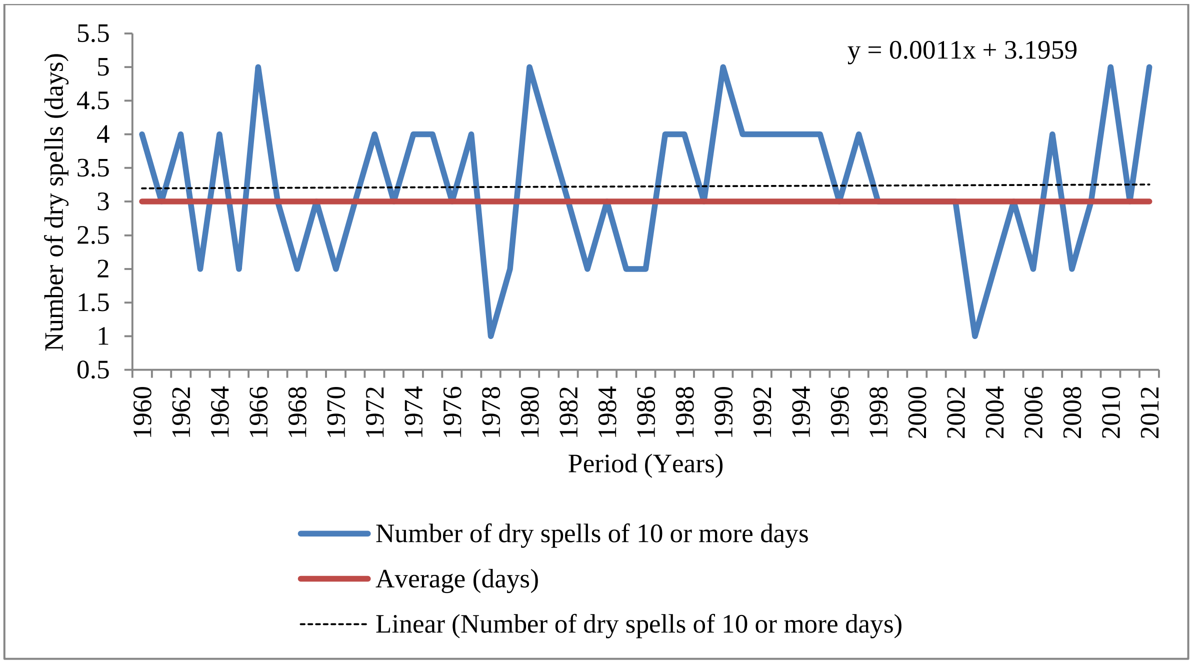
Test statistic	Z statistic	Critical values			Results
		a = 0.1	a = 0.05	a = 0.01	
Mann-Kendall	0.629	1.645	1.96	2.576	NS
CUSUM	6	7.619	8.493	10.179	NS

5.4.1.4 *Mid-season dry spells of ten or more days*

a. *Ibohora village*

Rainfall data at Igawa meteorological station indicate a high inter-annual variability of dry spells of 10 or more days during the past 52 years (Figures 5.13). The average number of dry spells of 10 or more days per rainy season over the past 52 years is 3, whilst the absolute number of dry spells per rainy season during the last 52 years ranges from 1−5. For the past 52 years, 20 years had above average numbers of dry spells, 12 years had below average numbers of dry spells, and 20 years had on average 3 dry spells of 10 or more days (Figure 5.13). The linear and trendline equation for Igawa meteorological station is positive (y = 0.0011x + 3.1959), which implies that there is a progressive increase in the number of dry spells in the area. However, more below average numbers of dry spells starting from the early 2000s are indicated (Figure 5.13).

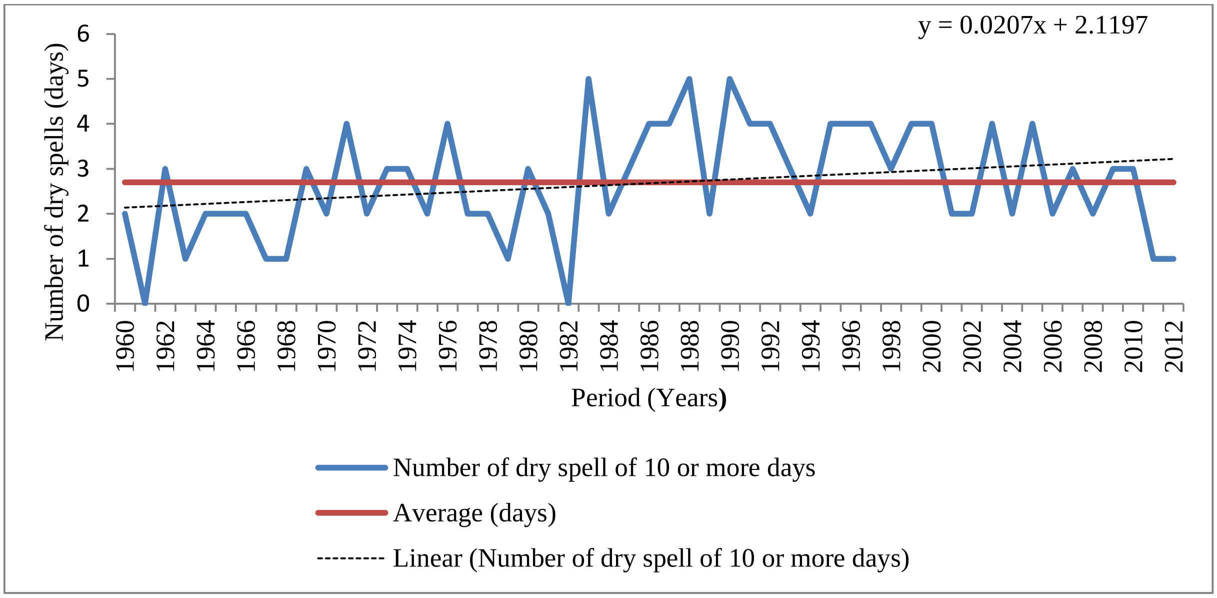
Figure 5.13: Number of dry spells of 10 or more days per rainy season at Igawa meteorological station



b. Ikuvala village

Rainfall data at Iringa meteorological station indicate a high inter-annual variability of dry spells of 10 or more days during the past 52 years (Figures 5.14). The average number of dry spells of 10 or more days per rainy season over the past 52 years is 2.7, whilst the absolute number of dry spells for rainy seasons during the last 52 years ranges from 0−5. Twenty six of the 52 years (i.e. 50%) analysed for dry spells of 10 or more days at Iringa meteorological station are above average (Figure 5.14). These years occurred primarily during the last three decades (1980s to 2010). The linear and trendline equation is positive (y = 0.0207x + 2.1197), implying that the number of above average dry spells of 10 or more days is progressively increasing in the area by 0.2 events/decade.

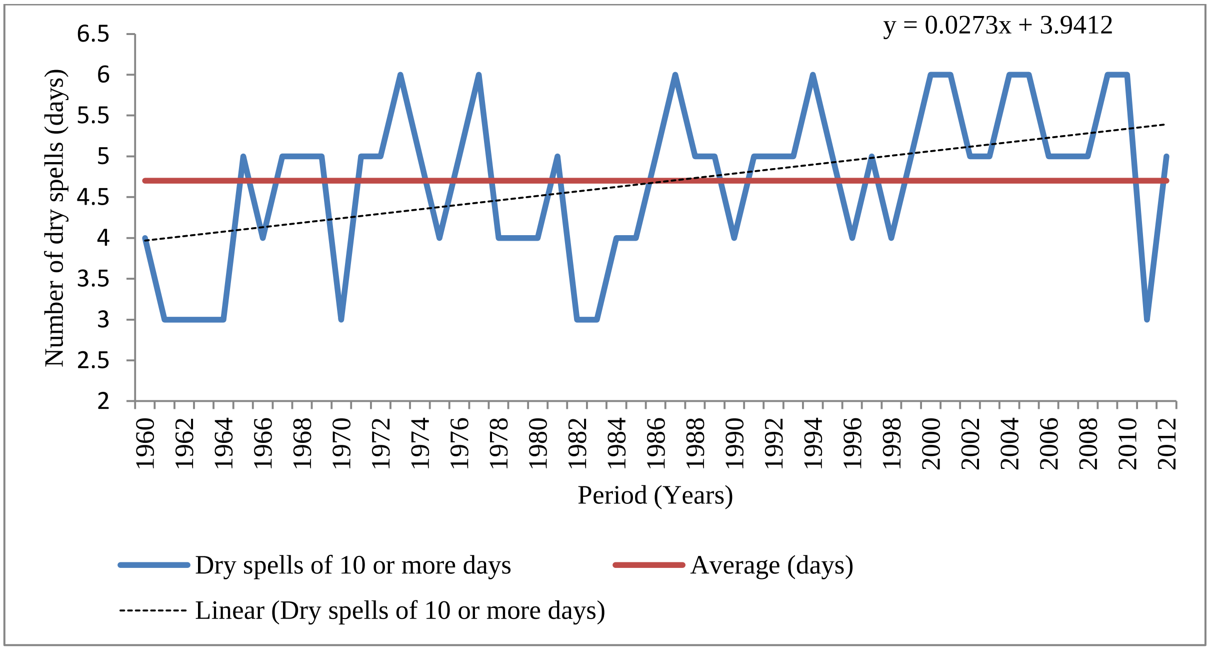
Figure 5.14: Number of dry spells of 10 or more days per rainy season at Iringa meteorological station



c. *Ruaha Mbuyuni village*

Mtera meteorological station indicates a similar trend to that at Iringa meteorological station (Figure 5.15). The average number of dry spells of 10 or more days per rainy season over the past 52 years is 4.7, whilst the absolute number of dry spells per rainy seasons during the last 52 years ranges from 3−6. There is a significant increase in the number of above average dry spells, starting from the mid-1980s (Figure 5.15). Of the 33 years that indicate above average dry spells, 23 (70%) occurred from the mid-1980s to 2010. The linear and trendline equation support this observation, with the equation being positive (y = 0.0273x + 3.9412), implying a progressive increase (by 0.2 events/decade) in the number of above average dry spells of 10 or more days in the area during recent decades. This indicates that the downstream portion of the GRRB has the highest number of dry spells of 10 or more days when compared to the upper and mid portions of the sub-Basin.

Figure 5.15: Number of dry spells of 10 or more days per rainy season at Mtera meteorological station



5.4.1.5 *Droughts and wetness*

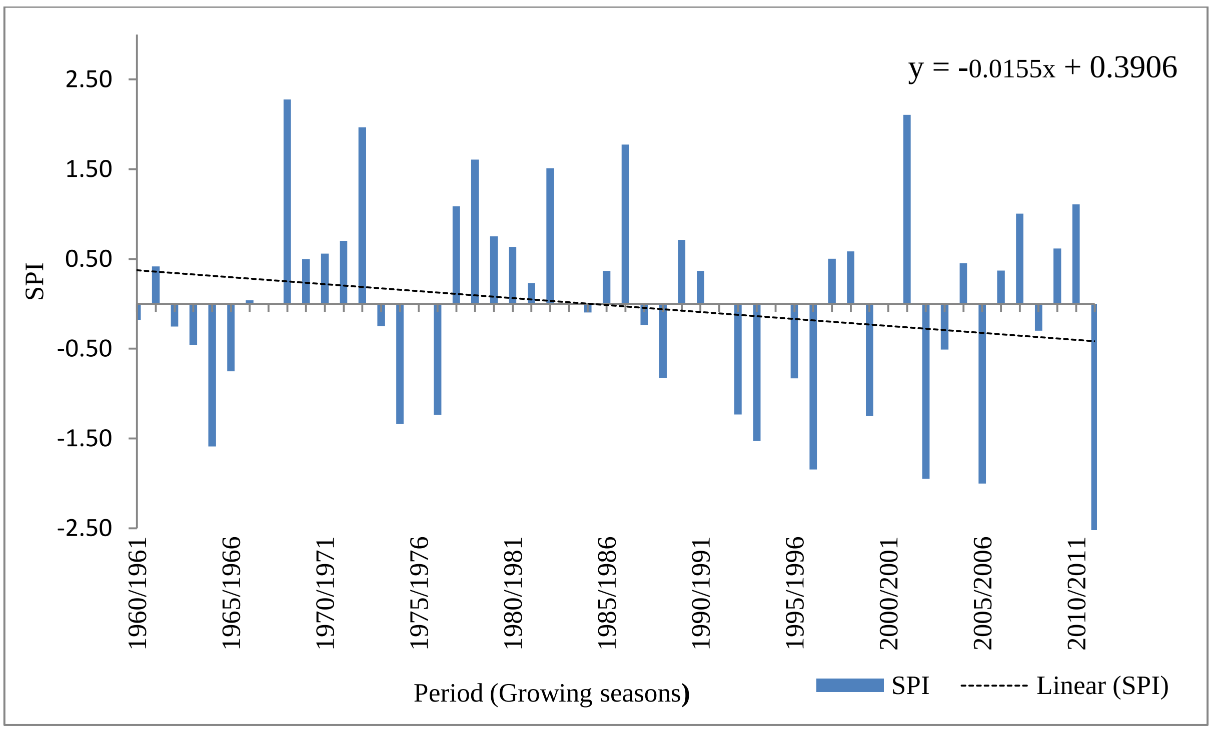
a. *Ibohora village*

The number of years that exhibited different drought and wet categories for the pre-defined SPI values were identified and plotted for the 1960–2012 period to observe their trends. Consequently, four severe drought periods have been identified in the last 52 years (1964/1965, 1993/1994, 1996/1997 and 2002/2003). Two extreme droughts during 2005/2006 and 2011/2012 were identified. Four moderate droughts are indicated on the SPI results in 1974/1975, 1976/1977, 1992/1993 and 1999/2000 (Figure 5.16).

Seven out of the nine extreme and severe droughts mentioned earlier happened during the last two decades (1990−2010). Figure 5.16 shows a decreasing trendline (y = -0.0155x + 0.3906), which means that the area is becoming increasingly dry over the last 52 years. The trendline shows that starting from the mid-1980s, the area started to experience droughts more regularly. Some years have been relatively dry (e.g. 1983/1984 and 1984/1985), yet had significant impacts on food crop production. For example, farmers reported severe food shortage during 1984, when they received government food aid. This might be a consequence of dry spells that follow after seed germination, which causes crop failures.

Two extremely wet periods (1968/1969 and 2001/2002) are indicated by the SPI results during the past 52 years. In addition, five severely wet periods in 1972/1973, 1978/1979, 1982/1983, 1986/1987 and 2010/2011 are indicated in the SPI results. There are a greater number of major wet periods before 1987, and this concurs with both the perceptions of farmers and the rainfall records (Figure 5.16).

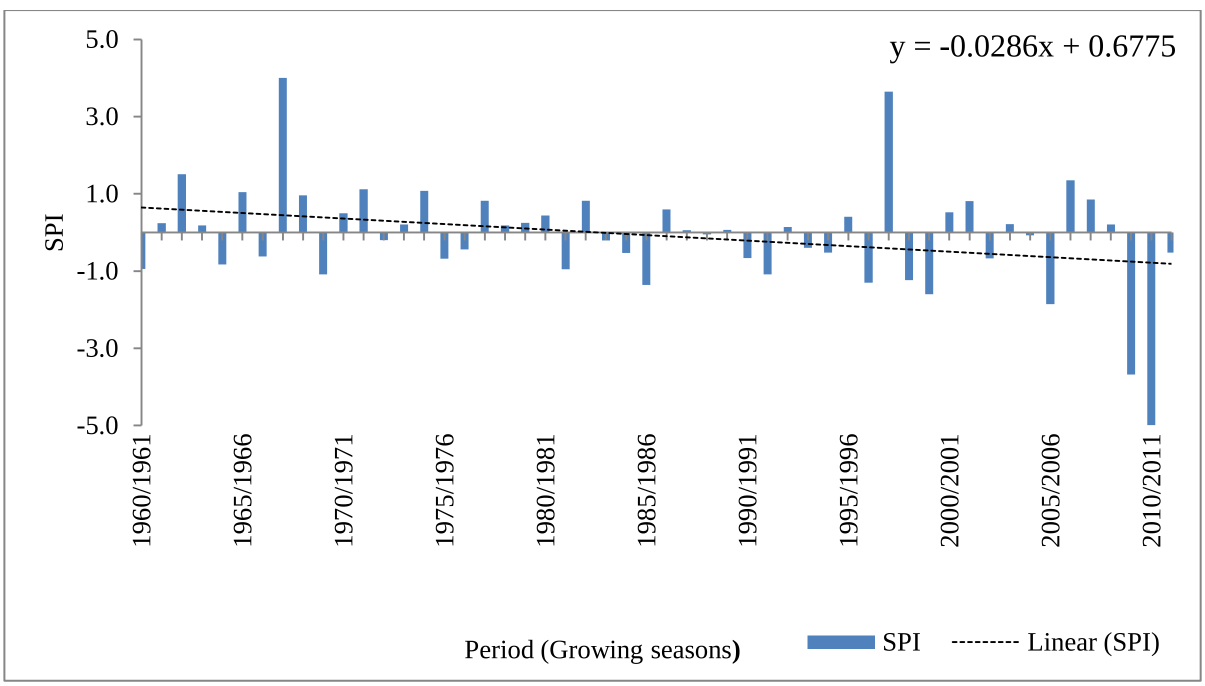
Figure 5.16: The 52 years standardized precipitation index (SPI) for Igawa meteorological station



b. Ikuvala village

The number of years that exhibited different drought and wet categories for the pre-defined SPI values were identified and plotted for the 1960–2012 period to observe their trends. The SPI values for the Iringa meteorological station indicate five moderate drought periods in 1969/1970, 1985/1986, 1991/1992, 1996/1997 and 1998/1999. Two severe droughts are indicated by SPI values in 1999/2000 and 2005/2006, and two consecutive extreme droughts are indicated in 2009/2010 and 2010/2011 (Figure 5.17). Therefore, out of nine major droughts, eight occurred between 1985 and 2012. The graph shows a decreasing trendline (y = -0.0286x + 0.6775), which means that the area has had an increasing tendency towards drought conditions over the past 52 years (Figure 5.17). Conversely, the SPI values indicate two extremely wet periods in 1967/1968 and 1997/1998. One severe wet period during 1962/1963 is indicated by SPI results.

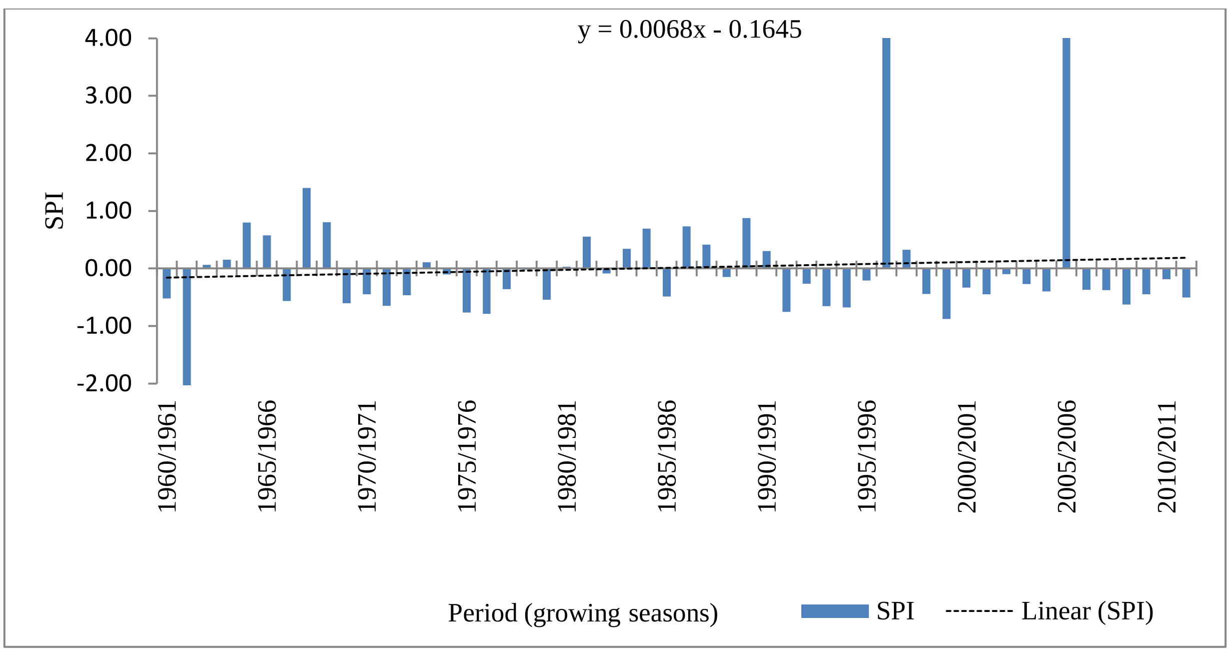
Figure 5.17: The 52 years standardized precipitation index for Iringa meteorological station



c. Ruaha Mbuyuni

Results at Mtera meteorological station indicate that the extreme dry year included 1961/1962, whilst other relatively dry periods were in 1966/1967, 1969/1970, 1971/1972, 1975/1976, 1976/1977, 1991/1992, 1993/1994, 1994/1995, 1999/2000, 2008/2009, 2009/2010 and 20011/2012. The extreme wet years were 1996/1997 and 2005/2006 (Figure 5.18). Figure 5.18 shows a positive trendline equation (y = 0.0068x - 0.1645), which indicates an increase in wet years compared to dry years during the recent decades, at the rate of 0.06 events/decade. This trend could be influenced by extreme wet years/seasons which occurred during the 1996/1997 and 2005/2006 periods.

Figure 5.18: The 52 years standardized precipitation index for Mtera meteorological station



5.4.2 Farmers' perceptions on climate change and variability

Having established the detailed trends of key rainfall indices in the previous section, in this section the details of how farmers perceive such changes is examined. Farmers in the study villages have always been facing climatic variability at both spatial and temporal scales.

The perceptions of various climate phenomena and variables were assessed at both household and village levels and thereafter, generalized to a wider basin-level.

To enable a more informed and 'human' dimensions understanding of how farmers' perceived and indeed were trying to interact, if at all, with possible changes in climate, a number of farmers' perceptions to possible climate variability and change were probed. From the farmer participation inputs, a detailed history of farmers' experiences and responses to such events was constructed. This links with the second objective of this PhD, which seeks to generate a baseline of climatic and non-climatic stresses that smallholder farmers have and are currently facing, against which one can begin to determine any vulnerabilities to climate variability and change.

a. Ibohora village

Most farmers from Ibohora village (97%) have perceived a significant change in rainfall and temperature patterns over the past four decades (Table 5.7). When asked about the changes they have observed during focus group discussions, farmers highlighted that temperature is increasing, water both for domestic and irrigation purposes is increasingly unreliable, there is a high frequency of droughts, rainfall amount is decreasing, there is an increase in mid-season dry spells, rainfall is becoming intense and patchy, and the onset of rainy/growing season is increasingly unpredictable and in most cases starts later than normal. In recent decades, the frequency of rainfall during the growing season has been decreasing as reported by the majority of farmers (88%) from Ibohora village. Fifty five percent of farmers reported that the intensity of rainfall has been increasing from the early 1990s. The rainfall pattern was reported by 67% of farmers to be unpredictable, inconsistent and increasingly becoming patchy (Table 5.7).

Table 5.7: Farmers' perceptions on changes in rainfall pattern

Variable	Categories	Percentage of respondents			Total average N=90	χ2 P-Value
		Ibohora n=30	Ruaha Mbuyuni n=30	Ikuvala n=30		
		%	%	%	%	
Significant change in weather patterns	Yes	97	73	44	71	14.835 0.001**
	No	3	27	56	29	
Frequency of rainfall	Increase	6	3	0	3	20.655 0.000
	Decrease	88	59	42	63	
	NA	6	38	58	34	
Intensity of rainfall	Increase	55	36	30	40	10.494 0.033**
	Decrease	12	0	6	6	
	NA	33	64	64	54	
Rainfall starts late and ends early	Yes	82	48	48	58	15.975 0.003**
	No	12	6	3	8	
	NA	6	46	49	34	
Rains come earlier than normal	Yes	12	36	33	28	34.804 0.000**
	No	82	18	18	38	
	NA	6	46	49	34	
Rainfall consistence	Consistent	27	12	12	18	15.524 0.004**
	Not consistent	67	39	36	48	
	NA	6	49	52	34	
Days with dry spell	Increasing	58	36	30	41	16.989 0.002**
	Decreasing	36	18	18	23	
	NA	6	46	52	36	

** Significant at 5%

Recurrent droughts and a lack of water for irrigation were noted as the main climate-related concerns in Ibohora village. Severe droughts were reported to occur during the years/seasons 1999/2000, 2005/2006 and 2009/2010 (Figure 5.19). For 1973/1974 and 1983/1984, droughts were reported to be less severe. During the 1970s and early 1980s, when the village had a reliable supply of water in the irrigation canal, droughts did not have severe impacts on agriculture. Farmers recalled one extreme wet rainy season during the 1997/1998 *El Niño* (Figure 5.19).

Figure 5.19: Timeline of extreme events and coping strategies at Ibohora village

Years / Drivers		1970s 1980s 1990s 2000s 2010s
Climatic	Drought	↑ ↑ ↑ ↑ ↑
	Flood	↑ *El Niño*
Non-climatic	Infrastructure	→ Irrigation canal built →
	Technology	→ Ox-Plough Power tiller → Phone
	Market	→ Cooperatives → Free market
	Land Access	↔ Allocated → Selling/buying
	Population	→ Increase
Responses (Major changes in):	Farming practices	.............Changed
	Crops	..… New rice Var…. ………horticultural
	Irrigation system	…….Canal/gravity……………………………….Pumps …………………
	Off-farm activities	………………………….Shops
	Pests and Weeds	…. Ants and rice weeds………………………..……………......increase
	Soil fertility	…………………………………….decrease

(Dotted lines show the period when major changes associated with a certain stress occurred)

b. *Ikuvala village*

In the second village, Ikuvala, farmers' perceptions are largely associated with daily challenges they face. These include unpredictable rainy seasons, frequent droughts, intensive rains, increased temperature, poor quality of drinking water, a lack of water pools as existed in the past (in the lowlands until May), strong winds and tree cutting for charcoal making. Results indicate that 44% of farmers from Ikuvala village agree that there has been a significant change/variability in climate over the last four decades (Table 5.7). A relatively larger percentage of farmers in Ikuvala village (56%) reported that they have not noticed any significant changes in climate over the past years (Table 5.7). This could be explained by farmers' experiences that the weather has become unpredictable in every growing season and it is difficult to plainly say whether it is changing or rather varying from season to season. The frequency of rainfall during the growing season has been decreasing as reported by 42% of farmers from Ikuvala village. Thirty percent of farmers reported that the intensity of rainfall has been increasing from the early 1990s. Rainfall pattern was reported by 36% of farmers to be unpredictable, inconsistent and increasingly becoming patchy (Table 5.7). Therefore, the majority of farmers are not aware of the changes in rainfall intensity (70%) and unpredictability of rainfall pattern (64%).

Farmers recounted that the onset of the rainy seasons is not normally distributed across the whole village. They noted that in some years the highlands/mountain side receives an early onset of rains and the lowlands receive a late onset, or vice-versa. For example, during the year 2008, the rain started in the highlands only, so those with farms on the mountain slopes began to cultivate, whilst it took a further three weeks for the lowland farmers to receive their first rain. The trend was reversed during the following year (2009) when the lowlands received rains three weeks earlier and started to cultivate.

Figure 5.20: Timeline of extreme events and coping strategies at Ikuvala village

Years / Drivers		1970s 1980s 1990s 2000s 2010s
Climatic	Drought	↑ ↑ ↑ ↑↑
	Flood	*El Niño* ↑
Non-climatic	Infrastructure	→ Road
	Technology	→ Ox-plough, Tractors → Phone
	Market	→ Tomato market
	Land Access	→ Allocated → Selling/buying →
	Population	→ Increase
Responses (Major changes in):	Farming practices	……………… Changed
	Crops	……Improved maize varieties……………...Tomatoes boom
	Irrigation	………………………….Increase
	Off-farm activities	………………….. Increase
	Pests and Weeds	……….……………………………………….Decrease
	Soil fertility	

(Dotted lines show the period when major changes associated with a certain stress occurred)

Interestingly, villagers attributed the patchiness of rainfall with the road contractor's witchcraft. According to villagers, it did not rain in some places where they were still constructing either a road or a bridge.

Households perceive some past years as extremely dry due to insufficient rain during the growing seasons; these years include 1970, 1981, 1999, 2006 and 2007 (Figure 5.20). Farmers linked the extreme dry years with a number of changes which happened in response to the droughts, such as the introduction of improved seeds/new crop varieties which are drought resistant and that have a short time to maturity, increased off-farm activities, increased frequency of pests and diseases and low soil fertility (Figure 5.20).

Farmers recalled only one growing season (1997/1998) which had abundant rains, which was an *El Niño* year. This extreme weather condition caused floods in many parts of Tanzania. Farmers reported that it rained for 42 consecutive days during that season. Consequently, the village experienced crop failure due to flooding and soil erosion. Other major changes experienced during this time include greater numbers of crop pests and weeds in tomato farms (Figure 5.20).

c. Ruaha Mbuyuni village

Ruaha Mbuyuni farmers perceive changes in weather pattern as a decrease in rainfall, recurrent and prolonged droughts during the growing seasons, and the emergence of new socio-economic activities in the village. These observations were reported by farmers during focus group discussions. Farmers also reported that the onset of rainy seasons is unpredictable, the intensity of rains has increased and frequency of droughts has been on the increase during the past twenty years. They did not remember the year, but they reported that it had rained only once during a particular rainy season. Some years had high intensity rains (e.g. 1998 and 2008), which led to the destruction of river banks and the river changed its course.

A large proportion of farmers in Ruaha Mbuyuni village (73%) perceive that there has been a significant change in climate during the past forty years (Table 5.7). Fifty nine percent of farmers reported that the frequency of rainfall during the growing season has been decreasing. Thirty six percent of farmers reported that the intensity of rainfall has been increasing from the early 1990s. Rainfall pattern was reported by 39% of farmers to be unpredictable, inconsistent and increasingly becoming patchy (Table 5.7). Therefore, the majority of farmers are not aware of the changes in rainfall intensity (64%) and unpredictability of rainfall pattern (61%).

Figure 5.21: Timeline of extreme events and coping strategies at Ruaha Mbuyuni village

Years / Drivers		1970s 1980s 1990s 2000s 2010s
Climatic	Drought	↑
	Flood	*El Niño* ↑ ↑
Non-climatic	Infrastructure	Canal → Pumps →
	Technology	→ Plough, Tractors → Phones
	Market	Onions Market →
	Land Access	→ Free → Buying/Selling
	Institutions	Credit facilities →
	Immigration	Increase →
Responses (Major changes in:	Farming practices	………Changed
	Crops	………….. new varieties
	Irrigation	………………….Pumps
	Population	………..……… increase
	Off-farm activities	……………..shops, rest.
	Pests and Weeds	……………….. increase
	Soil fertility	………………..decrease

(Dotted lines show the period when major changes associated with a certain stress occurred)

Farmers reported the year 1975 as the driest year remembered (‘dead dry’), and apparently all crops failed. In contrast, during the years 1998 (*El Niño*) and 2008, rain was heavy and resulted in floods (Figure 5.21). The Lukosi River changed its original course due to the destruction of its bank, hence halting water flow to the intake of the irrigation canals for the entire year. Farmers considered these years as similar to dry years because crops failed due to both floods and a lack of water in the irrigation canals. The river bank has since been re-constructed and water is again flowing in its original course and supplies water to the intake of the irrigation canals.

The comparison between the farmer perceptions and climatic indices from analysed rainfall station data is presented in Table 5.8 below and discussed in the following discussion section. The aim is to gauge the agreement or disagreement between the two techniques of investigating climate change and variability in the study area. Results indicate that farmers' perceptions in Ibohora and Ikuvala villages were congruent with rainfall station records, except for Ruaha Mbuyuni village, which shows a discrepancy (see details in Table 5.8 and the discussion section that follows after section 5.4.3).

Table 5.8: Comparison of farmer perceptions and rainfall station data

Village	Perceptions of rainy season	Rainfall indices				Observation
		Onset	Cessation	Length	Dry-spells /Droughts	
Ibohora	Later onset, early cessation, declining length, increasing dry spells	Later	Early	Declining	Increasing	Congruent
Ikuvala	Early onset, inconsistent cessation, inconsistent length, increasing dry spells	Early	Early	Increasing	Increasing	Congruent in most indices except for the length of the rainy season
Ruaha Mbuyuni	Inconsistent onset, early cessation, inconsistent length, increasing dry spells	Later	Later	Declining	Increasing	Discrepancy in most indices except dry spells that is congruent.

5.4.3 Factors influencing the perceptions of smallholder farmers on climate change and variability

After focusing on perceptions by farmers in the study areas on changes in rainfall patterns in the previous section, in this section, the factors influencing their perceptions on such changes are examined. Three groups of factors were tested in the logit model, which include access to information and technologies (i.e. education level of the household head), location of the village, and farming experience of household heads (Table 5.8).

These factors were selected with the view that they determine farmers' perceptions and eventual response to climate variability. A number of perceptions common to all villages were selected to be tested against these factors. The perceptions include significant change in weather (SCW), change in frequency of rainfall (CFR), change in intensity of rainfall (CIR), rainfall starts late (RSL), rainfall starts earlier (RSE), rainfall not consistent (RNC) and days with dry spells (DWDS) (Table 5.8).

Table 5.9: Factors influencing smallholder farmers' perceptions to climate change and variability

	SCW	CFR	CIR	RSL	RSE	RNC	DWDS
Access to information and technologies							
Education level of household head	0.041 (0.958)	0.409 (0.539)	-0.259 (0.665)	0.532 (0.367)	0.404 (0.537)	-0.226 (0.704)	-0.027 (0.965)
Location							
Village	-1.813 (0.000)**	-1.355 (0.000)**	-0.770 (0.014)**	-0.816 (0.008)**	0.397 (0.217)	-0.819 (0.009)**	-0.794 (0.014)**
Farming experience							
Head of household farming experience	0.000 (0.999)	0.159 (0.282)	0.316 (0.057)	0.128 (0.377)	0.301 (0.121)	0.355 (0.037)**	0.319 (0.065)

** Significant at 5%

Access to information and technologies is not a factor that influences farmers' perceptions in the study area. The model results show that there is no correlation between the education level of household heads and the selected perceptions (Table 5.8). This could be attributed to the moderate level of education of farmers in the study area (see section 5.2.1). A study in the Limpopo basin, South Africa, indicated that education level is not a factor that influences farmers' perception to changes in weather pattern (Gbetibouo, 2009). Conversely, other studies have reported that access to climate services or information and agricultural technologies influences farmers' perceptions to changes in climate (e.g. Changnon, 1992; Stern & Easterling, 1999; Glantz, 2001; Letson *et al*., 2001; O'Brien & Vogel, 2003; Yanda & Mubaya, 2011).

Results indicate that there is a significant correlation between village location and six out of seven selected perceptions (Table 5.8). These perceptions are such as significant change in weather patterns (P = 0.000), reduced frequency of rainfall (P = 0.000), increased rainfall intensity (P = 0.014), rainy season starts late (P = 0.008), rainfall is not consistent (P = 0.009) and increased risk of dry spells during the rainy seasons (P = 0.014). This implies that the location of the village in the study area influences the perceptions of farmers towards changes in weather patterns. The results corroborate well with questionnaire survey findings that indicate that most farmers from lowland villages with access to irrigation agriculture (97% and 73% from Ibohora and Ruaha Mbuyuni respectively) perceived that there has been a significant change in weather patterns during the past four decades. Only 44% of farmers from Ikuvala village (dry-land with no irrigation agriculture) have similar perceptions (Table 5.7). According to Gbetibouo (2009), access to irrigation agriculture reduces the likelihood of a farmer to perceive changes in weather/rainfall pattern.

The number of years of farming experience was analysed in the model to measure its influence on farmers' perceptions to climate change during the past four decades in the study area. The model results show that there is a significant correlation (P = 0.037) between the farming experience of household heads and the perception that rainfall is not consistent during recent years, as compared to the 1970s/1980s. This implies that more experienced farmers have the view that rains are not consistent, more so than farmers with only a few years of farming experience in the study area. The study by Gbetibouo (2009), in the Limpopo basin of South Africa, reported similar findings that experienced farmers (i.e. more than 30 years) claimed that rainfall is decreasing, and noted a change in the frequency of droughts and floods. Therefore, with experience, farmers are more likely to perceive a change in weather patterns.

Discussion

Smallholder farmers in the GRRB have demonstrated diverse perceptions regarding the changes in climatic factors over the past 40 years (farmers could recall only the past 40 years). Various changes associated with frequency, intensity and consistency of rainfall patterns during the past four decades were reported by farmers. The main perceived changes as described in the previous sections include decreases in rainfall amount, rainfall becoming erratic with regards to spatial-temporal variations, increase in the frequency and length of droughts, increases in mid-season dry spells, delayed rainfall onsets, reduced length of the growing season, increases in rainfall intensity and increases in average temperature. This is congruent with questionnaire survey results, which indicate that majority of farmers are aware of significant changes in rainfall patterns during the past four decades (Table 5.7). Findings from other researchers report similar perceptions of farmers in sub-Saharan Africa. For example, farmers in the southern highlands of Tanzania, western and southern Africa (e.g. Thomas *et al*., 2007; Kangalawe, 2009; Mertz *et al.*, 2009; Kangalawe, 2012), associate the concept of climate change with variability in weather conditions, including changes in wind pattern and increased seasonality of rainfall. These findings indicate that the changes in weather pattern have greatly affected the agricultural sector which employs the majority of the population in the sub-Saharan Africa. This awareness of changes in rainfall pattern corroborated well with observed rainfall records at Igawa, Iringa and Mtera meteorological stations.

The rainfall records for two (i.e. Igawa and Mtera) out of three meteorological stations indicate that the onset of rainy season has been starting later than average during the past 52 years. Conversely, the rainfall records from Iringa meteorological station indicate the opposite, and this corroborates well with the perception of farmers from Ikuvala village (Table 5.9). Nevertheless, the minority of farmers from Ruaha Mbuyuni perceive that rainy seasons have become unpredictable and in most cases rainfall has been starting later than average. This is congruent to the trends of rainfall records at Mtera meteorological station which show a delayed onset of rainy seasons over the past 52 years (Table 5.8). Two (i.e. Igawa and Iringa) out the three meteorological stations show that the rainy season has been ending earlier than average during the past 52 years. This differences and commonalities in perception of climate change and rainfall records between villages/meteorological stations may be due to the differences in location or biophysical differences in the sub-basin (this is analysed in detail in section 5.4.3).

The observed shifts in the onset and cessation of rainy seasons could have affected the livelihood activities of smallholder farmers, including both agricultural and other sectors. The impact of this trend is a shortening of the growing season, which does not suit the crops grown in the study villages, as these normally require a minimum of three months to mature (e.g. maize and rice). Other studies have reported the difficulties of determining the start of the rainy season brought by the observed erratic nature of rainfall patterns (e.g. Oladipo *et al*., 1993; Camberlain & Okoola, 2003; Mugalavai *et al*., 2008). The onset of the rainy season is the key determinant factor in the areas dependent on rain-fed agriculture (Mugalavai *et al.*, 2008; Tadross *et al.*, 2009). Other studies conducted in southern Africa reported increasing trends towards a delayed onset of the rainy season, prolonged droughts, and reduced lengths of rainy season (Waiswa, 2003; Love *et al*., 2006; Cooper *et al*., 2007; Twomlow *et al.*, 2008). Most farmers in the GRRB depend on rain-fed farming, because even those villages with access to irrigation water have only a small portion of the potentially irrigable land lined with irrigation canals. Moreover, the shortening of the rainy season is a challenge, not only to the timing of the growing season, but also to the choice of suitable crops.

The overall increase in the risk of dry spells of ten or more days as indicated by rainfall records from all meteorological stations shows that farmers depending on rain-fed agriculture have been facing reduced crop yields during at least the past two decades. The majority of farmers from the Ibohora village have a similar perception with regards to the increase in mid-season dry spells. However, only one third of farmers from Ikuvala and Ruaha Mbuyuni villages have the perception that mid-season dry spells have increased. This implies that being in the semi-arid area which has been receiving below average rains in most growing seasons, farmers from these two villages could not attest if dry spells are increasing. This is affirmed by the findings by Yanda and Mubaya (2011), who reported that farmers who are subjected to frequent droughts, have a low perception of climate changes. A dry spell of 10 or more days is believed to destroy the growing of crops, hence leading to crop failures or reduced crop yields (Sawa & Adebayo, 2011). A number of studies in Tanzania have reported similar findings during different periods and in different areas. For example, Charnley (1994) reported that more frequent crop failure in the Usangu Plains could be accounted for by more frequent mid-season dry spells. Poor rainfall distribution coupled with drought periods, particularly inter-seasonal dry spells, greater water extractions by rice farmers and land use changes (i.e. tree plantations), have amplified the problem of moisture stress in Tanzania (Paavola, 2003; Tillya & Mhita, 2006). Moreover, the shortening of the rainy season and frequent mid-season dry spells reduce crop yields (Paavola, 2008; Lema & Majule, 2009; Mongi *et al*., 2010).

The upper part of the GRRB is more prone to mild and moderate droughts, as indicated in the SPI values. Farmers' recollections of extreme wet and dry years are partly concurrent with the standardized precipitation index (SPI) results for Igawa meteorological station. The 1997/1998 El Niño is the wettest year remembered during the last 40 years, yet the SPI results do not indicate it as an extreme wet year. This might be due to inaccuracy of the rainfall records collected during that year or may be a wrong perception or poor memory by farmers. The SPI results for Iringa meteorological station to a large extent compare well with farmers' perceptions. As for the upper part of the sub-basin, it does not indicate extreme drought for the years 1983/1984 and 1984/1985, which were perceived by farmers as extremely dry and led to severe food shortages. Moreover, the SPI results indicate that from the early 1990s, the area started to experience more droughts than before. Generally, SPI values indicate that this mid region of the GRRB is susceptible to moderate droughts, with occasional severe and extreme droughts. There has been a high inter-annual and inter-decadal variability between dry and wet years during the last 52 years in the downstream part of the sub-basin. For example, the 1960s show a high inter-annual variability between dry and wet years, the 1970s were mostly dry years, 1980s show high inter-annual variability between dry and wet years, whilst 1990s to 2000s were mostly dry years, with two extreme wet years. Moreover, SPI values indicate that the downstream part of the GRRB (Ruaha Mbuyuni) is susceptible to relatively dry periods.

Findings from household surveys, focus group discussions and observed rainfall records at the village and sub-basin levels provide evidence that climate variability is happening in the study area. The evidence of rainfall records at three meteorological stations and farmer perceptions confirm that farmers are facing climate variability and extremes. This is in agreement with regional and international studies which have come up with similar findings (e.g. IPCC, 2007, 2012, 2013), and other studies conducted in Africa (e.g. Kruger & Shongwe, 2004; Grab & Craparo, 2011; Shongwe *et al.,* 2011; Niang *et al.,* 2014). Findings from this PhD study affirm that there has been an increasing trend towards dry spells and extreme climatic events (e.g. droughts and excessive rains) in the GRRB, as also concluded by others as cited above. However, recent regional and global model projections indicate that East Africa will have reduced dryness and increased heavy precipitation towards the end of the 21st century (Shongwe *et al*., 2011; IPCC, 2012, 2013).

5.4.4 Non-climatic or other stresses

After presenting and discussing climate related stresses in the previous section, attention now turns to examine some of the non-climatic stresses as they may be more pressing than climatic stresses to smallholder farmers.

Table 5.10: A summary of non-climatic stresses per village

Village Name	Non-climatic stresses
Ibohora	Water for irrigation allocated by the investor (three times a week during rainy season only), poor access and high prices of agricultural implements and inputs, out migration of youth (work force), poor condition of the road and a lack of capital to purchase water pumps for irrigation.
Ikuvala	Lack of irrigable land, soil erosion (gully erosion) due to farming on mountain slopes, high price of fertilizers, water scarcity for domestic use, decline of soil fertility and absence of a health centre, weak market, superstitious beliefs.
Ruaha Mbuyuni	Poor farming implements, price fluctuations of farm inputs and implements, low soil fertility, poor access to small loans/capital to help in purchasing farm inputs and implements, and to start small businesses; immigration of people in search of employment (Aljazeera hotel, bars and restaurants), businesses (onion businesses) and water for irrigation, and weak markets.
District officials	Shortage of water for both domestic and irrigation uses, markets for crops, poor access to farm inputs and implements, poor roads, deforestation and forest fires.

The IPCC 4th and 5th assessment reports highlight that complex combinations of other stresses (i.e. socio-economic and political) aggravate vulnerability to climatic stresses (Boko *et al.*, 2007; Niang *et al*., 2014).

This discussion stems from non-climatic stresses presented in Figures 5.16, 5.18 and 5.20. While stresses in most cases were similar, some differences were reported by farmers linked to the various villages. Such differences may be linked to differing biophysical contexts. A number of stresses are noted; the main being access to water, access to markets and coordinating institutions (Table 5.10). The following sections expound more on these stresses.

5.4.4.1 Access to water and irrigation infrastructure

Farmers in Ibohora village reported that before the demise of the National Agriculture and Food Cooperation (NAFCO) in 1978, which owned the rice irrigation farms, drought was not a problem due to the reliable and year-round water supply in village irrigation canals. The farms were sold to a private company (Mbarali Rice Farms) in 2006, together with the irrigation system. It was during this time when the regular supply of irrigation water to the village canals ceased, and thus the rationing system was adopted. The private company started to allocate water to the village canal three days a week, but only during the rainy season. According to farmers, the rationing system has been the reason for declines in agricultural production and a source of water conflicts in the village because the allocated water does not reach all farms, especially those located downstream of the canal.

Farmers in Ibohora village reported a greater shift from conventional irrigation practices (canals and jerry cans) to irrigation pumps, starting from the early 2000s. This widespread use of pumps for irrigation is linked with an inadequate supply of water in the irrigation canals and recurrent droughts during recent decades (Plate 5.1). Other factors that have stimulated the use of pumps include market growth of emerging cash crops (e.g. tomatoes, onions and vegetables). It was interesting to note that the land near the Mbarali River was dominated by commercial farmers from outside the village. Farmers highlighted that most of the people who own/rent pumps and plots near the Mbarali River are from the nearby urban centres such as Ubaruku and Rujewa. These farmers cultivate tomatoes, vegetables and sugarcane for commercial purposes. Few farmers from within the village practice irrigation farming using motorised pumps because most of them cannot afford to own or rent a pump.

Plate 5.1: Dry irrigation canals in Ibohora village

Source: Fieldwork, November 2010.

More water use conflicts were reported by farmers from Ibohora village to occur during dry years. The village receives irrigation water in the canal three days a week during the rainy seasons. Farmers reported that during dry years, those with plots upstream of the scheme block all the water, leaving downstream farmers without irrigation water throughout the week. The village government reported to have no institutions of managing the scheme and farmers who depend on the irrigation canal. This has led to some farmers intimidating others (using traditional weapons) and blocking water so that they can adequately irrigate their own farms during droughts. The finding concurs with that of Reid and Vogel (2006), who reported water conflicts in times of severe climate stress in KwaZulu-Natal. These conflicts were inflicted by a lack of water management and the problems of unequal access due to a lack of institutional support and appropriate governance structures within the village irrigation scheme.

Ikuvala village has no source of water for irrigation, thus the villagers practice rain-fed agriculture only. This has been a challenge to farmers due to the fact that rainfall has become erratic and the frequency of droughts has increased during recent decades (refer section 5.4), as also reported by Kangalawe (2009, 2012). Farmers reported that they rely on hiring irrigable land in nearby villages when droughts occur. Poor reliability of water for domestic use is also a constraint for Ikuvala farmers. The water table is very low, making it even more difficult to rely on ground-water sources. There is only one deep well, which still releases small quantities of water. Villagers rely on natural springs in the mountains and water supplies from the nearby emerging urban centre (Ilula-Mwaya).

The boom of irrigation pumps (Plate 5.2) is reported to have started during the mid-2000s (Figure 5.20) in Ruaha Mbuyuni village. When asked about what prompted the increase in pump irrigation, the farmers reported that the main reasons are the growing onion business in the village and droughts. More commercial farmers are renting larger tracts of land along the Lukosi and Great Ruaha Rivers to cultivate onions and sell to large markets in Dar es Salaam. According to the district agricultural officer, these farmers are called "progressive farmers", because they have an entrepreneurial/business mind. Farmers with sufficient capital (rich and medium income), own pumps and could buy or rent plots from locals near rivers (during the farming season). According to farmers, the availability of credit facilities has stimulated the purchase of pumps and increased immigration and off-farm activities in the village.

5.4.4.2 Access to markets and other infrastructure

Other stresses also include markets, crop prices and coordinating institutions. Weak markets and low prices for agricultural products are among the stress factors that are impacting on the daily lives of farmers in the GRRB. The district officials acknowledged that markets are the main determining factors in the production of horticultural crops in the study region. Sometimes when the price is very low, it causes the capital for large-scale farmers to collapse. Farmers reported using mobile phones to reach large markets, but still they do not get good prices due to various reasons that include poor transportation (i.e. poor roads and transport) of products from farms to the market. Prices are regulated by major market forces in large towns, and do not take into consideration the costs incurred by farmers.

Plate 5.2: A photo showing the pump used for irrigation in Ruaha Mbuyuni

Source: Fieldwork, November 2010.

Farmers reported that the market is dominated by middle-men who buy products from farmers and sell to dominating markets in urban centres. This leads to farmers not receiving good prices from the middle-men due to the lack of a well-functioning market in their villages. When asked about the situation and coordination of crop markets in the study districts, district officials reported that markets are not working properly due to dominance by middle-men who are undermining the official institutions tasked to run them. There is no authority that regulates the price for horticultural crops. Thus, market forces regulate the demand and supply. The trend shows that when production is high, the price goes down and vice versa. For example, during recent growing seasons (2010-2012), the production of maize has gone down consecutively; and prices went up respectively. The price for 100kg of maize during 2010 was 35,000 TSHs, during 2011 it was 45,000 TSHs and by 2012 it had reached 100,000 TSHs. These prices were observed during the same season for the years reviewed (Field observation, 2012). Other researchers have reported crop price increases in recent years as a secondary impact of climate variability and change in sub-Saharan Africa (Ahmed *et al*., 2009; Friedman & Schady, 2009; Calzadilla *et al*., 2013). This situation adds on another layer of burden to communities experiencing recurrent food shortage due climate variability.

Farmers from Ikuvala village highlighted that the market for tomatoes started to improve during the early 2000s. Both the demand and produce price went up during that period in large markets (i.e. Dar es Salaam), thus motivating many farmers to engage in tomato farming. During this period, tomato production increased, and was followed by a boom in off-farm activities such as the opening up of small enterprises. The increased involvement in off-farm activities by farmers was reported to be exacerbated by a high frequency of droughts during the past decade, where farmers started to use the money earned from selling tomatoes and vegetables, and to invest in other non-farm activities that are less sensitive to climate change.

A farmer reported to have lost 70% of his tomato harvest in Ikuvala village during the 2011/2012 season (Field observation, 2012). The reasons mentioned include lack of a well-functioning crop market in the village, poor transportation and low prices. The tomatoes started to rot in the farm store, and when transported to the market at the nearby urban centre (Ilula-Mwaya), the middle-men sorted out more rotten tomatoes that could not be bought. In addition, the farmer received a very low price. He said that it cost him 1,000,000 TSHs to manage the tomato farm, but that he sold for only 150,000 TSHs. Farmers suggested that the government should incentivise the establishment of agro-processing industries for value addition where farmers could sell all their produce. This could stimulate more farming and provide employment to farmers. This could also provide additional income to farmers and eventually improve their adaptive capacity to the impacts of climate change/variability by diversifying to non-farming activities that are less sensitive to climate change/variability. Market access has also been reported by other researchers to be a stress that impacts negatively on smallholder farmers who depend on an agricultural economy (Eakin, 2005; Reid & Vogel, 2006; Eriksen & Silva, 2009). They found that there are unfavourable market relations between traders and smallholder farmers in rural areas. This situation intensifies during stressful years and smallholders become locked into low economic return activities, thus reducing their adaptive capacity. This implies that reliable markets for crops can enable smallholder farmers to diversify economically into activities that are less sensitive to the variability and uncertainties of the agricultural sector.

5.4.4.3 The institutional dimensions of vulnerability to climate stress

Another key stress factor mentioned is access to effective institutions, including financial institutions. A lack of financial institutions in Ibohora and Ikuvala villages was reported to be a stress that is impacting on the lives of farmers. Farmers reported that financial institutions are important because they could provide loans to farmers. Loans are required by farmers to help them purchase farm input and implements that could boost their agricultural production. Farmers reported that the lack of funds to purchase improved seeds, pumps for irrigation, fertilizers and pesticides is a challenge that reduces their adaptive capacity to impacts of climate change. Ruaha Mbuyuni farmers mentioned stresses related to business and institutions. The village has a financial institution (FINCA) and four farmer groups (KIHASI, MWAVILU, LUKOSI and GEZAULOLE). These groups receive loans from FINCA and use them to manage small businesses and farming activities. Most of the members are women involved with restaurants and a few men involved in onion farming and small business enterprises. Farming in this village is better linked to business (cash crops) than the other two villages. Loans are required to purchase farm inputs and implements, regardless of the rainy season, whether good or bad. It is difficult for individual farmers to access loans due to various reasons, including a lack of collateral. Thus, farmers are encouraged to form groups and register at the village government office for them to qualify to receive loans. Similar findings have been reported in semi-arid areas of Zimbabwe (e.g. market, macro-economic changes, changing institutional arrangements and HIV/AIDS) (Moriarty & Lovell, 1998; Campbell *et al*., 2002, Mubaya, 2010).

Discussion

Findings suggest that the challenges of the agricultural sector need to be approached by considering the multiple stresses surrounding it and not singling out climatic hazards only. Although the study sub-divided the sub-basin into smaller agro-ecological zones, not much difference was observed in terms of types of stress factors affecting the lives of smallholder farmers. This was determined by analysing the findings from the questionnaire survey and focus group discussions from all study village cases. Findings from this study confirm that smallholder farmers in the GRRB are not spared by the multiple stresses compounding other smallholder farmers in sub-Saharan Africa.

It is difficult to single out climate change impacts from other stresses impacting on the lives of farmers in the GRRB and rural Tanzanian farmers at large. This concurs with other studies that have presented similar arguments from various sub-Saharan countries (e.g. Eakin, 2005; Reid & Vogel, 2006; Mbow *et al*., 2008; Ziervogel & Taylor, 2008; Eriksen & Silva, 2009; Mubaya, 2010; Nielsen & Reenberg, 2010). These studies found that farmers are equally affected by a number of stresses that have little or no connection to climate, but which are perceived to be even more pressing. Findings from this PhD study and studies cited, show the importance of approaching stresses compounding the lives of smallholder farmers using a whole system approach. For example, if one only focuses on vulnerability to the impacts of climatic stresses, then responses become focused only on programmes to address the residue impacts of climatic stresses (e.g. early warning systems and flood controls or drought tolerant crop varieties). But, if the focus includes other stresses together with climatic stresses, responses will be well planned to address impacts in a holistic way (e.g. planned irrigation systems, access to market, good policies and institutions). This is affirmed by other researchers (e.g. O'Brien *et al*., 2004; Füssel & Klein, 2006), who reported the importance of considering multiple stresses when dealing with vulnerability of farmers.

Some efforts to help improve the capacity of smallholder farmers to cope with both climatic and non-climatic stresses are implemented by the district authorities. At the district-level, the government has introduced some programmes to empower farmers with skills that will help them to address other factors that affect the agriculture sector. All sectors that enhance the productivity of the agriculture sector are being addressed. These include improving the market infrastructure and access, construction and rehabilitation of roads to enable transportation of agricultural produce from farms to stores or markets, training on entrepreneurial skills so as to take advantage of available and emerging opportunities (e.g. business enterprises), access to small loans and creating an enabling environment for establishment of agro-processing industries.

5.5 RESPONSE STRATEGIES TO IMPACTS OF CLIMATE VARIABILITY AND CHANGE

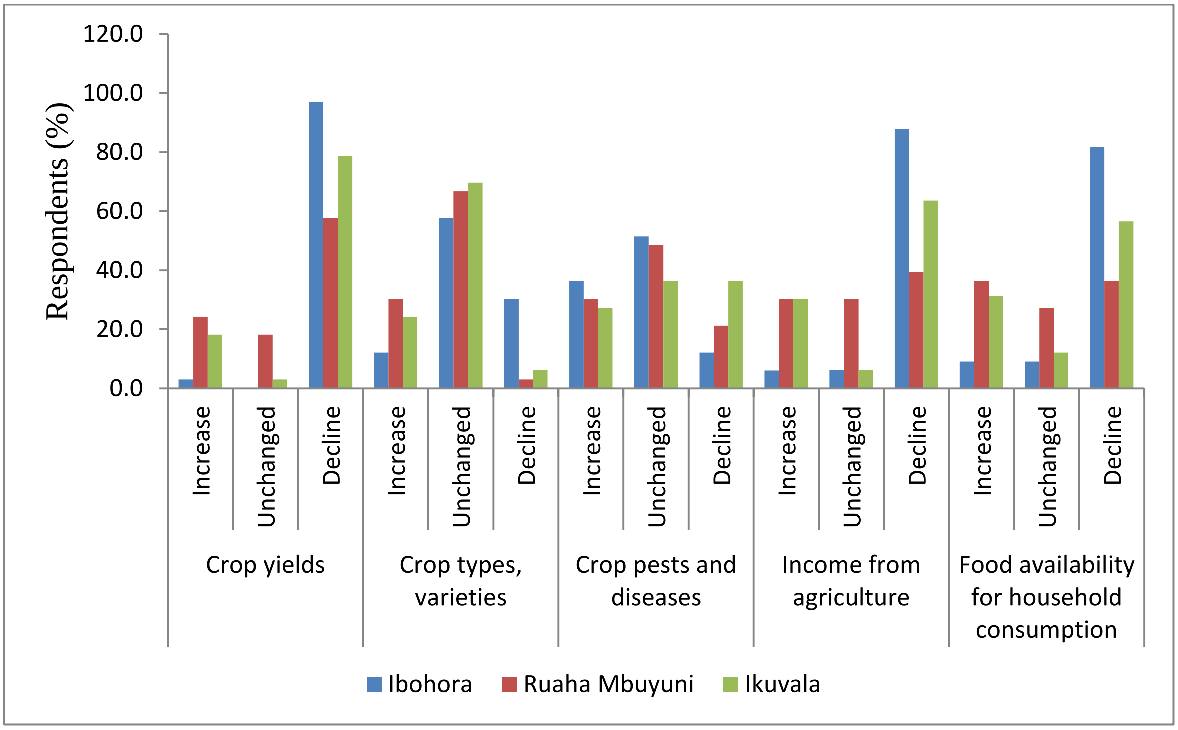
It is evident from the evidence discussed in the previous sections that climate variability, particularly rainfall variability is a reality in the study area, as indicated by the observed rainfall records and perceptions of farmers. This section thus focuses on the impacts of climate variability and change, and subsequent response strategies. This section is linked to the third objective of this study, which seeks to better understand the coping options and adaptation strategies to impacts of both the sudden-onset of extreme events and the more pervasive climatic change/variability. It further connects with the response strategies section in the analytical framework, where both short-term coping strategies and long-term adaptation strategies are examined. Finally, the factors influencing farmers' choice of response strategies during food shortage are discussed.

5.5.1 Impacts of climate variability and change

5.5.1.1 *Impacts of droughts during the rainy season*

Crop yields have been declining due to various reasons including high frequency of droughts during recent decades in the study villages. The majority of farmers from all three villages (97%, 57.6% and 78.8% from Ibohora, Ruaha Mbuyuni and Ikuvala respectively) reported that there has been a decline in crop yields during the past 40 years (Figure 5.22). Crop production during the 1970s to mid-1980 was better compared to the past two decades. For example, crop yields were reported by farmers to be declining progressively during the past three growing seasons (2008 to 2011).

Figure 5.22: Impacts of prolonged droughts on agriculture during the past 40 years



Results indicate that most farmers from the study villages (57.6%, 66.7% and 69.7% from Ibohora, Ruaha Mbuyuni and Ikuvala respectively) reported that crop types and varieties grown have not changed during the past 40 years. A relatively small percentage of farmers (12.1%, 30.3% and 24.2% from Ibohora, Ruaha Mbuyuni and Ikuvala respectively) reported that there has been an increase in crop types and varieties grown over the study period (Figure 5.22). A relatively high percentage of farmers from Ibohora (51.5%), Ruaha Mbuyuni (48.5%) and Ikuvala (36.4%) reported that the type of crop pests and diseases have not changed during the past four decades, whilst a relatively small percentage (36.4%, 30.3% and 27.3% from Ibohora, Ruaha Mbuyuni and Ikuvala respectively) reported that crop pests and diseases have been increasing (Figure 5.22).

The majority of farmers from Ibohora (87.9%) and Ikuvala (63.6%) villages reported that there has been a decline in household income from agriculture. Furthermore, a relatively high percentage (39.4%) of farmers from Ruaha Mbuyuni village reported that the income from agriculture has been declining compared to those who reported that it has not changed (30.3%) or it has increased (30.3%). In the same line, the majority of farmers from Ibohora (81.8%) and Ikuvala (56.6%) villages reported that there is a decline in food availability, whilst a relatively high percentage (36.4%) of farmers from Ruaha Mbuyuni reported a similar finding compared to those who said that it has not changed (27.3%) or it has increased (36.3%) (Figure 5.22).

5.5.1.2 *Impacts of excessive rains during the rainy season*

Excessive rains were reported by farmers during focus group discussions to be less common than droughts. The *El Niño* year (1997/98) was reported to have excessive rains in the study villages. In a separate case, Ruaha Mbuyuni farmers reported excessive rains during 2006 and 2008. Crops failed and farmers were forced to hire upland farms and use irrigation pumps. Farmers in all villages reported that excess rains during the growing season lead to flooding, water-logging, erosion, and excessive leaching, consequently resulting in crop failures. During this situation, farming costs increase as more fertilizers and other chemicals are required. This also leads to crop losses due to insect pests and diseases, including those that are stored on the farm. Gully and sheet erosion in Ikuvala village were reported to be exacerbated by *El Niño* and associated intensive rains. This led to the destruction of crops and hence reduced food availability in the village. Roads were destroyed by intensive rains (e.g. in 2012/2013) which made it difficult to transport crops from farms to markets (Plate 5.3). Excessive rains were reported by farmers, moreover also damaged crops stored on farms. One farmer reported to have lost more than 100 bags of onions stored on farm due to floods in Ruaha Mbuyuni village.

5.5.2 Positive impacts of climate variability and change

It was generally reported by farmers in the previous sections that climate variability has led to mainly negative impacts. There was a marked decrease in rainfall and crop yields in all the study villages. The researcher received positive results of impacts of climate variability only from Ibohora village. Farmers from Ibohora reported a noticeable decrease in labour force to work in the fields because many youths had left for neighbouring urban centres to look for casual labour and start businesses. Some of the migrated youths were reported to be sending remittances to their parents back home. Other researches in southern Africa have reported the significant contribution of remittances to the livelihoods of rural communities (Ziervogel & Taylor, 2008).

Plate 5.3: Section of the road destroyed by excessive rain at Ikuvala village

Source: Fieldwork, 2013

Farmers in Ibohora village indicated that when droughts occur, they diversify into non-farm activities (i.e. small enterprises), which supplement the poor harvests during those times. A farmer from Ibohora village said that "*during the 2010/2011 growing season it rained for* *only 27 days in total (from November 2010 to May 2011). It was raining on one day and followed by a dry spell of several weeks until the crops wilted, then it rained again. But the positive part of it was that farmers had automatically learnt entrepreneurial skills and engaged in alternative livelihood activities such as small businesses enterprises".* Moreover, Ikuvala farmers benefited from *El-Niño* rains in 1997/1998, which led to the beginning of water springs in the mountains that continue to provide water for domestic consumption and livestock, amongst other uses.

Discussion

Changes in climate have been observed by farmers to have impacted both positively and negatively on their livelihoods in the study area. Agricultural production is perceived to be negatively impacted by unpredictable rainy seasons. However, other factors might have contributed to the reduced agricultural production in the study area, such as a decline in soil fertility, planting seeds that are not suitable to weather conditions, water extraction by rice farmers, tree plantations, increased pressure on land due to the increasing population, and a lack of good market prices for cash crops that have demoralised some farmers to continue expanding their farms. Promotion and adoption of more drought tolerant and short-term maturing food and cash crops such as cassava, millet and sorghum, could be one of the solutions to the decline in crop productivity in the study area. Apart from agriculture, other impacts perceived to have been brought by changes in climate, include the destruction of roads due to floods/excessive rains, disappearance of vegetation species, drying of water sources and deforestation.

A declining trend of some parameters is observed across all study villages with respect to the impacts of prolonged droughts on agriculture during the past 40 years. These parameters include the state of crop yield, income from agriculture and food available to households. The decline in crop yields was partly driven by the observed trends of climate indices (e.g. delayed onset of the growing seasons and mid-season dry spells) and partly by low availability of inputs, which contributed to crop failures. This is in agreement with the study by Kangalawe *et al*. (2011) who reported that the delayed onset of rains in the Great Ruaha river catchment area had made it difficult for farmers to follow the cropping calendar, thus affecting the timing of the growing season. This implies that more farmers/households have been increasingly vulnerable because most of them accrue their income from selling crops. Other studies from Tanzania (e.g. Malley *et al*., 2009; Rowhani *et al*., 2011) and other sub-Saharan countries (e.g. Lobell *et al*., 2011; Roudier *et al*., 2011; Berg *et al*., 2013; Niang *et al*., 2014) reported a noticeable decline in crop production as a result of the high frequency of droughts.

There has been no major change in the main crop types (i.e. maize and rice) grown for the past 40 years. These crops are still relevant, according to farmers, despite declining yields. However, a relatively small percentage of farmers (mainly from Ikuvala and Ruaha Mbuyuni) indicated an increase in crop types they grow during recent decades. They have been adopting both improved seeds of the same traditional crop types and new crops during this period (see details in the next section). There is, however, a general reluctance among farmers to plant improved seeds or adopt new crops due to various reasons, such as taste of the food and buying seeds at every farming season. This has probably contributed to the chronic food insecurity in the study area as the planting of traditional seed varieties that require considerable water and take a longer period to mature in this erratic weather, has led to crop failures.

The type of pests and diseases has remained the same across the study villages. However, few farmers (mainly from Ibohora and Ruaha Mbuyuni) reported an increase in pests and diseases, whilst a relatively low percentage of farmers from Ikuvala reported a decline of pests and diseases over the past 40 years. This may be due to the fact that pests and diseases mostly affect few farmers involved in commercial farming of tomatoes and onions. Some of the pests and diseases impacting on agriculture include Fungus, Ants and stalk borers. Fungus (*ukungu* in vernacular language) infestation on tomatoes and onions is reported to have increased, especially during the current trend of progressive droughts during growing seasons. Ants and stalk borers were reported to have increased and affect crops such as tomatoes, maize and rice. A similar finding was reported from a study which was undertaken in semi-arid areas of Tanzania (Mary & Majule, 2009). The study associated the increase of crop pests and diseases with the high frequency of droughts. Farmers in the study area reported that new crop varieties have attracted new types of pests and diseases because they started to increase during their adoption and when drought frequencies began to increase. Other studies have reported an increase and change in the distribution of pests and diseases in the face of climate variability, thus impacting on crop production (e.g. Shao, 1999; Anderson *et al*., 2004; FAO, 2007; Kangalawe, 2012).

Moreover, not only droughts have had an impact on crop production in the study area, but also excessive rains and floods. Some of the reported impacts include destruction of roads and other infrastructures, thus hampering transportation of produce, both pre- and post-harvested damage on crops, erosion and water logging. A similar finding has been reported in southern Africa (e.g. Mutekwa, 2009). For example, during the 2003/2004 and 2007/2008 growing seasons, there were excessive rains in Zimbabwe which led to post-harvest damage of crop produces, thus leading to a serious food insecurity on households. However, in the study area (especially Ikuvala village), excessive rains were reported to have a positive impact on upland farming and farmers depending on this type of farming receive a good harvest.

5.5.3 Coping with change - The role of local strategies to best reduce risks to climate changes

In the previous sections, it is indicated that observed climate variability is increasing, particularly extreme events such as floods, droughts and mid-season dry spells. The most dominant of these stresses are droughts and mid-season dry spells. This variability has been noted to impact negatively/positively on the agricultural production in the study area, especially during recent decades. In this section, strategies used by smallholder farmers to respond to the impacts of such changes are examined.

5.5.3.1 *Farming methods used during climate induced droughts*

Most farmers from Ruaha Mbuyuni (60.6%) and Ikuvala (78.8%) practice mulching to conserve moisture during droughts, whereas, only a small percentage of Ibohora inhabitants (24.2%) use mulching. Intercropping of different crops in one portion of land is the response strategy used by most farmers from Ruaha Mbuyuni (69.7%) and just over half of farmers (51.5%) from Ibohora village. A relatively small percentage of farmers (42.4%) from Ikuvala practice intercropping during drought periods (Figure 5.23). Ruaha Mbuyuni and Ibohora villages have access to irrigation water, thus practice garden irrigation farming which favour the intercropping practice. Few farmers from Ikuvala village practice intercropping in upland farms (rain-fed) and those who hire irrigable land from neighbouring villages. Farmers indicated to intensively employ this method during recent decades with the aim of reducing the risk of crop failures. Both drought tolerant and less drought tolerant crops are mixed. These include maize, sunflower, vegetables and legumes.

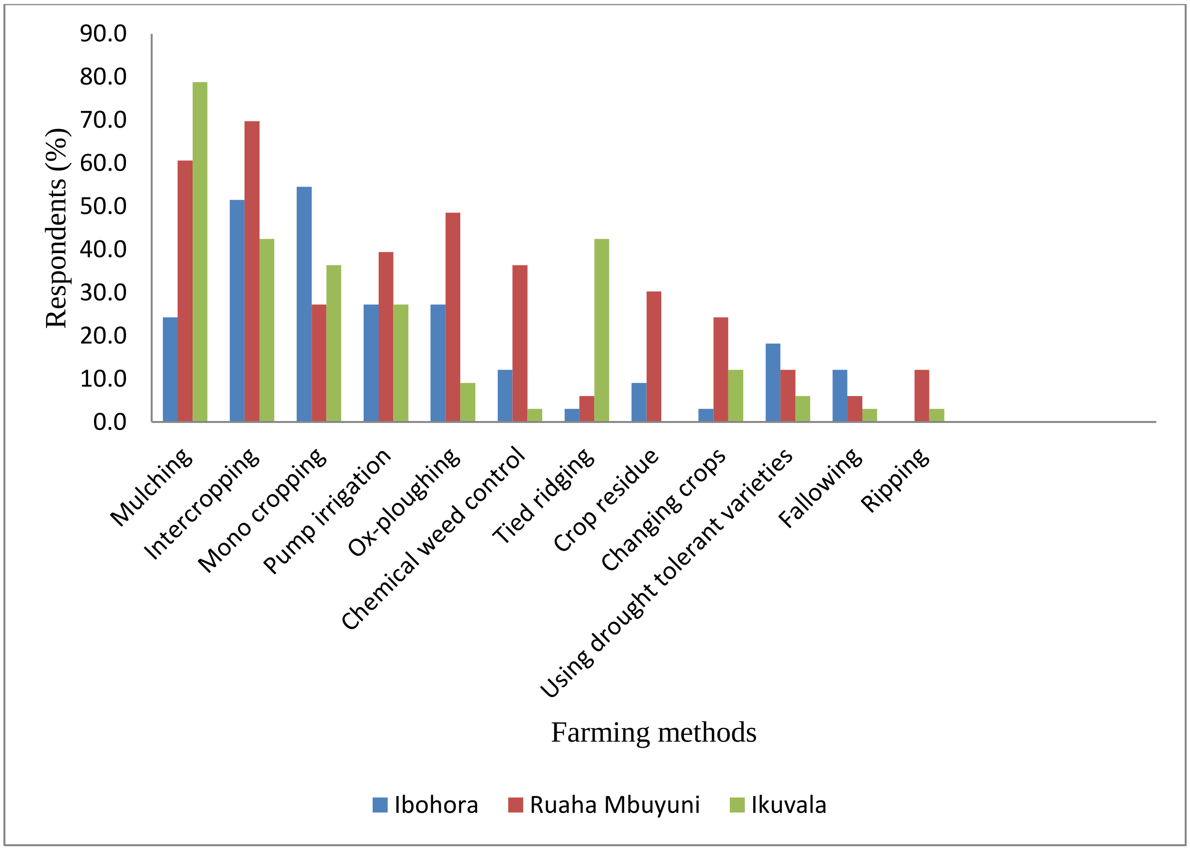
Mono-cropping is a traditional farming practice that has been used in all villages, but mostly in Ibohora village (54.5%) (Figure 5.23). Less than fifty percent of farmers from Ruaha Mbuyuni (27.3%) and Ikuvala (36.4%) villages practice mono-cropping. These two villages engage more on the mono-cropping practice because they rely on large scale agriculture. For example, large-scale commercial farming of rice and maize is under a mono-cropping system in these villages. Mono-cropping reduces the risk of diseases and pests between crops, and thus is a favoured technique for large scale farming.

Less than half of farmers from all villages (27.3% from Ibohora, 39.4% from Ruaha Mbuyuni and 27.3% in Ikuvala) use the pump irrigation method (Figure 5.23). Findings indicate that a relatively higher percentage of farmers from Ruaha Mbuyuni practice irrigation farming using motorised pumps. This has been a common practice in this village, especially in commercial onion and vegetable farming. Some commercial farmers in Ibohora have been adopting this irrigation method due to the access to irrigation water and the upcoming tomato and vegetable business. Ikuvala farmers practice pump irrigation in hired plots at nearby villages. Nevertheless, this irrigation method was reported to be used by farmers with financial capital (medium wealth and rich) due to the high cost of managing the pumps. Many farmers resort to group hiring of pumps so that they could pull resources together to manage the pumps.

A relatively small proportion of smallholder farmers (18.2% from Ibohora, 12.1% from Ruaha Mbuyuni and 6.1% from Ikuvala villages) are using drought tolerant seeds and varieties (Figure 5.23). In the same line, only few farmers from the study villages (3.0%

from Ibohora, 24.2% from Ruaha Mbuyuni and 12.1% from Ikuvala) have been practicing changing crop farming methods. These findings are congruent with results in the previous section which indicated that more farmers are reluctant to adopt new crop types due to various reasons.

Figure 5.23: Farming methods used during climate induced droughts



The previous section (5.4) outlines the increase in dry spells and the decrease in season length due to delayed onset and early cessation of rainy seasons. Therefore, planting drought tolerant crops and short time maturing improved seeds, are among the response strategies that could improve agricultural productivity in the study area. For example, Mutekwa (2009) reported that Zimbabwean farmers have adopted hybrid maize varieties that take a shorter period to mature and produce more yields. A study in the southern highlands of Tanzania reported that among the response strategies at farm-level, include the use of early maturing and drought tolerant varieties of rice and maize (Kangalawe *et al.*, 2011).

A number of other farming methods are adopted by a few farmers in the study villages, these include chemical weed control (practiced more in onion farming in Ruaha Mbuyuni, 36.4%), tied ridging (practiced more in Ikuvala village to cope with erosion in slopes, 42.4%), crop residues to conserve moisture and fertilise the land, fallowing and ripping (Figure 5.23). During focus group discussions, farmers from the study villages provided a related list of farming methods. These include vegetable farming in irrigated gardens along river banks, planting short time maturing crop varieties, planting or sowing early, the use of crop residues to preserve moisture, switching crops to restore soil fertility and control pests, fallowing and ox-ploughing. A study on smallholder farmers in Zimbabwe reported that response strategies used, included planting short-term maturing varieties, crop diversification, and changing planting dates (Mutekwa, 2009). Moreover, crop diversification has been found to be effective as it improves household food security by reducing the risks of crop failures due to changing weather conditions (Mutekwa, 2009).

5.5.3.2 *Response strategies used during food shortages*

The previous sections have shown that farming in the GRRB has been impacted by climate variability and non-climatic factors during recent decades, leading to food shortages. In response to food shortages, farmers have been adopting different measures so as to sustain their families. These response strategies are different amongst different villages (this will be addressed in detail later).

All responses to food shortage are reported to be used by the minority of farmers in all three villages (Figure 5.24). Although few farmers from the study villages (21% from Ibohora, 9 from Ruaha Mbuyuni and 16 from Ikuvala) reported having reduced the number of meals per day in response to food shortage, Ikuvala and Ibohora villages have a relatively high percentage that do so. A similar response is indicated by results with regard to reducing the amount of food eaten in response to food shortage. Where a relatively high proportion of farmers from Ibohora (20%) and Ikuvala (16%) use this practice compared to Ruaha

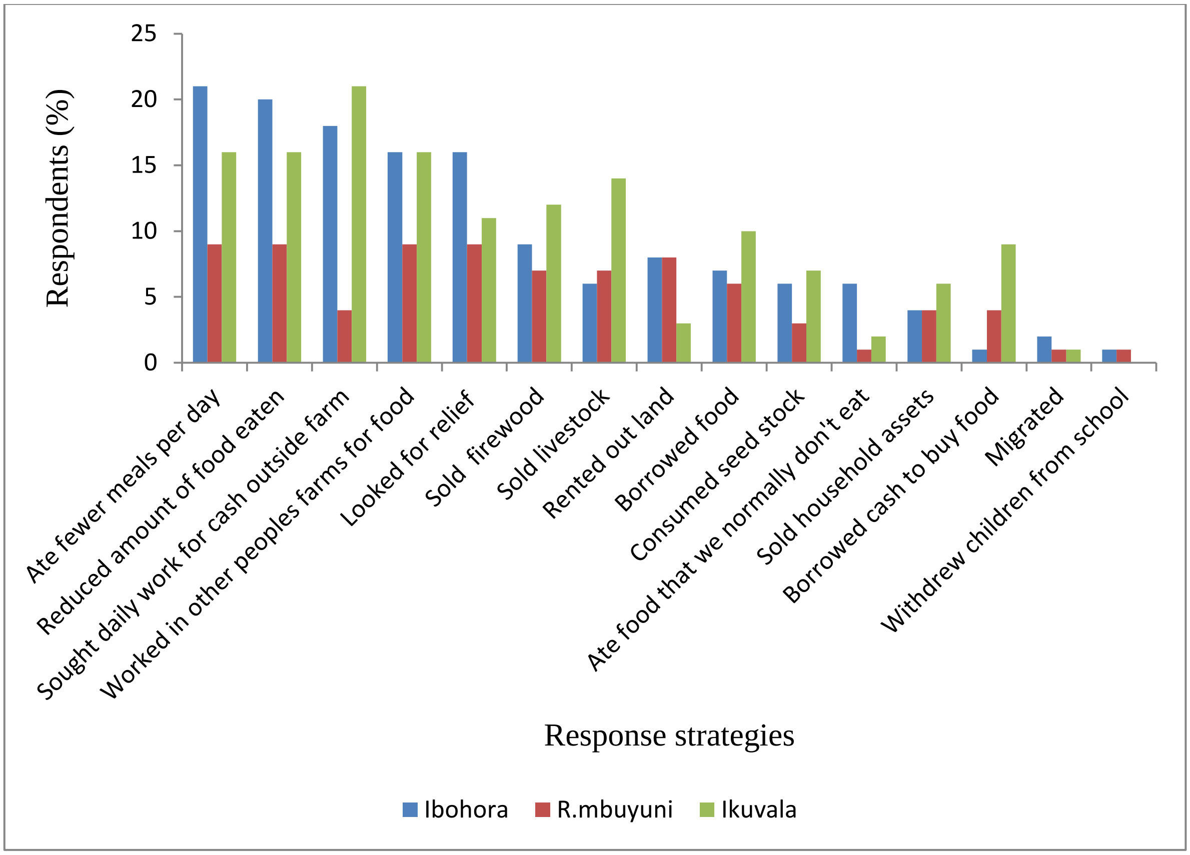
Mbuyuni (9%). This implies that Ruaha Mbuyuni inhabitants rely on other options to respond to food shortage. As reported in previous sections in this chapter, Ruaha Mbuyuni inhabitants have more options due to a high diversity of activities in the village. These include off-farm activities (i.e. business and employment opportunities), access to financial support through both formal and informal loans, and, when possible, replanting their fields due to availability of irrigation water throughout the year.

Farmers reported during group meetings that coping strategies such as eating fewer meals and reducing the amount of food eaten per day were used by poor households only. They chose these strategies due to the fact that they had no other options and little savings that forced them to save the little they had, so as to survive the time leading up to the next harvest. Similarly, Kennedy (1992) and Jaspars and Young (1995) reported that during drought, households may reduce the number of meals per day so as to make food stocks last up to the next harvest.

Few farmers respond by selling livestock (particularly small livestock such as goats, sheep and poultry) during times of food shortage (Figure 5.24). A relatively high percentage of them are from Ikuvala (14%) compared to Ibohora (6%) and Ruaha Mbuyuni (7%), which have a lower proportion of farmers using this strategy. In the previous sections (e.g. section 5.2), findings indicate that Ikuvala farmers own more livestock compared to Ibohora and Ruaha Mbuyuni. Farmers reported that sales depend on the nature of the need, and they started by selling small-scale livestock before selling cattle. A study by Eakin (2005) in central Mexico found that farmers coped with food shortages by selling small livestock in order to acquire sufficient funds to purchase maize. Likewise, Mertz *et al*. (2010) reported that keeping livestock, particularly small-scale livestock is a common coping strategy that may be used to solve short-term problems.

Other response measures include seeking daily work for cash outside farms (18% from Ibohora, 9% from Ruaha Mbuyuni and 21% from Ikuvala), working on other people's farms for food (16% from Ibohora, 9% from Ruaha Mbuyuni and 16% from Ikuvala), and looking for food aid (16% from Ibohora, 9% from Ruaha Mbuyuni and 11% from Ikuvala). Extreme measures used by some farmers include selling firewood, selling of household assets, eating food that is normally not eaten (e.g. wild food), renting out land for cash, borrowing food, borrowing cash to buy food, migrating and withdrawing children from school (Figure 5.24).

Figure 5.24: Response strategies used during food shortages during the past 40 years



A study by Kessy (2004) in North-western Tanzania reported that depletion of household assets is among the most important coping strategies used during food shortage. Other researchers reported that reduced food consumption and selling of household assets are among the strategies used in response to harvest failure (e.g. Kochar, 1995; Kinsey *et al*., 1998; Niimi *et al*., 2009). Findings from this study and other studies cited therein, imply that response measures to food shortage by smallholder farmers depend, first on access to resources or options locally available, and second, on other options elsewhere during extreme cases.

Discussion

The poverty level of poor households during food shortages may be exacerbated by coping strategies employed by farmers in the study area. For example, poor households spend most of the growing season working on other people's farms and engaging in off-farm activities so as to sustain their families. Consequently, there is a high risk of a chronic food shortage amongst the majority of farmers in all the study villages if concerted efforts are not made to support poor farmers with reliable adaptation strategies to the projected climate changes. Farmers suggested some factors that could improve their adaptive capacities, such as access to affordable agricultural implements and inputs, extension services, irrigation infrastructure including pumps, access to small loans and markets.

Migration is seen as both a stressor and coping/adaptation strategy by smallholder farmers in all villages. Farmers from Ibohora village reported that out-migration is more prevalent during droughts. More men (youth in particular) migrate to nearby urban centres in search of casual works and small businesses. Some married men were reported to migrate temporarily during droughts and most of them do not remit back, and hence leave the burden of taking care of the family to women. Most youths were reported to migrate permanently and settle into nearby urban centres, thereby reducing the labour force required by their households. They normally engage in casual jobs and some begin small businesses. Youths were reported to return back during the growing seasons and engage in farming of cash crops, then return back to urban centres after having sold their produce. Few households reported to receive remittances from their children living in urban centres. This is contrary to what has been observed previously in South Africa and Mexico (Eakin, 2005; Ziervogel & Taylor, 2008) where young people migrate to find various employment opportunities in cities and remit back to their villages, thus making migration one of important coping strategies.

Out-migration in Ikuvala village was reported to be temporary and happens during both dry and normal years. Farmers reported to migrate to nearby villages and hire irrigable land to compliment the rain-fed agriculture. The hired plots are planted with tomatoes, vegetables, beans and maize in valley bottoms, for both commercial and household consumption purposes. Some large-scale commercial farmers of tomatoes migrate every year, regardless of it being a dry or wet year. They migrate temporarily to nearby villages and some to distant regions seeking for irrigable land to cultivate tomatoes for commercial purposes.

Ruaha Mbuyuni farmers reported more in-migration, both temporary and permanent. Migrants come to this village seeking for irrigable land, business opportunities and employment in restaurants. The influx of migrants is reported to be high during dry years and they come from nearby villages where there is no source of water for irrigation. The expanding onion business and casual works on farms, restaurants and bars (liquor shops) was reported to be the main attraction for immigrants. Some immigrants reported that they remit back or they have communications with their relatives back home, whilst others have decided to settle in Ruaha Mbuyuni and occasionally visit their relatives. Other challenges brought by immigrants include social-cultural changes and increased incidences of STDs (i.e. HIV) due to the influx of women and a parking lot for trucks. Immigration also increase pressure on the land that in turn raises the land rent where few locals can afford to hire. Farmers reported that some people rent out their land to meet their immediate cash needs and end up having the same problem of food shortage due to limited suitable land located within the irrigation system.

Basically, most of the response strategies presented in this section are reactive, and they are used by farmers in response to impacts of climatic hazards (e.g. droughts, floods and dry spells). In this case, these strategies are more linked to the short-term coping strategies. However, response strategies analysed in the previous section (farming methods) are more proactive, thus relating more to long-term adaptation strategies. A detailed categorisation of response strategies will be discussed later in this chapter.

5.5.4 Household experience and response to climate variability (case studies).

General findings on the climatic stresses (e.g. droughts and floods/excessive rains) that smallholder farmers have been facing and their response strategies are profiled in the previous sections. In this section these findings are built up by presenting detailed case studies that illustrate individual farmer experiences during climatic stresses and the subsequent coping strategies. The integral part of adaptation to climate change revolves around how an individual perceives and thinks about such change (O'Brien & Hochachka, 2010). One case from each village is therefore presented in this section.

- *The case of Smallholder Farmer I- Ikuvala village*

This farmer was born in the 1980s in Ikuvala village, Kilolo district. He is married and they have four children. Currently, the household owns 9 acres of land, 5 livestock (4 cattle and 1 pig), a bicycle, ox-plough and a mobile phone. In the past (more than 10 years ago), they were cultivating 2 to 3 acres of maize, but now they have expanded to cater for tomato production that earns them a good income. During recent years, the household has been hiring 2 acres of land within the village to increase maize production to meet family demands for food. They use an ox-plough as the tillage method, both currently and in the past. The only difference is that at present they plant with appropriate spacing and apply farm yard manure to improve the soil fertility. They started farming in 1994, with 2 acres of maize, then after three years started to grow tomatoes, hence the size of the plot having increased. After *El Niño* (1998), the amount of rainfall started to decline progressively, and hence they started to diversify crops by growing sunflower which is drought tolerant. The village experienced serious drought during the year 2006 and maize was affected more than sunflowers. During that year they experienced substantial crop failures, especially maize, and decided to diversify further to horticultural crops that mature within a short time and generate quick cash, which was used to buy food and cater for other family needs. These crops include tomatoes, green pepper and cowpeas. He said that during years with enough rains, four acres produces 15 to 20 bags of maize, whilst during dry years the yield ranges between 8 to 9 bags only. Tomato yields per acre during years with good rains is 70 *tengas* (one *tenga* is equivalent to three buckets of twenty litres each), whilst during dry years it drops to 20 *tengas*. He receives weather forecast information from a local radio station (Ebony FM in Iringa town), but the information is of no value because it is not reliable or accurate (normally generalizes for the entire Iringa region). Average temperatures in October help them predict whether the following growing season is going to be dry or wet. When the temperatures are above average, then it is an indication of a wet year and vice versa. Both droughts and excessive rains had negative impacts on this family. For example, the 2006 drought left cattle without enough pasture, hence reducing the power for ox-ploughing, and crops wilted. The 1998 excessive rains led to flooding and water-logging on farms and also surface runoff that accelerated erosion on sloping areas. He highlighted that during years with excessive rains, for example in 1998, the family responded by shifting from cultivating in the lowlands to the highland areas, shifting settlements to upland areas and selling livestock to buy food since fields were destroyed by excessive rains. Their response measures during dry years include selling small livestock (e.g. goats and sheep) and engaging in small businesses (i.e. selling of buns). Moreover, he highlighted that the adaptation strategies to future drought are such as hiring lowland plots and engaging in irrigation farming (i.e. hiring *vinyungu* in nearby villages) and expanding farming of horticultural crops. He concluded by pointing out that *mtaji* (referring to financial capital) is the determining factor when it comes to choice of coping or adaptation strategies at a household level.

- *The case of Smallholder Farmer II- Ibohora village*

The farmer was 55 years old and was born in Ibohora village, Mbarali district. She became a widow in 1997 after her husband's death. She started farming in the 1980s, by then they owned and cultivated 8 acres (3 acres of maize, 3 acres of rice and 2 acres of tomatoes and vegetables). Rains were good and they produced enough food and cash crops. After the death of her husband, life changed because she could not manage alone to cultivate all the land and produce enough food to meet the demands of the family. Currently (2011), she can manage to cultivate only 6 acres of land (4 acres of maize and 2 acres of rice). She no longer cultivates tomatoes due to recurrent droughts and a lack of water for irrigation. She uses a hand hoe for tillage and ox-plough that is hired at 40,000 TSHs per acre. She highlighted that recently, the crop yield per acre has dropped significantly, compared with the 1980s. For example, in the 1980s the average yield was 60 bags of maize per 3 acres and 60 bags of rice per 3 acres, whilst in 2011 the yield dropped to 15 bags per 4 acres, and thus did not harvest anything in the 2 acres of rice, which wilted due to drought and a lack of water in the irrigation canal. She receives weather forecast information through hearing from a neighbour who has a radio. She admitted that she has never relied on it when preparing for the growing season because she does not know its importance. She remembers that between the 1970s and 1980s rains were good. Just after *El Niño* (1998), the village started to experience years with recurrent and prolonged droughts, with 2006 being the worst drought remembered. She highlighted some response measures that she took during both dry and excessive wet years. For example, during the 1998 floods, she responded by making drainages to drain the water from the farm and also planted on upland farms. During dry years, she resorts to irrigation farming of vegetables using jerry cans on small gardens hired near the river (used for food and selling), and selling firewood and snacks. When asked about the long term or future adaptation strategies, should the situation continue to worsen, she hinted that the plan is to purchase a motorised pump and engage in irrigation farming (e.g. plant maize and rice twice a year and plant horticultural crops many times a year to increase the income).

- *The case of Smallholder Farmer III- Ikuvala village*

This farmer was 47 years old and a native of Ruaha Mbuyuni village, Kilolo district. He married in 1987 and started farming by then. Currently, he owns 37 acres of land, 8 livestock (5 cattle and 3 goats), hand hoes, has a television set and radio, mobile phones, 2 motorcycles, a generator and 4 irrigation pumps. He started farming in 1987 on half an acre where he planted maize during the rainy season and onions during the dry season. In 1997, he expanded to 2 acres and increased the variety of crops grown from maize and onions to green pepper, red pepper and vegetables. The reasons for expansion include a good market for vegetables and peppers that also matured within a short time, the declined production of maize, high cost of managing an onion farm and increased family demands for food and cash. During the year 2011, he added another acre to make 3 acres planted during that season. He planted 1.5 acres of maize/onions, 0.5 acre of red pepper and 1 acre of beans, all under pump irrigation. The tillage methods used are ox-plough and tractor (hired) and hand hoe for weeding only. Crop yields began to decline after 1998, for example during that year 2 acres produced more than 100 bags of onions (all were damaged by *El Niño* floods on the farm). He said during the 2011 growing season, 1.5 acres produced only 65 bags of onions. The main reasons for the decline are increased crop diseases (i.e. Fungus/*ukungu*) and pests such as armyworm. Therefore, the yields depend most on the application of fertilizers and pesticides. He has access to the weather forecast information through media, such as television and radio. He responds according to the forecast and advice given by extension officers. For example, the 2011 growing season was forecasted to be dry and crops failed, therefore he opted for a second round of planting using short-term maturing varieties/seeds. Generally, he highlighted that rains were good up to the mid-1990s; thereafter rains became unpredictable with frequent droughts except in 1998. To cater for family food demands and the unpredictable weather, he has adopted some response measures which include subdividing the farm and planting different crops in each plot, such as maize, onions, green pepper, red pepper and vegetables which generate quick cash that is used to purchase food. Other measures include selling livestock, renting out land (100,000 per acre) and renting out irrigation pumps (100,000 TSHs per acre per season); the money is used to buy food. He has prepared for the future by engaging in non-farm income generating activities that are less sensitive to climatic changes. He has built a house with three rooms in the village centre where he plans to open a business and rent out other rooms. He also has a plan to purchase dairy cows for business purposes.

The implication from the three cases is that access to resources (e.g. financial, land and irrigation infrastructure), and farm inputs and implements are key factors in enhancing the adaptive capacity of smallholder farmers, regardless of their biophysical and socio-economic differences.

- **Discussion and categorisation of response strategies**

In this section, response strategies are categorised into either coping or adaptation strategies, based on the findings and literature cited. The list of coping and adaptation strategies is teased out to indicate main reactive responses (e.g. short-term coping strategies) and more transformative (e.g. long-term adaptation strategies). It is again important to define coping and adaptation concepts so as to permit an analytical categorisation of these concepts. Coping strategies may be defined as short-term strategies employed by a farmer in response to food shortage (Davies, 1996; Ellis, 1998; Vincent *et al*., 2013). Adaptation is defined as long-term modifications in livelihood activities, farming practices or policies in response to climatic stresses (Boko *et al*., 2007; Niang *et al*., 2014). In this PhD thesis, short-term strategies that farmers use more often during times of climatic extreme events and food shortages, are considered to be coping strategies. Conversely, long-term strategies that have become part of their livelihood strategies and are used by farmers at all times (i.e. during both good and bad crop production years) are categorised as adaptation strategies. This categorisation of response strategies follows that presented in Chapter Two (Table 2.3).

a. Coping strategies

Farmers reported during focus group discussions that most of the response strategies that are used during extreme events and food shortages or low crop yield years are regarded as coping strategies because they are used to respond to a short-term crisis, rather than at all times (Table 5.11). Selling of household assets can be regarded as a coping strategy because it is used by farmers during a food crisis only. These assets also include livestock and poultry. It was reported that for a livestock keeper, selling cattle is the last resort because cattle are a symbol of prestige and wealth (Mubaya, 2010). Reducing the amount of food eaten and eating fewer meals per day is a form of coping strategy that is employed mostly during years with food shortages. Few farmers reported to only eat food that is not normally eaten (i.e. wild food) during critical food crises. Other coping strategies that are used mostly by households during a food crisis include borrowing cash to buy food, borrowing food, selling firewood, renting out land and looking for government food aid. Other examples include vegetable garden farming, seeking daily work for cash outside the farm, working on other people's farms for food, temporary migration and ripping.

During recent growing seasons (2008/2009, 2009/2010 and 2010/2011), crop diversification into vegetable farming in small gardens was reported to be increasing. Horticultural crops such as vegetables and spices have helped farmers generate quick cash during low yield years. Vegetable garden farming is transforming into an adaptation strategy because recently farmers continue to use it even during high crop yield years. Few farmers were reported to be engaged in these activities as their normal source of livelihoods, whilst the majority were reported to engage in these activities during years with both failed food and cash crop yields. Some households also engage in these activities only to supplement the low cash crop production in a particular year in order to avoid selling food to cater for other family needs.

Remittance can be regarded as a form of coping strategy as it was reported to intensify only during years with food crisis. People reported to receive remittances in different forms, such as food and cash from relatives or neighbours. In northern and southern Africa, families secure income from remittances received from family members who migrated to cities and others working in mines (Reid & Vogel, 2006; Mertz *et al*., 2009; Mutekwa, 2009). A study by Mutekwa (2009) reported that young people in Zimbabwe are migrating to South Africa and Botswana due in part to political/social and climatic reasons. However, there is a difference between migration found in the study area and in these two studies. In the study area, migration is a short-term response to a climatic disaster, but in western and southern Africa, migration is regarded as long-term strategy that provides livelihoods to rural people, regardless of the climatic conditions. Therefore, although this finding can only be confirmed for Tanzania, it may be a phenomena becoming more widespread elsewhere in Africa as a coping strategy. However, coping strategies vary across households or communities in space, time, preferences and ability to change (Kessy, 2004; Trærup & Mertz, 2011). According to Kessy (2004), depletion of household assets is the common coping strategy in response to a food shortage in most households of Tanzania.

There are more similarities than differences in coping strategies used by smallholder farmers in the GRRB and other countries in Africa, Asia and Latin America. These strategies include seeking off-farm activities, collecting wild food, seeking casual labour, selling household assets, seeking government food aid, borrowing food, temporary migration, re-sowing, reducing the amount of food eaten, reducing the number of meals per day, planting drought resistant crops and cultivation in swamps (e.g. Thomas *et al*., 2007; Eriksen *et al*., 2008; Mbow *et al.*, 2008; Reenberg *et al.*, 2008; Eriksen & Silva, 2009; Mertz *et al*., 2009; Mutekwa 2009; Mongi *et al.*, 2010; Nielsen & Reenberg, 2010; Trærup & Mertz, 2011; Abidji *et al.*, 2012; Bagamba *et al.*, 2012; Ozor *et al.*, 2012; Ashraf & Routray, 2013).

Table 5.11: The timing of various farming methods

Variable	Categories	Percentage of respondents			Total average N=90	χ2 P-Value
		Ibohora n=30	R.Mbuyuni n=30	Ikuvala n=30		
		%	%	%	%	
Ripping	All the time	0	0	0	0	1.023 0.600
	During drought years	0	3.0	3.0	2	
	NA	100	97.0	97.0	98	
Crop residues	All the time	9.1	9.1	3.0	8	1.239 0.538
	During drought years	0.0	0.0	0.0	0	
	NA	90.9	90.9	97.0	92	
Chemical weed control	All the time	0.0	24.2	0.0	8	19.584 0.001**
	During drought years	12.1	6.1	0.0	7	
	NA	87.9	69.7	100.0	85	
Pump Irrigation	All the time	3.1	39.4	6.1	17	28.266 0.000**
	During drought years	24.2	3.0	0.0	9	
	NA	72.7	57.6	93.9	74	
Using drought tolerant varieties	All the time	3.1	30.3	21.2	18	7.481 0.113
	During drought years	12.1	9.1	9.1	11	
	NA	84.8	60.6	69.7	71	
Changing crops	All the time	3.0	9.1	3.0	6	3.671 0.452
	During drought years	0.0	0.0	3.0	1	
	NA	97.0	90.9	94.0	93	
Mulching	All the time	21.2	21.2	9.1	17	3.551 0.470
	During drought years	3.0	0.0	0.0	1	
	NA	75.8	78.8	90.9	82	
Intercropping	All the time	51.5	48.5	81.8	59	11.605 0.071
	During drought years	3.0	3.0	0.0	2	
	NA	45.5	48.5	18.2	39	
Mono-cropping	All the time	51.5	66.7	42.4	53	6.162 0.187
	During drought years	0.0	3.0	0.0	1	
	NA	48.5	30.3	57.6	46	
Fallowing	All the time	18.2	21.2	33.3	23	3.836 0.429
	During drought years	0.0	3.0	3.0	3	
	NA	81.8	75.8	63.7	74	

** Significant at 5%

The study area is unique in its shift towards irrigated vegetable garden farming during both the dry and wet seasons. Generally, a combination of coping strategies used in the study area is similar to those in other African countries. However, Asian countries (e.g. Bangladesh, Pakistan and China) have an advanced combination of coping strategies compared to the study area and other African countries (e.g. Selvaraju *et al.*, 2006; Thomas *et al.*, 2007; Yang *et al.*, 2007; Eriksen *et al.*, 2008; Mbow *et al.*, 2008; Eriksen & Silva, 2009; Mertz *et al.*, 2009; Bryan *et al.*, 2009; Campbell *et al.*, 2011; Habiba *et al.*, 2012; Kpadonou *et al.*, 2012; Macharia *et al.*, 2012; Ashraf & Routray, 2013). The main reason is that these countries are more prone to climatic disasters and have developed coping strategies through lived experience and high government investments in coping strategies. Some of the coping strategies that can be replicated to the study area include tree planting to rehabilitate water catchments, the use of local herbicides, variety planting methods, cutting back on the area farmed (intensification), reduced cropping, a focus on livestock keeping (i.e. small livestock), and storing fodder for use during the dry season.

b. Adaptation strategies

Farmers from all study villages use most of the farming methods during dry and normal growing seasons as indicated in Table 5.11. Most of the adaptation strategies that were identified by the farmers are based on lessons learnt from previous climatic stresses and to some extent advice from Agriculture Extension Officers. These strategies include irrigation farming (i.e. particularly using pumps), intercropping and planting drought tolerant crops (e.g. cassava, sorghum, millet and sunflower). Farmers who do not own a pump or cannot afford to hire a pump, acknowledged that this irrigation method is a reliable adaptation strategy, which can help farmers improve agricultural production and make them resilient to the impacts of climate variability. Most of them reported to have a plan of owning a pump in the near future because the weather pattern is progressively becoming less predictable. Some farmers resort to group hiring of irrigation pumps, but this also requires their plots to be adjacent to each other so that the pump's pipe can reach them. The limitations of using the pump irrigation method include its high purchasing price and high operation costs, and farmers ought to have a farm close to the river.

Other adaptation strategies include engaging in off-farm livelihood activities and keeping cattle and small livestock (e.g. poultry and pigs). The off-farm activities include small businesses (i.e. shops, restaurants, selling local brew), building houses for renting in urban centres and food and cash crop businesses. In Ruaha Mbuyuni village, which has most business opportunities, the majority of farmers are engaged in different types of activities linked to businesses, so as to diversify their source of income. Even villages with limited business opportunities, such as Ibohora and Ikuvala, some of the farmers are engaged in some sort of businesses, taking advantage of nearby emerging urban centres (rural-urban complementarities/linkages). The finding adds to the broad literature already established by other studies that were conducted in Tanzania and other countries. For example, diversification to non-farm activities such as brick and charcoal-making, casual labour and carpentry, have also been reported by other studies as adaptation strategies used by farmers in Tanzania and southern Africa (Paavola, 2006; World Bank, 2009; Liwenga *et al*., 2008; Majule, 2008; Bushesha 2009; Gbetibouo, 2009). During the 2002/2003 drought in Mozambique, households diversified into business enterprises such as kiosks and shops (Eriksen & Silva, 2009). However, the study found that such activities were not very viable during a prolonged drought and had all but ended by 2003. This was also the case in Ibohora village where farmers reported that the sustainability of small businesses depended on the purchasing power of local households. During prolonged droughts, households tend to narrow down their expenditure so as to meet the food needs, and this jeopardized the existence of kiosks which sell various commodities. This indicates that access to goods and services change depending on livelihood economic situations.

Efforts are being made by the local government and NGOs to provide entrepreneurial skills to some groups of farmers, so that they can take advantage of existing opportunities and diversify from agriculture. For example, farmers in the Iringa region of Tanzania have been receiving entrepreneurship training on diversification of economic activities, such as raising and selling chickens so as to better cope with the impacts of climate variability (Kangalawe *et al*., 2011). Farmers reported to be purchasing small livestock (e.g. goats and sheeps) and poultry during good crop production seasons and selling them during times of food crisis. This strategy is common in Ibohora and Ikuvala villages where there is limited business opportunities compared to Ruaha Mbuyuni village.

Most of the adaptation strategies used by smallholder farmers are similar to those used in other African countries. Few resemble the ones used by farmers in Asian and Latin American countries. The common adaptation strategies include livestock keeping, migration, small-scale commerce, vegetable garden farming, canal irrigation, new short-duration and drought-tolerant crop varieties, intensification of non-agricultural activities, diversification of agriculture, and growing alternative crops such as sunflower, sorghum and cassava (e.g. Eriksen *et al.*, 2005; Selvaraju *et al.*, 2006; Thomas *et al*., 2007; Mbow *et* *al.,* 2008; Mertz *et al.,* 2009; Bryan *et al.*, 2009; Mertz *et al.,* 2010; Mongi *et al.,* 2010; Kangalawe *et al.,* 2011; Abidji *et al.*, 2012; Habiba *et al.,* 2012; Ozor *et al.*, 2012). The only unique strategies to the study area are pump irrigation practices and intensification on vegetable garden farming at villages with access to irrigation water sources (e.g. rivers).

West African and Asian countries indicate a more advanced combination of adaptation strategies used by farmers. For example, farmers in West African countries have diversified their livelihoods to non-crop farming activities such as businesses, livestock keeping and fishing, whilst Asian countries (e.g. Bangladesh, China and Pakistan) have invested more in technology, inputs and technical expertise (e.g. Selvaraju *et al.,* 2006; Thomas *et al*., 2007; Yang *et al.,* 2007; Eriksen *et al*., 2008; Mbow *et al.*, 2008; Eriksen & Silva, 2009; Mertz *et al.,* 2009; Bryan *et al*., 2009; Campbell *et al*., 2011; Habiba *et al.,* 2012; Kpadonou *et al.*, 2012; Macharia *et al.,* 2012; Ashraf & Routray, 2013). Some adaptation strategies may be easily replicated in the study area and they do not need large investments and technical expertise to adopt. These include market-based options, agro-fishing practices, soil conservation, changing planting dates, pond excavation, retention of rainwater in canals, integrated crop-livestock farming systems, water harvesting, soil fertility improvement, tree planting, planned adaptation and investing in advanced technology and extension services. Smallholder farmers in the study area can also capitalize on the emerging opportunity of beekeeping, which has recently received considerable government support.

The findings from this study and those cited, imply that the adaptation process must adopt a whole system approach for it to be successful, thus enhancing farmers' adaptation to the impacts of both climatic and non-climatic hazards. This could begin at the local level, by transforming local experiences and farmers' behaviour, policies and institutions (e.g. community, the public and private sectors), and investment in terms of affordable technologies and infrastructure (e.g. irrigation systems, roads, agro-industries and markets). Moreover, the investment by both the public and private sectors in the adaptation process is inevitable if we want to improve the adaptive capacity of farmers in the sub-Saharan Africa region.

Table 5.12: A summary of main coping and adaptation strategies

Study villages	Coping strategies	Adaptation
Ibohora	Selling household assets, out-migration and selling own labour	Planned canal and pump irrigation, agriculture intensification and planting drought tolerant crops.
Ikuvala	Hiring irrigable land, selling household assets, out-migration and selling own labour	Agriculture intensification and commercialization, planting drought tolerant crops, savings in a form of livestock keeping and building house for rent in urban centres.
Ruaha Mbuyuni	Renting-out land, selling household assets and selling own labour	Planned canal and pump irrigation, agriculture intensification and commercialization, planting drought tolerant crops, savings in a form of livestock keeping, business enterprises, employment and building house for rent in urban centres.

5.5.5 Factors influencing the choice of response strategies during food shortage

After focusing on response strategies (coping and adaptation strategies) in the previous sections, the factors influencing the choice of these strategies are now analysed. According to Deressa *et al.* (2011), there is a range of social and economic factors which determine one's ability to select response strategies to climate change. These factors may include education level and sex of the household head, size of the household, ownership of assets (e.g. livestock), access to extension and climate services, and access to credit. According to Bebbington (1999), the household characteristics can influence the choice of strategies available to cope with shocks.

Results indicate that the age of household heads is likely to influence the choice of response strategies during food shortage (Table 5.13). Model results show that the age of the household head and response strategies such as working on other people's farms for food and selling firewood are significantly correlated (P = 0.02 and 0.046 respectively).. During focus group discussions, it was revealed that households that were headed by older men and women are more likely to choose these strategies than younger household heads, because they do not require any form of capital. The model analysis further shows that the age of the household head and these response strategies are negatively associated (Table 5.13). The negative sign means that the age of household heads reduces the likelihood of choosing these adaptation strategies during food shortages. This might be due to the fact that older people have a reduced ability to work on farms or to collect firewood for sale.

Findings indicate that the gender of household heads is likely to influence the choice of response strategies. Gender and response strategies such as reducing amount of food eaten are positively and significantly correlated (P = 0.012) and eating fewer meals per day (P = 0.013) during food shortages (Table 5.13). Female-headed households (especially widows) are more likely to choose these strategies because they could save and use the little food they had for a longer time. It was revealed that men have a tendency of migrating and leaving behind wives and children during food shortages. During such circumstances, women have no option other than saving the little food they have. Consequently, female-headed households are more vulnerable and less likely to adapt to climatic stresses compared to male-headed households. For example, studies in Tanzania (e.g. Tenge *et al.*, 2004), Uganda (e.g. Buyinza & Wambede, 2008; Nabikolo *et al.*, 2012) and Ethiopia (e.g. Nhemachena & Hassan, 2008), found that male-headed households are better placed to take up adaptation strategies, and have access to new agricultural technology and suitable land. This suggests that gender of the household head influences the choice of response strategies during food shortages.

Model results further indicate a significant correlation between marital status of the household head and choice of response strategies, such as reducing the amount of food eaten (P = 0.019) and eating fewer meals per day (P = 0.013). But the association between marital status of the household head and these response strategies is negative (Table 5.13). The negative sign means that marital status of the household head reduces the likelihood of choosing these response options during food shortage.

The location of the village among the three studied villages is a factor that is likely to influence households' choice of response strategies during food shortages. Model results indicate that the village location and response strategies such as borrowing cash to buy food are positively and significantly correlated (P = 0.010) and selling firewood (P = 0.030)

(Table 5.13). Therefore, the location of a village is a positive determining factor that is likely to influence the choice of adaptation strategies during food shortages. For example, farmers from Ruaha Mbuyuni village had more business opportunities than those from Ibohora and Ikuvala villages. Therefore, the later was more likely to engage in businesses and casual work during food shortages.

Wealth rank is the strongest of all factors that are likely to influence farmers’ choice of response strategies, as indicated by model results in Table 5.13. Results show a positive and significant influence of wealth rank to the choice of strategies, such as selling of household assets (P = 0.016), consuming seed stock (P = 0.002), reducing amount of food eaten (P = 0.000), eating fewer meals per day (P = 0.000), seeking daily work for cash outside the farm (P = 0.001), borrowing cash to buy food (P = 0.016), borrowing food (P = 0.020), working on other people’s farms for food (P = 0.001), and selling firewood (P = 0.000). The results suggest that wealth status of the household head is more likely to influence the choice of response strategies during food shortage. This is concurrent with farmers’ perceptions that wealthier households have more options when it comes to coping with shocks of climate change. According to Agrawal (2010), relatively wealthy households have more options and resources that can be used during food shortages. The model results are in agreement with farmers’ responses during focus group discussions, that poor households have no savings to help them during food shortages. Therefore, they rely much on natural resources around them and human labour as their coping strategies. Farmers highlighted that poor farmers will continue to be even poorer if the current trends of weather are to persist, because they spend most of the growing season working on other people’s farms for cash instead of working on their own farms (Young & Jaspars, 1995).

Access to information and technology (i.e. educational levels of household heads) is less likely to influences farmers’ choice of response strategies during food shortage, as indicated by model results in Table 5.13. This is not a surprising result because people with access to information and technology are less likely to be affected by food shortage due to a wide range of activities they undertake. Yanda and Mubaya (2011) reported that higher education increases opportunities for engaging in non-farm activities, thus use such options to respond to food shortage.

Table 5.13: Factors influencing the choice of response strategies during food shortage

Demographic	Selling livestock	SHA	CSS	AFNE	RAFE	AFPD	SDWFC	Migrated	BCBF	BF	WPFF	SFW	ROL	Remittances
X1- Age of household head	0.007 (0.761)	0.006 (0.807)	-0.013 (0.598)	0.002 (0.939)	0.019 (0.466)	0.032 (0.233)	-0.063 (0.004)	-0.062 (0.256	-0.013 (0.642)	-0.014 (0.493)	-0.046** (0.020)	-0.053** (0.046)	0.037 (0.156)	0.031 (0.129)
X2- Sex of household head	-1.530 (0.103)	0.352 (0.739)	-0.768 (0.487)	0.085 (0.949)	3.377** (0.012)	3.434** (0.013)	-1.755 (0.055)	-3.419 (0.112)	-0.717 (0.581)	0.170 (0.851)	-0.913 (0.259)	-0.039 (0.971)	-3.046 (0.036)	-0.439 (0.610)
X3 -Marital status	0.287 (0.751)	-2.159 (0.068)	-0.921 (0.409)	-0.064 (0.960)	-3.311** (0.019)	-3.667** (0.013)	0.911 (0.268)	2.516 (0.266)	-0.332 (0.794)	-0.673 (0.444)	0.618 (0.408)	-1.018 (0.325)	2.446 (0.066)	1.435 (0.074)
Access to information and technologies														
X4 – Education level of household head	1.214 (0.138)	-0.304 (0.694)	-0.167 (0.826)	-0.906 (0.370)	0.444 (0.569)	0.935 (0.268)	-0.338 (0.610)	-3.021 0.116	0.272 (0.766)	0.162 (0.810)	0.224 (0.725)	-0.361 (0.639)	-0.492 (0.512)	0.735 (0.257)
X5 – Access to weather information	-1.005 (0.167)	-0.306 (0.432)	-0.440 (0.467)	-1.080 (0.448)	0.093 (0.709)	0.065 (0.798)	0.178 (0.402)	1.016 (0.085)	-0.165 (0.636)	-0.162 (0.619)	-0.120 (0.654)	0.252 (0.285)	-0.232 (0.529)	-0.201 (0.502)
X6 – Change in weather pattern	-0.301 (0.649)	-0.591 (0.463)	0.145 (0.862)	-0.689 0.568	1.040 (0.197)	1.170 (0.161)	0.654 (0.341)	-5.405 (0.128)	0.568 (0.498)	0.084 (0.902)	-0.062 (0.924)	1.342 (0.116)	-0.040 (0.962)	0.599 (0.375)
Location														
X7- Village	0.508 (0.185)	0.264 (0.601)	0.410 (0.405)	-0.426 (0.528)	0.588 (0.185)	0.526 (0.250)	0.516 (0.169)	-3.974 (0.159)	1.455** (0.010)	0.519 (0.200)	0.148 (0.678)	1.068** (0.030)	-0.369 (0.413)	0.206 (0.558)
Wealth rank														
X8- Wealth	0.459 (0.515)	2.097** (0.016)	2.763** (0.002)	0.822 (0.488)	3.079** (0.000)	3.513** (0.000)	2.553** (0.001)	1.254 (0.455)	2.236** (0.016)	1.666** (0.020)	2.183** (0.001)	3.752** (0.000)	0.055 (0.944)	1.147 (0.072)

**Significant at 5%

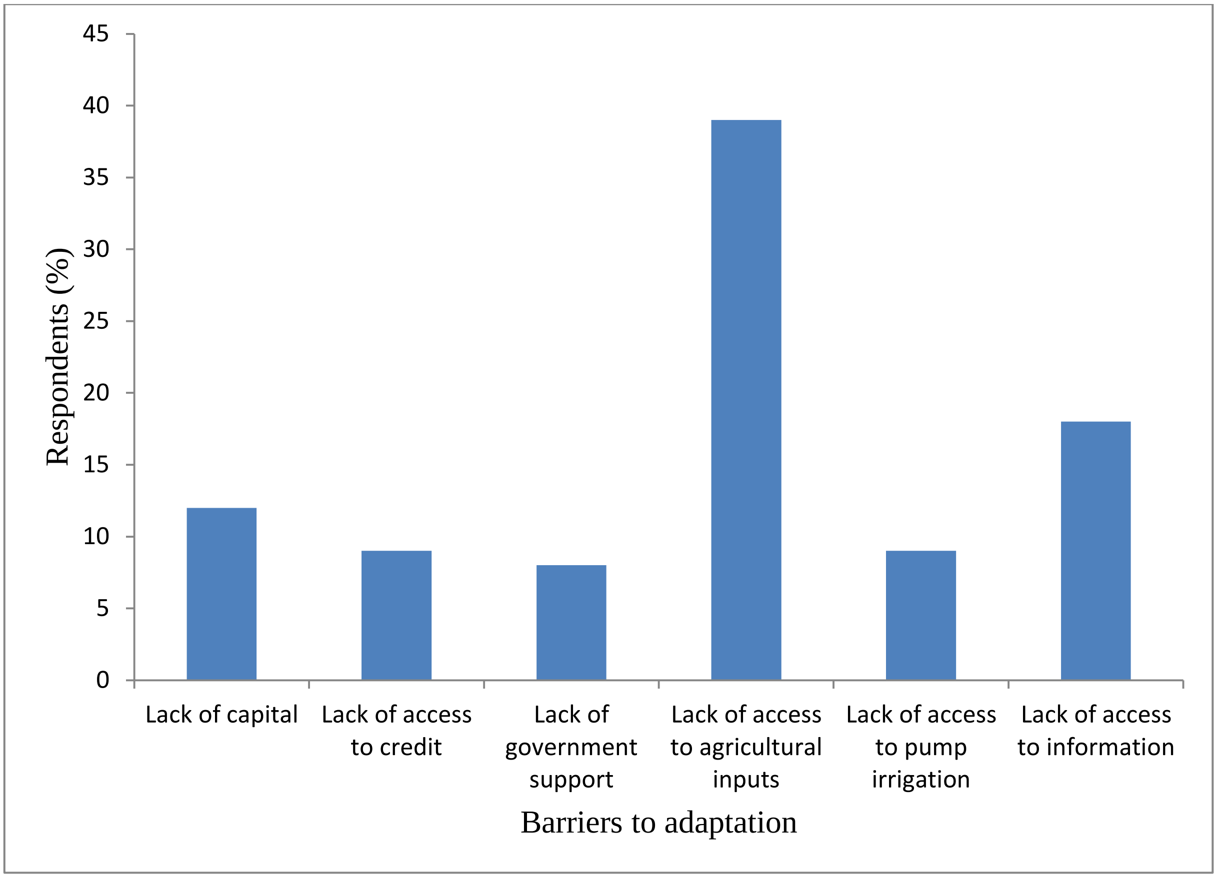
5.6 FACTORS UNDERMINING FARMERS' ADAPTIVE CAPACITY

After discussing in detail the response strategies and factors that influence farmers' choices of these strategies in the previous sections, the focus in this section is on factors that undermine farmers' adaptive capacity. It is important to assess these factors as they may increase farmers' vulnerability and constrain adaptation to impacts of climatic and non-climatic stresses. This section is linked to the fourth objective which seeks to determine how coping and adaptation may be constrained or enhanced given climate variability and change. Smallholder farmers' adaptive capacity is usually constrained by both biophysical and socio-economic factors (O'Brien *et al.,* 2007; Fazey *et al.,* 2010; Stringer *et al.,* 2010).

Farmers highlighted a number of factors that undermine their adaptive capacity to impacts of climate variability. Africa's adaptive capacity is limited by multiple factors, including access to resources (e.g. Ellis & Mdoe, 2003; Adger & Vincent, 2005; Brooks *et al*., 2005a; Grothmann & Patt, 2005; Thornton *et al*. 2006). Limited access to agricultural inputs is reported to be the main hindering factor as reported by 39% of farmers in the study area (Figure 5.23). The high price of fertilizers on top of reduced soil fertility is an additional hindrance factor that is causing reduced crop yields in the study area.

Limited access to capital (i.e. social, natural and financial) and credit facilities are also barriers to adaptation to climatic stresses in the GRRB. Most of the farmers are poor (refer section 5.2) and there are no financial institutions that provide credit in two of the three study villages. The only financial institution in Ruaha Mbuyuni has not reached all farmers due to a lack of collaterals required. Farmers need financial support so as to purchase farm inputs (i.e. fertilizers and chemicals), implements (i.e. irrigation pumps and tractors), and improved seeds that can improve the agricultural production and hence improve their adaptive capacity to climatic stresses. Other studies have reported that access to credit increases the likelihood of adaptation (e.g. O'Brien *et al*., 2000; Gbetibouo, 2009).

Figure 5.25: Barriers to adaptation in the study area (GRRB)



Studies in other parts of Africa have reported that access to climate services can help to reduce the vulnerability to climatic stresses (Patt & Gwata, 2002; Ziervogel, 2004; Patt *et al*., 2007; Traerup & Mertz, 2011). Access to climate information and services is, however, fraught with challenges that include 'communication', understanding of both producer and user information needs etc. Amongst the farmers in the villages examined for this thesis, limited or poor access to information such as seasonal weather outlooks and suitable agricultural practices were additional constraints to adaptation by farmers in the study area (Figure 5.23). Results show that 87% of farmers from the study villages had no access to seasonal weather outlooks from the Tanzania Meteorological Agency (Table 5.14). This could be attributed to the poor spatial distribution and poor operation of most meteorological stations in Tanzania. Poor access to weather information could be due to a lack of appropriate packaging and explanation in easily accessible language and precision of data to suit farmers at the local level. These factors corroborate well with findings from other regions in Africa. Some researchers, for example, claim that there are several factors that interfere with the uptake and effective use of forecasts in southern Africa (O'Brien & Vogel, 2003; Ziervogel & Calder, 2003), including the spatio-temporal scales of long-range forecasts, the timing of forecasts, and the diverse information and interpretation needs of various users.

Few farmers (13%) reported accessing weather information through the media. Even with those making use of such information there were few observable instances of cases where such information was applied into agricultural practices. Farmers receive the information through various sources such as radio (7%), television (1%) and fellow farmers (1%), whilst some receive the information from both radio and fellow farmers (4%) (Table 5.14).

Table 5.14: Farmers responses regarding access to weather information

Variable	Categories	Percentage of respondents			
		Ibohora n=30	Ruaha Mbuyuni n=30	Ikuvala n=30	Total Average N=90
		%	%	%	%
Access to weather forecasting	Yes	12	12	18	14
	No	88	88	82	86
Source of information	Radio (1)	9	3	9	7
	Television (2)	0	3	0	1
	NA (3)	88	88	85	87
	Fellow farmers (4)	3	0	0	1
	1 and 4	0	6	6	4
General content	Poor	6	6	0	4
	Average	6	6	15	9
	Good	0	0	3	1
	NA	88	88	82	86
Delivery channel	Poor	3	9	6	6
	Average	9	0	12	7
	Good	0	3	0	1
	NA	88	88	82	86
Language of presentation	Poor	9	9	6	8
	Average	3	0	12	5
	Good	0	3	0	1
	NA	88	88	82	86

The level of usability of weather forecast information is very low among farmers in the study villages. Given the lack of accessibility of the information few farmers seemed to care and acknowledge the importance of weather information in agriculture. Most of them have a low confidence in both the seasonal outlooks and daily weather forecasts from TMA due to the lack of precision, especially during the rain season.

Results indicate that the general content of weather information broadcasted in the media was not adequate for farmers. Only 1% of all farmers are satisfied with the content of weather information, 8% said it is average, 4% reported it is poor and 86% could not comment anything (Table 5.14). This could be due to the coarse spatial coverage of the forecasts provided by TMA (i.e. covering two to three regions); thus the accuracy for the local scale is sometimes poor (e.g. village level). This suggests that TMA, where scientifically plausible given constraints of downscaling data from general circulation models, coarse-scales to finer scales, try and reduce the spatial scale of weather forecasts. Farmers and meteorologists should try and find ways of improving the messages and 'needs' of users (e.g. farmers) so as to enhance, where possible, appropriate farming practices, such as the timing of planting season and choice of most suitable crop varieties.

Farmers also reported that a lack of information about appropriate seeds and timing of the growing seasons and subsequent dry spells during the rainy season hinders them from attaining high crop yields. Normally, they rely on the previous experiences that sometimes fail them due to a lack of precession.

Issues of land access and use are key features of many African farming contexts. Access to land has changed from the 1970s when the population was small and people could acquire additional land allocated by the village government, unlike the current system where, where one has to purchase the land and get a title deed. This has been a limiting factor because it has reduced the flexibility of farmers to cope with climate variability because it is difficult for a farmer to access irrigable land for example, unless he/she has the capacity to rent or purchase that land. It is equally difficult for farmers to fallow their farms due to a lack of flexibility in acquiring alternate land. The soil fertility is also perceived to be declining and contributing to the observed decrease in productivity (in addition to climatic stresses). Additionally, poor access to inputs may have contributed to the challenges of adapting. This suggests that the adaptive capacity of smallholder farmers is declining over time due to the fact that there are greater limits to adaptation during recent decades.

The cooperative societies during the 1970s to 1990s provided a stable market to farmers, unlike the current free market system which is dominated by middle-men and unregulated prices for crops. There is a weak coordination of available crop markets in the study area. In principle, markets are managed in partnership between communities and the local government (district councils). This weak coordination has led to most farmers selling their crops on farms. Middle-men have taken advantage of this weak supervision of markets by both parties, and farmers reported to receiving low prices for their cash crops (also see section 5.4.5.2). According to Trærup and Mertz (2011), livestock keepers received a higher price when they sold their cattle to a well-functioning market during a food crisis. The lack of institutions and structures in the market system in the GRRB has progressively eroded the adaptive capacity of farmers because they cannot save and prepare for disasters. Instead, they end up being vulnerable to climatic disasters because they do not have sufficient savings to help them survive the disasters and the period leading up to the next harvest. This implies that the properly functioning crop markets may enhance the adaptive capacity of farmers by providing excess funds which can be used to diversify livelihoods.

- **Discussion**

All the barriers to adaptation noted in this study and those reviewed from the literature indicate a complex set of vulnerabilities that need a complex approach to address them. All barriers to adaptation are related to non-climatic/other stresses discussed in section 5.4.5. The main ones being access to resources (e.g. water, and irrigable land), financial capital (i.e. credits), functioning crop markets farm inputs (i.e. fertilizer), information and government support. These barriers show the current and on-going vulnerabilities compounding the lives of farmers. This implies that a holistic approach is required to address these complex stresses (i.e. current and future) compounding the lives of farmers so as to improve their adaptive capacity.

Asian and Latin American countries are doing relatively better towards addressing barriers to adaptation to climatic stresses. Different stakeholders in these countries are acting together towards responding to impacts of climatic events, and thus help to improve the adaptive capacity of farmers. Successful adaptation has been attained in Bangladesh due to several institutions including government agencies, NGOs, social, informal and private institutions and farmers groups operating together in the area (Selvaraju *et al*., 2006). According to Habiba *et al*. (2012), improved land tenure and planned adaptation helped to enhance the adaptive capacity of farmers in north-western Bangladesh. Access to extension and climate services, and new agricultural technologies improved the adaptive capacity of farmers in north-east China (Yang *et al*., 2007). Studies in Pakistan and Jamaica affirmed that farmers' access to forecasting information and input use enhances their adaptive capacity to climatic shocks (Campbell *et al*., 2011; Ashraf & Routray, 2013).

Some researchers have recommended strategies for enhancing the adaptive capacity of smallholder farmers in Africa and Tanzania in particular. These include creating policies and institutions that enable farmers to improve their adaptive capacity, for example by increasing access to information, credit and crop markets (Eriksen *et al*., 2008; Bryan *et al*., 2009; Eriksen & Silva, 2009; Kpadonou *et al*., 2012). Therefore, policy should be flexible rather than specific to climatic stresses (Mertz *et al*., 2009). Therefore, in order to reduce the barriers to adaptation to climatic stresses in the GRRB, it is necessary to increase the involvement of the government, the private sector and community organizations (e.g. cooperatives societies). Moreover, findings from this PhD study and the literature cited therein, suggest that adaptation strategies should be learnt from the local level (i.e. community based adaptation strategies) and receive support by national and international policies that create an enabling environment to better access required resources and technologies (Mubaya, 2010).

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The main aim of this study is to examine smallholder farmers' vulnerability, coping and adaptation strategies to climate change (including climate variability) and other stresses, and to investigate how such coping and adaptation may be constrained or enhanced.

Specifically the study seeks to:

i. To identify and understand past climate variability and extreme events through both (a) instrumental records (e.g. existing climatic station data) and (b) through social and anthropological methods that capture detailed lived experiences, perceptions and accounts from local people.
ii. To generate a baseline of climatic and non-climatic stresses that smallholder farmers have and are currently facing, against which one can begin to determine any vulnerabilities to climate variability and change.
iii. To better understand the coping options and adaptation strategies to both the sudden-onset of extreme events and the more pervasive climatic change/variability.
iv. Finally, to determine how coping and adaptation may be constrained or enhanced given climate variability and change.

Findings suggest that smallholder farmers in the GRRB are generally aware of climate variability and change and other stress factors affecting their livelihoods. For example, a stressor for all farmers is water availability and irrigation. Therefore, it is not, however, only about droughts and floods, but also about other stresses including market access, information, infrastructure, and access to resources (e.g. irrigable land, subsidized farm inputs and implements).

Farmers are not just passive with regard to changes in their livelihoods. There are opportunities in the study area that farmers are taking advantage of, so as to enhance their adaptive capacity. One main opportunity is agricultural commercialization. Findings show that more farmers are engaging in commercial farming of tomatoes, onions and vegetables. This commercial farming has helped farmers increase their income and some engage in other off-farm activities (e.g. business enterprises), and thus diversify the source of livelihoods. Another opportunity is taking advantage on the traditional ways of weather forecasting (i.e. seasonal outlooks), which help them to prepare for risks in the growing seasons.

Farmers respond to climatic and other stresses using various strategies. During droughts, for example, they mostly use irrigation (canal, pumping and cans), sell own labour and plant short-term maturing crop varieties. Vegetable garden farming is used to supplement the low crop yields. During excessive rains or floods, farmers resort to upland farming in order to avoid water logging. During food shortages, farmers use short-term coping strategies such as buying food, borrowing money, temporary migration, working in other people's farms for cash, reducing the amount of food and number of meals eaten per day among others. Moreover, the farmers' choice of response strategies during food shortages is influenced by various factors, including location, wealth rank, marital status and education level of the household head, and access to information and technology.

This PhD study contributes to the advancement of adaptation to climate change science and sustainability. Challenges and opportunities emanating from climate changes, as uncovered in this study are not unique to the study area, but resemble those of other countries with similar biophysical and socio-economic contexts, and policies. This is affirmed by studies from other regions (Asia, Latin America and sub-Saharan Africa) as cited in the thesis. Studies from Asian and Latin American countries provide a case that indicates that they have been successful in addressing climate change challenges. Their success is hinged on the "*planned adaptation*" phenomenon, where there is a considerable investment by the public and the private sectors in the adaptation process. The public and the private sectors in these countries have invested in new and affordable technologies, suitable seed varieties, inputs, irrigation infrastructure, use of weather forecast information and extension services. The policy environment in these countries is supportive, where local communities are involved in the adaptation process, thus making it easier to adopt new technologies and improve farmers' local technologies.

Again, the challenges noted in this PhD study are complex, which shows how complicated the stresses affecting the lives of farmers are. Addressing them generally without defining the underlying contexts of each stressor makes it even more complicated to enhance the adaptive capacity of farmers. This also provides an understating of the current and future vulnerability, and thus suitable planning of response measures. Moreover, this PhD study contributes to new science that emphasizes the need for scientists and smallholder farmers to come together in the process of assessing and addressing the vulnerability and adaptation to climatic stresses.

In this chapter, these conclusions are expanded within an existing international literary context. Key conclusions are drawn and suggested recommendations made for further studies and policy development.

6.2 KEY CONCLUSIONS OF THE STUDY

- *Conclusion One*

Smallholder farmers in the GRRB are vulnerable to both climatic and non-climatic stresses. The interpretation of vulnerability is vital so as to understand the underlying causes and contexts of vulnerability, thus addressing them with well-targeted solutions.

The main perceived and observed changes include rainfall becoming erratic with regards to spatial-temporal variations (i.e. patchiness), increases in mid-season dry spells, delayed rainfall onsets, reduced length of the growing season, increases in rainfall intensity, increase in the extreme events (e.g. droughts and excessive rains) and increases in the average maximum temperature. The impact of this trend is a shortening of the growing season, which does not suit the crops grown in the study villages as these normally require a minimum of three months to mature (e.g. maize and rice). This concurs with other studies that have reported how variability of the rainy season onset and cessation affects the timing of the planting dates (Oladipo *et al*., 1993; Camberlain & Okoola, 2003; Mugalavai *et al*., 2008). The overall increase in the risk of dry spells shows that farmers depending on rain-fed agriculture have been facing reduced crop yields during the past two decades, as a dry spell of 10 or more days is believed to destroy the growing of crops.

Findings indicate that smallholder farmers in the study area are also vulnerable to non-climatic stresses, apart from climatic stresses presented in the previous paragraph. This was also documented in the IPCC 4th and 5th assessment reports that a mixture of both climatic and non-climatic stresses compounds the lives of rural communities in Africa (Boko *et al.*, 2007; Niang *et al*., 2014). As others have documented from elsewhere, this study found that farmers' livelihoods are compounded by other stresses including access to water and irrigation infrastructure, access to markets and the coordinating institutions. While the primary non-climatic stresses in all study villages were similar, some differences were reported by farmers linked to the various villages. Such differences may be linked to differing biophysical contexts (e.g. agro-ecological zones). For example, farmers from Ibohora reported access to irrigation water (the rationing system) and access to farm inputs and implements as the main structural stresses. According to farmers, the rationing system has been the major reason behind declines in agricultural production and a source of water conflicts in the village because the allocated water does not reach all farms, especially those located downstream of the canal. The poor timing of subsidised farm inputs (e.g. fertilizer) was reported to interfere with the farming calendar, and sometimes farmers were forced to purchase fertilizer at a market price.

Farmers from Ikuvala village noted that the rain-fed agriculture, access to farm inputs and implements, and access to markets are main structural concerns. Ikuvala village has no source of water for irrigation, thus the villagers practice rain-fed agriculture only. This has been a challenge to farmers due to the fact that rainfall has become erratic and the frequency of droughts has increased during recent decades. Farmers reported that they rely on hiring irrigable land in nearby villages when droughts occur. Crop markets are not working properly in Ikuvala village due to dominance by middle-men who are undermining the official institutions tasked to run them. Farmers from Ruaha Mbuyuni mentioned access to financial institutions, irrigation farming and well-functioning markets as the main structural stresses. The boom of irrigation pumps is reported to have started during the mid-2000s in Ruaha Mbuyuni village. More commercial farmers are renting larger tracts of land along the Lukosi and Great Ruaha Rivers, thereby compromising smallholder farmers' access to the irrigable land. Ruaha Mbuyuni village has a financial institution (FINCA) and four farmer groups (KIHASI, MWAVILU, LUKOSI and GEZAULOLE). These groups receive loans from FINCA and use them to manage small businesses and farming activities. Loans are required by farmers to help them purchase farm input and implements that could boost their agricultural production. Farming in this village is better linked to business (cash crops) than the other two villages. Notwithstanding having a financial institution in the village, individual farmers find it challenging to access loans due to a lack of collateral.

In conclusion, findings from farmers' perceptions and observed climate data at the local meteorological stations, and supported with regional (e.g. Kruger & Shongwe, 2004; Shongwe *et al.*, 2011) and international literature (e.g. IPCC, 2007, 2012, 2013), provide evidence that the study area is facing climate variability and moderate extreme events (i.e. dry spells, droughts and excessive rains). Moreover, farmers are also vulnerable to non-climatic stresses, the main ones being access to water, markets and coordinating institutions.

- *Conclusion Two*

Response to climatic stresses by smallholder farmers depend, first on access to resources or options available locally, and secondly, on other options available elsewhere.

This study found that smallholder farmers depend on the locally available resources (including own labour) to respond to climatic stresses. Most responses due to sudden food shortages can be categorised as coping strategies (e.g. selling household assets, reducing the amount of food eaten, eating fewer meals per day, seeking daily work for cash and temporary migration). Other researchers reported that the depletion of household assets (e.g. livestock, bicycles) is a common and an important response strategy by rural communities during climatic stresses (Kessy, 2004; Nhemachena & Hassan, 2007; Mutekwa, 2009; Mertz *et al*., 2010). Farmers use different farming methods during dry and wet growing seasons as their adaptation strategies. Most of the adaptation strategies are based on lessons learnt from experiences of previous climatic stresses and to some extent advice from Agriculture Extension Officers. These include irrigation farming (e.g. using canal/gravity and pump), planting short-term and drought tolerant crops, vegetable garden farming, using weather forecast information to complement traditional ways of weather predicting.

As indicated by other researchers (e.g. Eriksen *et al.*, 2005; Selvaraju *et al.*, 2006; Thomas *et al*., 2007; Mbow *et al.,* 2008; Mertz *et al.,* 2009; Bryan *et al*., 2009; Mertz *et al.,* 2010; Mongi *et al.,* 2010; Kangalawe *et al.*, 2011; Abidji *et al.*, 2012; Habiba *et al.*, 2012; Ozor *et al.,* 2012), most of the response strategies used by smallholder farmers in the study area are related to those used by farmers in other African and Asian countries. The common response strategies include livestock keeping, migration, small-scale commerce, vegetable garden farming, canal irrigation, use of short-term maturing crops (e.g. sunflower and cassava), intensification of non-agricultural activities, and diversification of agriculture (including fish farming). The unique strategies to the study area are pump irrigation practices and intensification of vegetable garden farming (agricultural commercialisation).

In conclusion, findings from this study and others cited therein, indicate that although the locally available resources determine the choice of response strategies, there are more observed similarities than differences in coping and adaptation strategies within the GRRB and between the GRRB and other developing countries.

- *Conclusion Three*

While other studies found that adaptation must take place at different levels for it to be most effective, this study found it to be currently best undertaken at the local-level. Therefore, the involvement of institutions at the local-scale in the adaptation process is

vital so as to enhance smallholder farmers' adaptation to climatic and non-climatic stresses.

Most of the response strategies used by smallholder farmers were based on their past experiences and locally available resources. This study further found that there is no clear institutional structure from the local- to the region-level in the GRRB that support the efforts of smallholder farmers to cope and adapt with stresses. There is no specific plan and budget set aside to deal with unexpected disasters at the district level and this was reported as the major setback to speed up response to disasters. Some NGOs contribute to disaster management when they are approached by the district disaster management committee. This study concurs with the findings by Agrawal (2010); namely that the partnership between the community, private and public (government) institutions is crucial in enhancing the adaptive capacity of farmers. Adaptation to climatic stresses in this case was investigated at the local-scale so as to establish past experiences of farmers in responding to impacts of climatic stresses. Other researchers affirmed that local communities have a long experience in responding to climatic stresses, thus possess valuable local knowledge (Ajibade & Shokemi, 2003; Thomas *et al*., 2007; Nyong *et al*., 2007). Mubaya (2010) affirmed the importance of using the local knowledge for making recommendations and policies with regard to climate change adaptation.

Lastly, it is concluded that the adaptation process must start at the local-level by tapping into local experiences. Moreover, transforming local experiences and farmers' behaviour, policies and institutions at all levels (e.g. community, the public and private sectors) is vital in supporting local-level coping and adaptation strategies.

- *Conclusion Four*

Smallholder farmers' ability to adapt to the impacts of climatic stresses in the GRRB is constrained by socio-economic and environmental factors.

It was found that there are a number of factors that aggravate smallholder farmers' vulnerability to climatic stresses in the GRRB. These include access to agricultural inputs and modern implements, credits, functioning crop markets, weather information (i.e. daily forecasts and seasonal outlooks), coordinating institutions and irrigable land. For example, limited access to agricultural inputs is reported to be the main hindering factor as reported by 39% of farmers. Only one among the three case study famers reported to use and benefit from the weather forecast information. Normally, they rely on the previous experiences that sometimes fail them due to a lack of precision. The lack of information about appropriate seeds and timing of the growing seasons and subsequent dry spells in the rainy season hinder them from attaining high crop yields. Another example is access to land that changed from the 1970s when population was small and people could acquire additional land allocated by the village government. This has been a limiting factor because it has reduced the flexibility of farmers to cope with variability in weather because it is difficult for a farmer to access irrigable land for example, unless he/she has the capacity to rent or purchase that land.

The findings concur with other researchers (e.g. Nhemachena & Hassan, 2007, 2008; Deressa *et al.*, 2009), who reported that there are different factors that affect the use of adaptation methods in agriculture. Other researchers reported that the capacity of farmers to respond to stresses is aggravated by low level of investments and supportive policies (Fazey *et al.*, 2010; Stringer *et al.*, 2010). Based on these findings, it is concluded that there is a complex set of barriers that reduce smallholder farmers' ability to adapt to climatic stresses.

6.3 RECOMMENDATIONS

In this section, recommendations from this PhD study are presented. It is clear that there is considerable research already undertaken in this field, across Africa and beyond, thus there are recommendations already made for addressing climatic stresses. Nonetheless, little efforts have been made in the current study area using the adopted approach. Therefore, findings from this PhD study may provide a foundation for making recommendations for addressing impacts of climatic and non-climatic stresses on smallholder farmers in the GRRB and contribute to the broad body of literature.

- *Recommendation One*

Approach the challenges that compound the livelihoods of smallholder farmers, particularly agriculture, by clearly defining vulnerability surrounding it and not singling out only climatic hazards as the key stress. Therefore, policies and institutional structures should be transformed to address vulnerability from both climatic and non-climatic perspectives. This will help to address impacts of both climatic and non-climatic stresses compounding smallholder farmers.

Findings from this study have clearly indicated that smallholder farmers are compounded by a host of stress factors in their daily lives. Climate related hazards were mentioned as an additional stress to the already weak subsistence agriculture and vulnerable smallholder farmers in the GRRB. Agriculture which is the main economic activity for smallholder farmers in the GRRB was perceived by farmers to be already strained by climatic stresses. Recognizing the complexities in singling out climate change impacts from other stresses to agriculture, this study therefore recommends a holistic approach by targeting the whole system dealing with the agricultural sector. Policies and institutions should be designed or reformed so as to accommodate this reality that is facing smallholder farmers, and hence may improve their adaptive capacity to both climatic and non-climatic shocks.

- *Recommendation Two*

Integrate smallholder farmers' perceptions and indigenous knowledge with instrumental weather forecasts so as to ensure appropriate timing of farming activities and selection of suitable seeds and crop varieties. This could be done through strengthening the capacity of smallholder farmers and institutions at all scales by improving the understanding and eventual application of shorter-term weather forecasts and longer-term seasonal outlooks.

Most of the farmers have the perception that climate has changed and they singled out rainfall, temperature and wind as parameters of climate that have changed during the past four decades. During that time, farmers have been using traditional ways to forecast the seasonal weather conditions. Findings indicate that this approach has not been successful in helping farmers to secure an appropriate timing of the farming season and selection of suitable crops or seeds. The reliance on indigenous knowledge has partly been contributed by the coarse spatial distribution of meteorological stations and lack of awareness by farmers on the use of forecast information from the meteorological Agency. This has led smallholder farmers to rely on their past experiences that have proven to be unreliable during recent decades due to unpredictable and the increased frequency of mid-season dry spells. This study recommends an integration of indigenous knowledge into forecasts and building the capacity of farmers and extension officers for interpreting and applying seasonal weather forecasts in farming activities. This can be achieved by involving a selected group of farmers and village leaders from each village (*climate change adaptation envoys*) who will be receiving the seasonal weather outlooks and daily forecast information from extension or meteorological officers, and may then subsequently convey it to their villages through meetings.

- *Recommendation Three*

Provide support for appropriate agricultural innovations, access to optimally functioning crop markets, facilitate the establishment of agro-processing industries by the private sector or cooperatives and ensure access to loans that can develop opportunities for smallholder farmers as they respond to climatic stresses. Therefore, mainstream adaptation strategies to climatic and non-climatic stresses into development plans and programmes at all scales.

Findings indicate that there is weak government support to smallholder farmers in aspects such as farm inputs and implements, post-harvest storage, crop markets, facilitation of agro-processing industries and extension services. Farmers reported that there is poor timing of delivering the subsidised inputs, which is allocated in small quantities (only 50kg of fertilizer per eligible family). Agricultural innovations need not to be sophisticated or imported from abroad, so that farmers can be supported to upgrade the local and affordable technologies to improve efficiency. Lack of access to loans was mentioned as one of the primary stresses to achieving good agricultural production. Financing is needed by farmers so that they can purchase modern farm implements, fertilizers, seeds, rent irrigable land and for general farm management. Access to a functioning crop market is crucial to ensure that farmers receive a good price for their produce. This in turn will enable them to save and diversify the excess income into other non-agricultural activities, and eventually become more resilient to climatic shocks.

- *Recommendation Four*

Strengthen institutions that are involved in natural resource management (e.g. irrigation water and catchment areas) and invest in water harvesting technologies, dams and expansion of the irrigation infrastructure to cover the potential irrigable land.

Findings indicate that the agricultural sector, which is the main source of livelihoods to the farming communities in the GRRB, is already stressed by recurrent droughts and mid-season dry spells. Yet, rain-fed agriculture is a dominant practice to most farmers due to a lack of access to irrigable land. Access to irrigation farming by using gravity (canal) and pumping was mentioned by farmers to be a reliable adaptation strategy. This study recommends appropriate management of both the supply side (catchment areas, springs and rivers) and the demand side (irrigation infrastructures and coordinated distribution of irrigation water), including affordable access to irrigation pumps.

- **Overarching concluding remarks**

Findings and the literature cited in this PhD study suggest that adaptation starts at the local level, and therefore, it is recommended that policies be devised at such a level. Furthermore, local-level adaptation strategies need to be backed by national policies, plans and strategies for them to be effective. It is also important to note that some response strategies may become maladaptation when used in the long term, and on a large scale, thus leading communities into poverty (Mubaya, 2010; Vincent *et al.*, 2013).

Challenges and opportunities emanating from climate changes, as uncovered in this study are not unique to the study area, but resemble those of other countries with similar biophysical and socio-economic contexts, and policies. This is affirmed by studies from other regions (Asia, Latin America and sub-Saharan Africa) as cited in this study. Studies from Asian and Latin American countries provide a case that indicates that they have been successful in addressing climate change challenges. Their success is hinged on the "*planned adaptation*" phenomenon, where there is a considerable investment by the public and the private sectors in the adaptation process.

The overall conclusion is that there is need for scientists, smallholder farmers and other actors to come together in assessing the vulnerability to climatic and non-climatic stresses and enhancing adaptation to such stresses. This is affirmed by the agreement between farmers' perceptions (including their indigenous knowledge) and observed climate records, which show that these understandings/records are complementary. Findings also show that coping and adaptation strategies start at the local-level, thus the need for scientists and others to learn from the local-level, and eventually transform these strategies to more productive and sustainable livelihood activities. This indicates the need for climate information and services to be co-developed by producers and users of such information. This may ensure action-oriented information that can be used effectively and in a timely way to support the adaptation process.

6.4 KEY POINTS FOR FURTHER RESEARCH

It was beyond the scope of this study, due to time and resources, to undertake a detailed analysis of the smallholder farmers' barriers to adaptation in the GRRB. Therefore, a detailed study on limiting factors *vis a vis* efforts by the government and other stakeholders to address them is required, so as to improve smallholder farmers' adaptive capacity to climatic events. Moreover, a detailed study is required, so as to understand and examine the viable structure of institutions that could best assist smallholder farmers to address issues of adaptation to both the outcome and structural vulnerability in the GRRB, which can be up-scaled to other regions in Tanzania and beyond.

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APPENDIX A

Day of the year from 1st July (year 1) to 30th June (year 2)

Month: Date	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1	1	32	63	93	124	154	185	216	245	276	306	337
2	2	33	64	94	125	155	186	217	246	277	307	338
3	3	34	65	95	126	156	187	218	247	278	308	339
4	4	35	66	96	127	157	188	219	248	279	309	340
5	5	36	67	97	128	158	189	220	249	280	310	341
6	6	37	68	98	129	159	190	221	250	281	311	342
7	7	38	69	99	130	160	191	222	251	282	312	343
8	8	39	70	100	131	161	192	223	252	283	313	344
9	9	40	71	101	132	162	193	224	253	284	314	345
10	10	41	72	102	133	163	194	225	254	285	315	346
11	11	42	73	103	134	164	195	226	255	286	316	347
12	12	43	74	104	135	165	196	227	256	287	317	348
13	13	44	75	105	136	166	197	228	257	288	318	349
14	14	45	76	106	137	167	198	229	258	289	319	350
15	15	46	77	107	138	168	199	230	259	290	320	351
16	16	47	78	108	139	169	200	231	260	291	321	352
17	17	48	79	109	140	170	201	232	261	292	322	353
18	18	49	80	110	141	171	202	233	262	293	323	354
19	19	50	81	111	142	172	203	234	263	294	324	355
20	20	51	82	112	143	173	204	235	264	295	325	356
21	21	52	83	113	144	174	205	236	265	296	326	357
22	22	53	84	114	145	175	206	237	266	297	327	358
23	23	54	85	115	146	176	207	238	267	298	328	359
24	24	55	86	116	147	177	208	239	268	299	329	360
25	25	56	87	117	148	178	209	240	269	300	330	361
26	26	57	88	118	149	179	210	241	270	301	331	362
27	27	58	89	119	150	180	211	242	271	302	332	363
28	28	59	90	120	151	181	212	243	272	303	333	364
29	29	60	91	121	152	182	213	244	273	304	334	365
30	30	61	92	122	153	183	214		274	305	335	366
31	31	62		123		184	215		275		336	

APPENDIX B

A checklist of questions for focus group discussion

Section A: Village Profile

1. What is the name of this village? (*Probe what it means*)
2. When was the village established?
3. What is the total number of people in this village? (*Male, Female, Children, Disabled, Elderly)*
4. What is the total number of households in this village? *(Probe number of h/holds head by Female and Male)*
5. What are the major ethnic groups existing in this village and their origins? *(Probe on religions)*
6. What kinds of social services are available in this village? *(Probe number and conditions of healthy centre, primary and secondary schools under Government/Private sector, quality and quantity of drinking water and quality of roads)*
7. What are the main socio-economic activities in this village? *(Probe on farm and non-farm activities)*
8. What are the major problems limiting livelihoods/socio-economic activities in this village?

Section B: Examination of Knowledge and Perception of Climate Change and Variability

9. What do you understand by the term climate change/variability?
10. What are the main indicators depicting climate change and variability in this village?
11. How do you compare current patterns /trends of climate [rainfall, temperature, wind, humidity] with the past in this village? (Changing or Constant). *(Probe what have been the normal patterns of climate and the current patterns)*. If it is changing, since when the changes have been considerable?

12. What are the major events related to climate change/variability have been occurred in this village? [1970's – to date]
13. Which years do you consider as bad and good years in relation to climate change/variability? *(Probe the local indicators for bad and good years)*
14. What do you think are the causes of climate change/variability in this village?

Section C: Evaluation of the Impacts of Climate Change/Variability on Livelihoods Activities [Agriculture]

15. What are the major impacts of climate change/variability in this village?
16. Who are the most affected people in this village? [Socio-economic groups, Location, Age, Gender groups, Livelihood assets, Poor] Explain why and how?
17. What are the main food crops grown in this village?
18. What are the main cash crops grown in this village?
19. What are the major livestock kept in this village?
20. What is the farming calendar of this village?
21. Have there been any changes in farming calendar? If yes, what are the reasons
22. Which type of farming is practiced in this village? [Rain-fed agriculture or Irrigation]

    (Probe if there is any shift to other type and reasons behind)

23. What is the current status of agriculture production in this village*?(Probe how much they produce per year)*
24. How do you compare current crop production with the past 40 years? [*explain*]
25. Have you experienced a decline or increase in crops production? If so, what are the reasons
26. Have there been any changes in farming practices in this village? If yes, explain *[Probe on crop husbandry practices e.g. ways of land preparation, use of agricultural inputs i.e. fertilizers, pest control, weeding, agricultural mechanization]*. Have these changes been associated with climate change?
27. What is the status of food security in this village?

28. Are there incidences of food shortages in this village? If so, explain the causes of food shortages
29. What other stress factors constraining livelihood activities in this village?
30. What has been done to address those stress factors?

Section D: Assessment of Existing Local Strategies for Adaptation to Climate Change and Variability and their Limitations

31. What are the sources of weather information in this village?
32. What are the existing local strategies/indicators for predicting/ observing/interpreting changes in weather patterns in this village? *(Probe how they are used)*
33. How do you cope/adapt with a decline in crops production?
34. What are the coping/adaptation strategies during incidence of food shortage in this village?
35. What are the other existing local strategies for coping/adapting to extreme climatic events in this village? *[Floods, Drought, etc]*
36. How sustainable and effective are the various local adaptation strategies in terms of environment and socio-economic perspectives?
37. Are there any negative or positive environmental impacts that have been caused by local strategies for adaptation to climate change and variability? If yes, explain how
38. Are these local strategies for adaptation to climate change and variability mainstreamed in village plans?
39. What are the factors limiting the use of local strategies for adaptation to climate change and variability?
40. What should be done to address those limitations?

Section E: Assessment of Resilience to Climate Change and Variability among Farmers

41. Are there positive or negative changes in farmers' lifestyles brought by climatic extreme events/environmental changes?

42. Which category among farmers changed completely their lifestyle due to climatic extreme events/environmental changes?
43. Which category among farmers did not change completely their lifestyle due to climatic extreme events/environmental changes?
44. What factors weaken and/or strengthen farmer's resilience to these changes?

APPENDIX C

Questionnaire for data collection

SECTION A: GENERAL INFORMATION

Questionnaire No:

Researcher's Name:

Date: / /

day/month/year

1. General Information

Village:	Ward:
Division:	District:
Region:	Household ID

2. Demographic Characteristics

		Codes	**Response**
1.	Sex of household head	*1= male 2 =female*	
2.	Wealth rank category (Community perception)	*1= Poor, 2= Medium, 3= Rich*	
3.	Age of household head *(Actual number of years)*		
	Age of household spouse *(Actual number of years)*		
4.	Marital status of household head	*1=married 2=widowed 3=divorced 4=single, 5=polygamist*	
5.	Household head's farming experience in years		
6.	Education level of household head	*1=none, 2=primary, 3=secondary, 4=tertiary*	
7.	Position of household head in the community	*1=ordinary citizen* *2=head man* *3=religious leader*	
8	Other occupation of head of household head	*1=Business* *2=Teacher* *3=Other self-employment*	
9	Type of house	*Roof (1=Thatch 2=Iron tin roof 3=Tile)* *Walls (1=Mud and sticks 2=Unburnt brick 3=Burnt brick 4=Wood 5=Stone 6=Cement*	
10	How long have you been in this village?		
11	If migrated, when?		

12	If migrated, reason for migration	1. Agriculture 2. Business 3. Work/employment 4. Fishing 5. Hand craft activities 6. Formal employment 7. Others (specify)	

SECTION B. HOUSEHOLD INCOME AND CAPITAL ASSETS

3. What are your main sources of income in the past years and how important are these sources to your livelihood?

Income Source	**Yes/No**	**Rank**
a) Sale of crops		
b) Sale of livestock		
c) Informal work *(vibarua)*		
d) Formal employment		
e) Remittances		
f) Old age pension		
g) Pension fund from work		
h) Gifts received in kind		
i) No income at all		
j) Gardening		
k) Brickmaking		
l) Others (specify)		

Codes: Yes=1, No=2

4. What livestock do you own?

Assets	**Do you own?** *1= yes 2=no*	**If yes, how many?**	**Source:** *1=bought, 2=gift, 3=inheritance, 4=other source*	**Purpose for keeping** *1=Mainly for food 2=Mainly for cash 3=Equally for cash and food 4=For asset accumulation / prestige etc*
a. Cattle				
b. Goats/ Sheep				
c. Poultry (chickens, guinea fowls)				
d. Donkey				
e. Pigs				
Other (specify)………………				

5. What major agricultural and domestic assets/implements do you have?

Assets	**Do you own** *1= yes* *2=no*	**Number**	**Source:** *1=bought, 2=gift, 3=inheritance, 4=other source*
a. Ox-drawn plough			
b. Oxcart			
c. Ridging plough			
d. Cultivator			
e. Irrigation equipment (e.g. treadle pump, water pump, etc) Other (specify)…………………….			
f. Sprayer			
g. Hoes			
h. Ripper			
i. Axe			
j. Planter			
k. Radio/TV			
l. Bicycle			
m. Mobile phone			
n. Paraffin stove			
o. Sewing machine			
p. Other (specify) ……………………			

SECTION C: AGRICULTURAL PRODUCTION AND IRRIGATION DETAILS

6. How much land do you own and cultivate?

	Last year	**10 years ago**	**If there is a change, reasons for the change**	**Tillage method commonly used** *1=Manual with hoe 2= Animal traction 3= Tractor tillage*
a. How much land do/did you own (acres)				
b. How much land do/did you cultivate (acres)				
c. Area not being utilized (acres)				
d. Do/did you hire additional land / plots *(1=yes; 0=No)*				
e. If yes, how many acres? (acres)				
f. How much land on irrigation(acres)				

7. What are the priority crops grown now and twenty years ago?

Crops grown currently		**Crops grown twenty years ago**		
Crops grown now	How important is the crop for food security (see codes below)	Crops grown twenty years ago	How important was the crop for food security (see codes below)	If there is a change in priority of crop, why?
a)				
b)				
c)				
d)				
e)				

f)				
g)				
h)				

Codes for importance of crop 1=Very importance 2=Moderate importance 3=Not important

8. What are the indicators of a good crop production year?

Indicator (e.g. rainfall)	**Description (quantify if possible)**
a)	
b)	
c)	
d)	
e)	

b) In the last 10 to30 years, which years would you consider as having been good?
……………………………………………………………………………………………

9. What are the indicators of a bad crop production year?

Indicator (e.g. rainfall)	**Description (quantify if possible)**
a)	
b)	
c)	
d)	
e)	

b) In the last 10 to 30 years, which years would you consider as having been bad?
……………………………………………………………………………………………

10. What management practices, if any, do you use to manage the uncertainty (unreliability) of seasonal rainfall?

Description of practice	**When do you use it?** 1=Good Year 2=Bad Year 3=Average Year	**On what crops?**	**On what area?**
a)			
b)			
c)			
d)			
e)			

	What are the average yields for the following major crops in a good crop production year and a bad crop production year?				Production in the last 3 seasons					
	Upland Fields		Lowland/mbuga fields		2010/2011 season *1=Good 2=Bad 3=Average*		2009/2010 season *1=Good 2=Bad 3=Average*		2008/2009 seaso *1=Good 2=Ba 3=Average*	
Crop	Amount (in Kg)/ acre in a good crop production year	Amount (in kg) / acre in a bad crop production year?	Amount (in Kg)/ acre in a good crop production year	Amount (in kg) / acre in a bad crop production year?	Area planted (acres)	Amount harvested (in kg)	Area planted (acres)	Amount harvested (in kg)	Area planted (acres)	Amount harveste (in kg)
a) Maize										
b) Rice										
c) Sorghum										
d) Cassava										
e) Tomatoes										
f) Onions										
g) Others										

11. Changes of production for major crops

12. What improved or local technologies are you currently using in crop production and what are the objectives of using them?

Technologies being used (if local names are given, please describe the technology)	**On what crops are you using them?**	**When did you start using them?**	**What are the objectives for using them or what problems are you trying to address by using the technologies?**
a)			
b)			
c)			
d)			
e)			
f)			
g)			
h)			
i)			

13. Do you use irrigation for your cultivation?

Yes	No

14. If yes, where do you get your irrigation water from?

Surface water (Rivers)	Ground water	Rain harvesting	Others

15. What kind of irrigation do you use for surface irrigation?

Gravity/Canal	Pumping	Other (specify)

16. Irrigation agriculture details

	Crops	Cultivated area (Acres)	Rented land area (Acres)
Dry season			
Wet season			

17. Can you estimate the amount of water needed for irrigating the following crops

Crop	Minimum Amount (Litres)	Normal Amount (Litres)
a) Maize		
b) Sorghum		
c) Rice		
d) Tomatoes		
e) Onions		
f) Sunflower		
g) Others		

SECTION D: FARMER PERCEPTIONS OF TO CLIMATE CHANGE

18. Have you noticed any significant changes in weather patterns over the years in relation to agriculture?
1=Yes 0=No,

19. If **YES**, what changes have you observed and how did they impact on your household, the environment etc

	What are the impacts of these changes to your household/ livelihoods?	What are the impacts you have observed of these changes on the environment?	How did your HH respond to these changes/impacts
Rain: a) increasing / decreasing days of rain (frequency) b) 2) increased / decreased occurrence of extreme rainfall (intensity)			
Rainfall season: a) Rainfall starts late and ends early b) Rains come earlier than they normally should c) During the season, the rainfall is not consistent 4) increased / decreased days with dry spells			
Temperature: a) Increased number of hot days/nights b) Winters have become colder c) Summers have become hotter d) Winters have become colder			

Other: wind/storms?			

20.

21. Do you have access to the weather forecasting data/information? ***1=Yes 0=No,***

22. If yes, what different kinds of information do you get and where do you get it from?

Type of information	Source of information *1=Radio, 2=Extension 3=Fellow farmer 4=Television 5=other (specify)*	How would you rate the weather information that you receive? Rating: *1=Poor, 2=Average 3=Good*							Reasons for your rating	Suggestions to improve
		Timeliness	Adequacy	Frequency of dissemination	Usefulness	General content	Delivery channel	Language of presentation		
a)										
b)										
c)										
d)										
e)										

23. If the forecast information is positive i.e. it predicts that the rainfall will be enough and will be on time, what are some of the actions that you take in your farm?

Action	**Do you take this action?** *(tick if farmer mentions)*	**Why do you take this action?**
a)		
b)		
c)		
d)		
e)		
f)		
g)		

24. If the forecast information is negative i.e. it predicts that the rainfall will not be good or reliable, what are some of the actions that you take in your farm?

Action	**Do you take this action?** *(tick if farmer mentions)*	**Why do you take this action?**
a)		
b)		
c)		
d)		
e)		
f)		
g)		

25. Do you have any traditional / indigenous ways of predicting the weather patterns?

Weather pattern	**Prediction Indicators**
a) Drought Year	
b) Normal year (Rainfall)	
c) Flood Year	
d) Strong wind	
e) Normal wind	
f) Very hot dry season	
g) Normal dry season	

26. What are the trends that you have observed in the following in the last 30 years?

Variables	**Increased** *(tick)*	**Same** *(tick)*	**Declined** *(tick)*	**What would you say is the main causes of this change?**	**How are you coping with change?**
a) Crop yields					
b) Crop types, varieties					
c) Crop pests and diseases					
d) Livestock populations					
e) Livestock diseases					
f) Quality of pastures					
g) Rainfall amounts					
h) Water availability (for domestic use)					
i) Soil erosion					
j) Water erosion					
k) Wind erosion					
l) Income from agriculture					
m) Food availability for household consumption					

27. Are you using any of the following farming practices in your farm as a result of the changes in weather patterns?

Farming practice	**Do you use?** (*(Tick as if farmer mentions)*	**When do you use?** *1=All the time* *2=During drought years* *3=During good rainfall years*
a) Ripping		
b) Crop residues		
c) Chemical weed control		
d) Tied ridging		
e) Ox- ploughing		
f) Pump Irrigation		
g) Using drought tolerant varieties		
h) Changing crops		
i) Mulching		
j) Intercropping		
k) Mono cropping		
l) Fallowing		
m) Other		

28. Are there some crop production practices that you use in good rainfall years and avoid in drought years? If yes, which ones

Cropping practice	**Do you use in good rainfall years?** *0=No 1=Yes*	**Do you use in drought years?** *0=No 1=Yes*	**Reasons**
a) Use of fertilizers			
b) Use of cattle manure			
c) Hire of labour for farming activities			
d) Use of irrigation (canal)			
e) Use Pump Irrigation			
f) Purchase of improved seeds			
g) First weeding			
h) Second weeding			
i) Other			

29. What factors influence the choice of coping strategies mentioned above?
……
……
……
……………………………………………………………………………………………….

SECTION E: VULNERABILITY AND CLIMATIC IMPACT MANAGEMENT (COPING AND ADAPTATION STRATEGIES)

30. How long does the main harvest last in a good and bad year and how do you fill these shortages?

	Number of months harvest lasts	**Strategies the household uses to cope with shortage**
a) Average good year		
b) Average bad year		

31. Which of the following can you say was true for your household at any point in time during last year as a coping strategy for food shortages? (Tick appropriate box)

Strategy	**1 = Yes**	**2 = No**
a) Sold livestock		
b) Sold household assets		
c) Consumed seed stock		
d) Ate food that we normally don't eat (e.g. wild food)		
e) Reduced amount of food eaten		
f) Ate fewer meals per day		
g) Sought daily work for cash outside farm		

h) Migrated		
i) Borrowed cash to buy food		
j) Borrowed food		
k) Worked in other peoples farms for food		
l) Sold firewood		
m) Rented out land		
n) Withdrew children from school		
o) Looked for relief e.g. Government food aid, Remittances		
p) Other (specify)		

SECTION F: CONSTRAINTS AND OPPORTUNITIES

32. Do you think that you could/can harvest more from your farm? 1. Yes 2. No
33. If Yes, what are the factors hindering you from harvesting more from your farm?

……

What do you need so as to improve your harvest?

……

34. What are barriers of adaptation to impacts of Climate change?

....

. 41. What opportunities or benefits you have gained from impacts of climate change……………………………

APPENDIX D

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (NON MEDICAL)
R14/49 Pauline

CLEARANCE CERTIFICATE **PROTOCOL NUMBER H1 10205**

PROJECT	Living with climate variability and change: Lessons from Tanzania
INVESTIGATORS	Mr NM Pauline
DEPARTMENT	
DATE CONSIDERED	11.02.2011
DECISION OF THE COMMITTEE*	Approved unconditionally

NOTE:

Unless otherwise specified this ethical clearance is valid for 2 years and may be renewed upon application

DATE 04.03.2011 CHAIRPERSON ....
(Professor R Thornton)

cc: Supervisor : Profs C Vogel/s Grab

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

Signature

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES