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Vulnerability and Resilience of Dry Land Irrigation Farming Schemes Against Climate Change: A Case of Ruvuma Basin, South Eastern Tanzania

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Abstract

Dry land irrigation farming practises has remained critically important in supplementing nation's food security during dry season and household income for many rural farmers as well as poverty reduction and other various indirect benefits (employment and economic growth). Despite successful stories in the dry land irrigation farming schemes in South Eastern, Tanzania; the sector has been facing many challenges including the effects of climate variability. Therefore, understanding how the vulnerable and resilience dry land irrigation farming is to the adverse effects of climate change impacts, is critical for reducing vulnerability and enhance adaptive capacity of irrigation farmers. In particular, this thesis examine how irrigation farming schemes are exposed to the adverse effects of climate change variability and how irrigation farmers are responding, adapting and coping with the ongoing changes so to enhance food security, socio-economic development and mitigate the adverse effects of climate change impacts. Other factors making irrigation farming sensitive to climate change impacts and different livelihood diversification options used as coping strategies have been addressed as well.

A mixed-method approach, involving qualitative and quantitative methodology for data collection, was adopted. In this study, main techniques for primary data collection were questionnaire survey, key informant interviews, focus group discussions and participant observation in the field. A sample of 187 irrigation farmers and 5 key informants and 24 people participated in focus-group discussions making a total of 216 individuals. Secondary data were obtained through documentary review and data were analysed both qualitatively and quantitatively. Secondary data analysis shows a decreasing trend of rainfalls with unpredictable pattern while temperature data indicates an increasing trend.

Findings from respondents and interviews indicate that the dry land irrigation farming schemes are exposed to climate variability in terms of increasing extreme temperature, inconsistency periods of dry spells and strong winds which cause excessive evaporation and crop wilting. The majority of the farmers revealed that the farming scheme is very sensitive due to increased crop wilting and decreased soil moisture (*extreme temperature*) and unfertile soil due to water stagnation (*heavy rainfall*) and salt accumulation (*excessive evaporation)*. As the dry land farming schemes become more vulnerable to climate change so do farmers respond and adapt to these changes. Irrigation farmers have also been changing their farming practices overtime through soil and water conservation practices, planting crop varieties to withstand drought condition; changing cropping pattern and engaging in various socio-economic activities to diversify their income sources. Interventions options such as water harvesting technology, farm skills training, improved farming, ready market for fresh produce, and agricultural subsidies are recommendable to both stakeholders for the improved and sustained dry land irrigation farming schemes so as to enhance food security and income of farmers as well as socio-economic development.

Key words: Dry land farming schemes, climate change, impacts, vulnerability, adaptation, coping strategies, resilience.

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Acronyms

ASDP: Agricultural Sector Development Programme
CMRD: Community Managed River Diversion Schemes
CMCC-CMS: Centro Euro-Mediterraneo sui Cambiamenti Climatici Climate Model
EAC: East African Community.
ENSO: El Niño – Southern Oscillation.
FAO: Food and Agricultural Organization
FGD: Focus Group Discussion
GDP: Gross Domestic Products
GEC: Global Environmental Change
GoT: Government of Tanzania
ICID: International Centre for Irrigation and Development.
IFAD: International Fund for Agriculture and Development
IPCC: Intergovernmental Panel on Climate Change
ITCZ : Intertropical Convergence Zone.
IUCN: International Union for Conservation of Nature
KI: Key Interviews
LDC: Least Developing Countries
MAFSC: Ministry of Agriculture, Food Security and Cooperatives
MAM: March, April and May
MoW: Ministry of Water
NARI: Naliendele Agricultural Research Institutes
NAPA: National Adaptations Programme of Action
NAP: National Adaptation Plans – Agricultural Sector
NIMP: National Irrigation Master Plan
NSGRP: National Strategy for Growth and Reduction of Poverty
NHMM: Non-Homogeneous Hidden Markov Model
OND: October, November and December
RSCB: Ruvuma River and Southern Coast Basin Waters
SADC: Southern African Development Community
SAGCOT: Southern Agricultural Growth Corridor
SPSS: Statistical Program for Social Science
SPATSIM: Spatial and Time Series Information Modelling
SSA: Sub-Saharan Africa
SST: Sea Surface Temperature variations
TARP II: Tanzania Agricultural Research Programme II
TMA: Tanzania Meteorological Agency
URT: United Republic of Tanzania
UNEP: United Nations Environmental Programme
UNDP: United Nations Development Program
UNFCCC: United Nations Framework Convention on Climate Change
WUE: Water Use Efficiency
WIOMSA: Western Indian Ocean Marine Science Association.

CHAPTER 1: INTRODUCTION

1.0 Introduction

1.1 Background

Worldwide, agricultural industry has been known to enhance food security and support socio-economic growth in many developing nations (FAO, 2006; IFAD, 2007; Mary and Majule, 2009). For example, Viet Nam went from being a food-deficit country to the second largest rice exporter in the world, largely by developing its smallholder farming sector. In Ethiopia, agricultural sector which is largely dominated by small scale, mixed crop, and livestock farming is the mainstay of the country's economic growth. According to Deressa et al. (2008); the sector constitutes more than half the Ethiopia's gross domestic product (GDP), generates more than 85% of the foreign exchange earnings, and employs about 80% of the population. In Africa alone, the industry accounts for 65% of full-time employment, 25–30% of GDP, and over half of export earnings (Brown et al. 2008). Despite these successful stories; the sector has been faced with many challenges including effect of climate variability. Evidence shows that Africa is more vulnerable because 80% of its population depends on rain-fed agriculture for food and other livelihood needs (Sanga et al. 2013).

Countries in Sub-Saharan Africa are particularly vulnerable to climate change impacts, because of their vulnerability and limited capacity to adapt. Most local farmers in Sub-Saharan Africa have been facing many challenges in agricultural production including water scarcity in semi-arid areas (Tafesse, 2003). For example, in Tanzania agricultural activities depend entirely on rainfall and in most rural areas it is undertaken by local farmers who cultivate food and cash crops on marginal lands. In most cases due to availability of arable land; agricultural activities are carried out in semi-arid areas that receive less than 800 mm of rainfall per year (Shao, 1999; URT, 2007). The GoT, FAO as well other researchers are emphasizing on advancement in agricultural production through irrigation farming systems (Mehmet and Bigak, 2002; Mary and Majule, 2009; URT, 2009; FAO, 2011). The irrigation farming systems such as dry land irrigation farming schemes is a practise that utilizes water from rivers or wetlands to sustain agricultural food production by using local techniques and materials (URT, 2005). According to *ASDP Task Force Working Group Report (Irrigation Development in Tanzania),* there are three types of smallholder irrigation systems operating under small-scale schemes namely traditional irrigation schemes; improved traditional irrigation schemes and water harvesting schemes (URT, 2005). Most of these smallholder irrigation farming schemes in Tanzania are conducted during dry season practised by local farmers. These schemes are characterised by temporary diversion weirs, which often get washed away by floods during heavy rainfall and have to be reconstructed at the end of each rainy season (URT, 2005). The irrigation canals use local materials to control the flow of water and the canals are lined with earth materials which increase losses of water through infiltration and evaporation. In Tanzania, studies have shown that there are several types of dry land irrigation farming schemes such as *Ndiwa* Irrigation Scheme, common in Lushoto (Sokoni and Shechambo, 2005); *Vinyungu* Irrigation Scheme, common in Iringa (Mkavidanda and Kaswamila, 2001; Majule and Mwalyosi, 2003) and *Ndiva* Irrigation Scheme, common around Mwanga and Same Districts (Ikeno, 2011).

Most of dry land irrigation farming schemes though practised under small scale irrigation farming systems using local methods; these farming schemes have proved to be more beneficial and important in increasing food security and enhancing livelihoods (income) in most arid and semi-arid of rural areas during dry season (Mkavidanda and Kaswamila, 2001; Majule and Mwalyosi, 2003; Kaswamila and Masuruli, 2004; Sokoni and Shechambo, 2005). Nevertheless, low rainfall received annually in semi-arid and arid areas severely constrain this type of agricultural activities due to unpronounced or prolonged dry season which drastically reduces crop yields. The problem of low rainfall semi-arid and arid regions is always aggravated by climate variability (erratic and extreme weather condition such as drought and floods which threatens local farmers (Mary and Majule, 2009; Kotir, 2010; Gitz and Meybeck, 2012). These susceptible conditions affect dry land irrigation farming schemes and their livelihood survival through exposure, stress and risk to climate change impact (Malone, 2009; Pasteur, 2011). However, local farmers also through their own knowledge and skills have developed resilience mechanisms (responding and copping to the adverse effect of climate change) in order to counteract these effects and sustain their farming system throughout (Lankford, 2003;

Cooper et al. 2008). To address these challenges facing dry land irrigation schemes (farmers) in the face of climate change and understand the available opportunities; a careful understanding of how vulnerable the dry land irrigation farming schemes is to climate change and what is the ability of local farmers to respond and cope to these changes; is of paramount importance for enhancing food security, socio-economic development and mitigate climate change impacts.

1.2 Problem Statement

In many developing nations small scale irrigation farming systems have been known to enhance food security and support socio-economic growth (Mehmet and Bigak, 2002; FAO, 2006; Majule and Mwalyosi, 2003; IFAD, 2007). For example, in Tanzania where there is availability of water sources (*e.g.* river basin/wetlands); dry land irrigation farming schemes have been documented to increase productivity and income during dry season since food crops such as vegetables fetch higher price during this time of the year (Mkavidanda and Kaswamila, 2001; Majule and Mwalyosi, 2003; Kaswamila and Masuruli, 2004; Sokoni and Shechambo, 2005). As dry land irrigation farming schemes seen as a potential measures of supplemental moisture/water supply for crop production during dry season (Majule and Mwalyosi, 2003; Ikeno, 2011); so does the farming schemes been faced with problem of water scarcity and variability in rainfall due to climate change (Ikeno, 2011; Mutui et al. 2012; Kristjanson et al. 2012). The impacts of climate change have affected the already existing country's agricultural production upheaval and will continue to render the industry more vulnerable to other challenges. For example, the country has about a total of 29.4 million ha suitable for irrigation but only 144,000 ha are under partial or full irrigation farming systems (URT, 2009). Out of 144,000 ha suitable for irrigation only 120,378 ha is under traditional small scale irrigation schemes such as dry land irrigation farming schemes (Mkavidanda and Kaswamila, 2001); which signifying the importance and contribution of dry land irrigation farming schemes to national food security and livelihoods in most rural areas.

Several studies have documented various problems threatening dry land irrigation farming schemes such as deforestation and soil degradation (Banzi et al. 1992); water scarcity (Hanjra and Qureshi, 2010); climate change impacts (Reid, 2008; Kangalawe et al. 2011*)*; changes in river hydrology and its impacts (Lankford, 2003); vulnerability and resilient to climate change (Ekblom, 2012; PROLINNOVA, 2012; Tropentag, 2012). However, the lessons on vulnerability and resilience vary across areas with similar biophysical systems (Ekblom, 2012; Gitz and Meybeck, 2012). In Tanzania, few studies have been conducted on the vulnerability and resilient of irrigation farming schemes to climate change (Mahoo, 2009; Mary and Majule, 2009); however the best practices (lessons) need in-depth analysis using farmers knowledge and experience so as to incorporate many factors such as geographical condition, socio-economic and cultural differences. Specific, how dry land irrigation farming schemes is exposed (vulnerable) to the adverse effects of climate change impacts and how irrigation farmers are responding and coping (resilience) at farm level needs to be studied and well understood so as to continue improve agricultural productivity and sustain local livelihoods and this is the aims of the research study.

1.3 Objectives of the Research Study

1.3.1 General objective

The general objective of this research was to study and understand how vulnerable and resilient dry land irrigation farming schemes are against climate change in the selected villages of Ruvuma Basin, Tanzania.

1.3.2 Specific objectives of the research study

The specific objectives of this research were:-

i. To identify different dry land irrigation farming schemes used.

ii. To assess the vulnerability of dry land irrigation farming schemes.

iii. To assess the resilience of dry land irrigation farming schemes.

iv. To provide recommendation on adaptation options and coping strategies to climate change impact.

1.4 Research Questions

Dry land irrigation farming schemes in most arid and semi-arid of Sub-Saharan Africa faces major problems (Tefesse, 2003; Gitz and Meybeck, 2012). To add up on this, the impacts of climate change have already imposed unpredictable and enormous consequences. This calls for an urgent necessary action to address the problem. The major research questions for this study are as follows:-

i. What are the susceptible conditions (agro-ecological changes) that affect dry land irrigation farmers and their farming schemes in the face of climate change?

ii. What are the response local farmers use to mitigate climate change impact? Or what are emmerdiate creative response mechanisms developed by local farmers to counteract the effects of climate change?

iii. What are different adaptation options and coping strategies that irrigation farmers can use to encounter adverse effects of climate change impacts?

1.5 Scope of the Study Area

The study was conducted along the Ruvuma River and Southern Coast Basin Water. The river basin is shared between Mozambique, Tanzania and Malawi (Figure 1) where the lower course of the river is mostly found in Mtwara region.

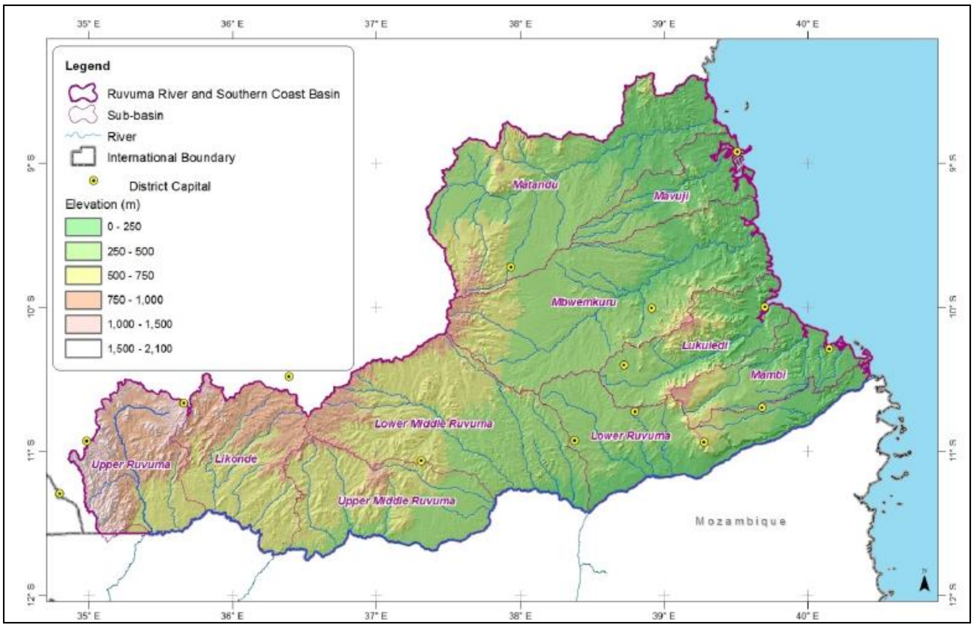

Figure 1.1: Map of Ruvuma River and Southern Coast Basin (Source: MoW, 2015).

The river is perennially fed by the headwaters of its chief tributaries of the Lucheringo, Likonde and Lugenda rivers in Mozambique, and from the Matagoro Mountains in southeastern Tanzania. Major tributaries on the Tanzanian side are Likonde, Muhuwesi and Lumesule. The study was confined along the Ruvuma River Basin, Mtwara and Lindi region in Tanzania. The sample areas (*2 villages*) were selected in Mtwara Rural District, Lindi Rural District and Ruangwa District. The River Basin is endowed with abundant resources (*rich in fertile soils, minerals, water and diverse vegetation*) which have contributed much to the national income and local livelihoods. Small scale farmers along the river basin have been practising local farming such as dry land irrigation farming schemes using varieties of local knowledge systems.

1.6 Definitions of Key Concepts

"Adaptation" is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2014).

"Adaptive capacity" (in relation to climate change impacts) The ability of a system to adjust to climate change (including climate variability and extremes) in order to moderate potential damages, to take advantage of opportunities or to cope with the consequences (IPCC, 2007).

"**Climate change"** refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007).

"Climate variability" refers to variations in the climate at all temporal and spatial scales beyond that of individual weather events (IPCC, 2014).

"Drought" refer to deficiency in rainfall, soil moisture, vegetation greenness, ecological conditions or socioeconomic conditions, and different drought types can be inferred. There are a number of classifications for drought according to its physical aspects namely, Meteorological, Hydrological and Agricultural (Bacanli et al. 2011).

"Meteorological drought" occurs when the seasonal rainfall received over an area is less than 75% of its long-term average value. If the rainfall deficit is between 26-50%, the drought is classified as 'moderate', and 'severe' if the deficit exceeds 50%.

"Agricultural drought" occurs when there is insufficient soil moisture to meet the needs of a particular crop at a particular point in time (Hatibu et al. 2000).

“Hydrological drought” is a deficiency in surface and sub-surface water supply. It is measured as stream flows and also as lake, reservoir and groundwater levels (Mishra and Singh, 2010).

“Dry land irrigation farming systems” is the farming practice in which farmers harness water from rivers, wetlands, ponds or rainfall to produce both food and cash crops during dry season at subsistence level using traditional irrigation techniques (Mkavidanda and Kaswamila, 2001).

“Irrigation” is any process other than natural precipitation which supplies water to crops, orchards, grass or any other cultivated plants (Stern, 1989).

“Vulnerability” is the propensity or predisposition to be adversely affected (IPCC, 2012). It is a degree to which a society or a socio-environmental system is unable to cope with adverse effects as a result of being exposed to any shock/stress. It is a dynamic concept, varying across temporal and spatial scales and depends on economic, social, geographic, demographic, cultural, institutional, governance and environmental factors. Similarly, IPCC (2014) defines vulnerability as degree to which a socio-ecological system is susceptible to or unable to cope with, adverse effects of climate change, including climate variability and climate extremes. It is the propensity or predisposition to be adversely affected and it encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

For the purposes of this study; vulnerability has been described by studying the effects of climate change impacts (*extreme climatic events such as temperature and rainfall variability*) on a socio-ecological systems (*dry land irrigation farming schemes*) and its (in) ability of a systems or people (*dry land irrigation farmers*) to cope with the stress/disturbance (*stressors*) along the Ruvuma Basin in South Eastern Tanzania.

“Resilience”:- *“a measure of the persistence of socio-ecological systems and their ability to absorb changes and disturbances and still maintain the same relationships between populations or state variables” (Holling, 1973).* In order to fully understand the rationally behind the vulnerability and resilience theory, there are number of crucial concepts that needs to be defined and understood in a local context. Some of these concepts include *sensitivity, susceptibility, variability, thresholds, the ability and adaptive capacity, and transformability*.

1.7 Outline of the Thesis

This research study is organised in ten chapters. The first chapter in this thesis explains the problem and its context in which it introduces the thesis by providing background information; statement of the problem, objectives as well as scope and significance of the study are given here. The second chapter is on climate change impacts, vulnerability and resilience of dry land irrigation farming schemes. The chapter provide an overview of agricultural production and irrigation farming from the global perspective, African continent and Tanzania in particular. Several challenges affecting agricultural production and irrigation farming are described here, including vulnerability (exposure) and adaptive capacity of small-scale farmers. Research gap, was contextualised here with aim of developing a pathway for developing conceptual framework. Chapter three presents the conceptual framework and key concepts by analysing key variables that were considered in this research. Through conceptual framework, research methodology followed in chapter four. This chapter provides details on the approach to research design, data collection, analysis and presentation of data. It also presents details of the study area in South Eastern Tanzania where the research took place in six villages. From chapter five to nine, different study findings were presented and discussed. Chronologically, these includes the State of local climate and climate change impacts; Overview of dry land irrigation farming in the study area; Irrigation farmers perception on climate change impacts in the study area; Vulnerability of dry land irrigation farming schemes and Resilience of dry land irrigation farming schemes as well as implication on policy and strategic interventions to reduce vulnerability and enhance farmers long term resilience to climate change impacts. The final chapter in this thesis presents key findings, conclusions and recommendations.

CHAPTER 2: CLIMATE CHANGE IMPACTS, VULNERABILITY AND RESILIENCE OF DRY LAND IRRIGATION FARMING SCHEMES

2.0 Introduction

The purpose of this chapter is to provide an overview of vulnerability and resilience of dry land irrigation farming schemes to the impact of climate change. Many features of the vulnerability and resilience of dry land irrigation farming schemes in this thesis are introduced and elaborated upon here. The chapter is composed of four broad sub-sections. The chapter begins with a broad picture of an introduction and overview on agricultural and irrigation farming practices worldwide and then narrow it down to describe the agricultural production and irrigation farming practices in Tanzania. It provides further information on the impact of climate change on irrigation farming schemes in Tanzania; and description on vulnerability and resilience of dry land irrigation farming schemes against climate change impact in Tanzania. Finally, in this chapter, the research gap on vulnerability and resilience of dry land irrigation farming schemes against climate change impact is introduced with the purpose of elaborating the need to conduct research and fill the gap by providing relevant information on a course of action to be followed in constructing a conceptual framework in chapter 3. The urgent concern over the vulnerability and resilience of dry land irrigation farming schemes against climate change impact is of vital important considering the equivocal and volatile nature of the farming practices and its enormous contribution to food security and household income in many rural areas of Tanzania and particularly along Ruvuma basin. Although most of the information presented here is from published and unpublished materials, some information comes from the field research and the author's experience in agricultural production and food security issues.

2.1 Overview of Agricultural Production and Irrigation Farming Practices

2.1.1 Global Overview of Agricultural Production

Worldwide, agricultural industry has been known to enhance food security and support socio-economic growth in many developing nations (URT, 2005b; Mary and Majule, 2009; Hanjra and Qureshi, 2010; IFAD, 2012; NEPAD, 2013; Devkota et al. 2015). Gollin (2010) adds that although agriculture constitutes rural poor families in many developing countries; it makes significant contributions to the size of the national economy – accounting for 25-30% of Gross Domestic Product (GDP). For example, Viet Nam went from being a food-deficit country to the second largest rice exporter in the world, largely by developing its smallholder farming sector with agriculture accounting for 20.1% in GDP (FAO, 2005). According to World Bank (2007); though at a slow pace, agricultural performance in Africa has improved where agricultural GDP growth in Sub-Saharan Africa has accelerated from 2.3% per year in the 1980s to 3.8% per year from 2000 to 2005. Similar results were reported by World Bank, 2015 for other countries where agriculture contribute a sizeable share to the national GDP (as indicated by GDP in selected LDC-table 2.1).

Table 2.1: Agriculture, value added (% of GDP) from selected LDC.

S/N	Country	2011	2012	2013
1	Bangladesh	17.1	17.1	16.3
2	Indonesia	13.5	13.4	13.4
3	Paraguay	22.3	18.1	21.5
4	Dominica	15.0	14.4	16.3
5	Jamaica	6.6	6.8	7.1
6	Burkina Faso	33.8	35.4	34.8
7	C. African Republic	53.5	53.9	58.2
8	Kenya	29.3	29.1	29.4
9	Tanzania	31.3	33.2	33.3

Source: World Bank, 2015

Over 70% of the world's poor in developing countries live in rural areas and are directly or indirectly dependent on agriculture for their livelihoods (FAO, 2005, IFAD, 2012; NEPAD, 2013). The size of the agricultural sector relative to the rest of the economy in developing countries implies that the growth of the sector has potential for large direct effects on economic growth and transformation of the national economy as well as household income for many rural farming communities. For example, in Sub Saharan Africa (here in after, referred as SSA) alone, agricultural plays a central role in supporting rural livelihoods and it accounts for 65% of full-time employment, contributes 25 – 30% of GDP, and over half of export earnings (World Bank, 2007; Brown et al. 2008; NEPAD, 2013). In Ethiopia for instance agricultural sector which is largely dominated by small scale, mixed crop, and livestock farming is the mainstay of the country's economic growth (Deressa et al. 2008). The sector constitutes more than half the Ethiopia's Gross Domestic Product (GDP), generates more than 85% of the foreign exchange earnings, and employs about 80% of the population (*ibid.)*. In Nigeria, although the country is endowed with mineral resources (for example, oil); agricultural sector contributes about 55% of gainful employment and almost 40% of the share of GDP (Pingali et al. 2008). The World Bank (2007), estimates that the population relying on agriculture accounts for 48% of the total African population (almost 70% in East Africa).

Generally, according to FAO (2009); agriculture is the major economic sector of many developing countries and most Least Developed Countries (LDC's) with main livelihood of 75% of the poor in developing countries. It has remained the primary source of employment and income in most of SADC's rural population with small-scale farmers contributing a large part of the annual yield (Gbetibouo and Ringler, 2009). It is also the major source of government revenue for most SADC countries in Africa. Chikodiz et al (2012); noted that in Zimbabwe, an estimated 80% of the population directly depend on agriculture; of this over 60% are small scale farmers. Most of these success stories in agricultural sector in developing countries have been contributed by small scale farmers who depend on rain fed agriculture and traditional irrigation for agricultural production. Parallel to these success stories, agricultural production has also been face with many challenges as described below.

2.1.2 Challenges Facing Agricultural Production

Despite these successful stories in various parts of the world; agricultural sector has been faced with many challenges including the effect of climate change and climate variability. These challenges are more noticeable in most developing countries due to poor farming practices, lack of technology and resources as well as overdependence on rainfall (FAO, 2005; Deressa et al. 2008; Kotir, 2010; Fischer et al. 2013). Major challenges facing agricultural production in SSA are indicated in the table 2.2 below with rainfall, lack of agricultural inputs and technology act as a leading challenge.

Table 2.2: Major challenges facing agricultural production in SSA.

S/N	Challenge facing agriculture production	Source
1	Overdependence on rainfall	Kotir, 2010; Fischer et al. 2013
2	Lack of agricultural inputs	Deressa et al. 2008;
3	Poor technological innovation	Lowitt et al. 2015;
4	Low crop yield	Savini et al. 2016
5	Price volatility and market failure	FAO, 2011b
6	Soil pH (acidity and alkalinity)	Msaky et al. 2010

In most developing countries, yields of most crops are still far below their potentials and the level of modern technology adoption in agricultural production and processing is still extremely low and far beyond in terms of efficiency (Tittonell and Giller, 2013). For example, according to EAC (2014); agricultural production and productivity in the East African Community countries is largely constrained by natural factors, policy and adoption of technologies as indicated in the table 2.3 below, with nature related and policy factors leading cause.

Table 2.3: Agricultural production and productivity constraints.

S/N	Challenge or Problem	Description	Other related or similar sources
1	Nature related factors	Degradation of natural resources	Msaky et al. 2010;
		Climatic and weather variability, and unpredictability	Calzadilla et al. 2008; Kotir, 2010
2	Policy related factors	Governance, legal and regulatory framework, Insecurity	Lankford, 2003; URT, 2003b; World Bank, 2007
		Inadequate access to productive resources, inadequate participation of local farmers, unfavourable terms of trade, price volatility	Brown et al. 2008; FAO, 2005 FAO, 2011b
		Poor physical infrastructure and utilities, Weak institutional framework, low public expenditure;	Deressa et al. 2008; Mainuddin and Kirby, 2009
3	Adoption of technologies	Inadequate research, extension services and training; and prevalence of pests and diseases	Mercer, 2011; Lowitt et al. 2015
4	Cross cutting and cross-sectoral related factors	High incidence of poverty; food access and nutrition, inadequate social infrastructure; and Gender imbalances	FAO, 2005; IFAD, 2012; Behrman et al. 2013;

Source: Adapted and modified, EAC, 2014

The dismal performance of the agricultural sector in SSA is due to long standing issues and interaction of complex factors such as poor market access and lack of supporting institutions; low incentives to agricultural intensification; unfavourable topography; low quality soils and inadequate policy environments; agro-ecological complexities and heterogeneity of the region (World Bank 2007; FAO 2009; Diao, 2010; Savin et al. 2016). These challenges are exacerbated by impact of climate change and climate variability which makes agricultural production (already affected by several factors) a more risk business ever to be undertaken in SSA. And most affected people are poor farmers who are exposed and have no resources to adapt and cope with ongoing changes (biophysical and socio-economic).

Evidence shows that Africa is more vulnerable because 80% of its population depends on rain-fed agriculture for food and other livelihood needs (FAO, 2011b; Sanga et al. 2013). For many years, agricultural production in SSA has remained highly dependent on rainfall and limited by technological innovation whereas productive land has been continuously degraded at an alarming rate reaching a threshold limit. According to Calzadilla et al (2008); rain-fed farming dominates agricultural production in SSA, covering around 97% of total crop land, and exposes agricultural production to high seasonal rainfall variability. Climate change may further undermine attempts to mobilize the necessary water resources, due to observed reductions in rainfall (Cioffi et al. 2014), particularly in the lower tropical latitudes (Zhang et al. 2007). Some experts are predicting further declines in rainfall and amplification of extreme events (Fischer et al. 2013; IPCC, 2014). On the other hand, land expansion potential has reached its limits in most agro-ecological zones, urging a rapid shift towards agricultural intensification type of productivity-led growth (Diao, 2010).

Responsible Ministries in each respective government in SSA's have been often urged to shift towards agricultural diversification and intensification (such as irrigation farming) so as to raise agricultural productivity which have the potential to contribute positively to growing national economy and reduce poverty (Wold Bank, 2008; FAO, 2011a; NEPAD, 2013). The Food and Agricultural Organization and other researchers are emphasizing on advancement in agricultural production through irrigation farming systems (Mkavidanda and Kaswamila, 2001; Mehmet and Bigak, 2002; Reid, 2008; FAO, 2011a) using rivers or wetlands as sources of water to sustain agricultural food production and ensure food security for many poor families in rural areas. The use of fresh water from the rivers, wetlands and other sources to irrigate crops during the dry season has proved beneficial due to increased chances of crop productivity as well as supplementing food availability during the dry season (Majule and Mwalyosi, 2009; Devkota et al. 2015; Ngowi et al. 2015). Thus, irrigation farming is seen as a key to supplement food production during dry season while enhancing household income earned through selling excess food and cash crops.

2.1.3 Overview of Irrigation Farming Schemes

Irrigation farming is an effective way to increase crop production and productivity that may result into poverty alleviation and food self-sufficiency in many developing countries (World Bank, 2007; FAO, 2011b). Worldwide, irrigated agriculture provides about 40% of the world's food production from 18% of the world's cultivated land (Mwakalila and Noe, 2004; World Bank, 2007). About 70% of worldwide water diverted from rivers or pumped from underground is used for irrigation farming (FAO, 2011a; Devkota et al. 2015). The irrigated land is far more productive than rain fed land, and the expansion of irrigation acreage over the past 30 years has contributed to gains in food production and food security (Millennium Ecosystem Assessment, 2005). For example in India, the 35% irrigated area provides more than 60% of the food production (World Bank, 2007). Dlamini et al (2014); adds that small scale irrigation farming practices has been practiced for many years through the necessity to maximize food supply for humanity. Belay and Beyene (2013) strengthen that in the contemporary literature, the farming practices are being recognized as central in increasing land productivity, enhancing food security, earning higher and more stable household incomes and increasing prospects for multiple cropping and crop diversification. A study by Angood et al (2003) and Brabben et al (2004); concluded that small scale irrigation development, resulted in considerable rural livelihood, food security, and nutritional improvement among the beneficiaries in Nepal and Bangladesh respectively. In addition, a study by Gebregziabher et al (2009) using a survey of beneficiaries of selected small scale irrigation farming schemes in the Tigray region of Ethiopia revealed that household income of irrigation users was higher than that of non-irrigators by about 50%.

In majority of SSA's, an opportunity which is yet to be fully exploited is irrigation farming (FAO, 2011b). Although African continent is endowed with major fresh water resources, only 6% of the total cultivated land is under irrigation in the continent, compared to 33% in Asia (World Bank, 2007; FAO, 2011b; Devkota et al. 2015) signalling many challenges facing irrigation sector such as overdependence on surface water (runoffs from rainfall); droughts prevalent and extreme floods and temperature as well as technological inefficiency such as dependence on traditional irrigation (that use crude methods of water extraction). These factors often destroy local farmer's crops and exacerbating food insecurity; however tackling extreme climatic events (such as frequent dry spell, drought and floods) can improve irrigation farming and thereby improve yield, household earning and enhancing food security. Irrigation farming is a key factor to improve agricultural production in dry land areas and supplement household income and food security during the dry season.

Throughout the world, many forms of irrigation farming practices exist, which calls the need for outlining the concept explicitly. By definition, irrigation is any process other than natural precipitation which supplies water to crops, orchards, grass or any other cultivated plants (Stern, 1989). Unami (2013) explain that, irrigation in general involves taking water from natural or artificial sources and supplying it to command areas where crops are grown. The Tanzania National Irrigation Master Plan (2002) and National Irrigation Policy (2009) defines irrigation as different means of applying specific amount of water at a particular location in order to meet the requirements of a crop growing at that location in amounts that are appropriate to the crop's stage of growth (URT, 2002; URT, 2009). Irrigation can also mean the application of water in amounts necessary to bring soil to the desired moisture level prior to crop planting essential for overcoming water deficiencies during dry season or in areas with low rainfall. Generally, the application of supplemental moisture (water) to grow crops particularly during dry season is termed as irrigation farming.

Different scales and types of irrigation farming schemes are being practiced throughout the world around most of the wetlands and river basins. These irrigation farming schemes practiced under different scales and types includes large irrigation farming schemes (Devkota et al. 2015); medium and small scale irrigation farming schemes (Gbetibouo and Ringler, 2009) as well as traditional (local) irrigation farming schemes (Majule and Mwalyosi, 2003). For the purpose of this study, traditional (local) irrigation farming schemes at a very small scale (0.4 ha to ≤1 ha) were considered focusing on individual farmers around Ruvuma Basin, South Eastern Tanzania. The majority of the irrigation farming schemes carried out in the study areas are small scale farming schemes employing local tradition methods of farming and generally depending on surface water (collected runoffs from rainfall) for irrigating crops. For example, FAO (2011a) noted that both small scale and traditional irrigation farming schemes (covering 7.3 million ha) around Nile Basin are highly dependent on the availability of stored water from Nile River. Similar findings were observed in Bangladesh where about 80% of farm holdings are small farms, cultivating on average only 0.08 ha - 0.3 ha with majority of them being marginal farmers depending on irrigation farming to supplement their agricultural production (Angood et al. 2003).

Small scale and traditional irrigation farming schemes throughout the world have been known to improve agricultural productivity, enhance food security and increase earning of the local farmers while providing much indirect employment and contributing to economic growth via food supply chain and multiplier effect. Various reports indicate that at the village level, small scale irrigation provides higher and more stable employment and the poor are the major beneficiaries (Sokoni and Shechambo, 2005; Pingali et al. 2008; Liwenga et al. 2012). Eneyew et al. (2014) in their study of the role of small scale irrigation in poverty reduction in Ethiopia observed that irrigation development improved household income and contributed to poverty reduction. In Central Asia, more than 70% of the rice is produced in rice–wheat systems in the irrigated lowlands of the Amu Darya and Syr Darya river basins (Devkota et al. 2015). Wherever practiced sustainably, small scale irrigation farming has proved to play a central and dynamic role in the improvement of rural livelihoods through provision of household income while enhancing food security during the dry season. The process of irrigating crops as potential measures of supplementing moisture/water supply during the dry season has also successfully tested for higher crop productivity in smallholder farming of the semi-arid world (Taffese, 2003; Fischer et al. 2013; Gomo et al. 2014; Devkota et al. 2015). In various literature studies, the irrigation farming schemes have been identified as an alternative in resolving many developing countries' present food crisis (IFAD, 2007; Dlamin et al. 2014) by providing better water control which, consequently results to significant increase in agricultural production and improved rural livelihoods (Kaswamila and Masuruli, 2004; Kulkarni, 2011; Liwenga et al. 2012; Kihupi et al. 2015).

In general, small scale irrigation development brings a range of potential benefits at local, regional and national level. It contributes to economic growth by generating export crops, reducing imports and thus saving foreign exchange and increasing home food supplies, which may lead to lower prices (Brabben et al. 2004; Gebregziabher et al. 2009; FAO, 2011b; Devkota et al. 2015). Other scholars add that the poor in general benefit through a trickledown effect through lower food prices (Brown and Gibson, 2008), more secure supply of food at reasonable prices (Angood et al. 2003) as well as indirect income earning via agricultural food value chain such as vegetable products (Eshetu et al. 2010). In many countries the farming practices has played a major role in eliminating food insecurity nation-wide while increasing household earning for the majority of the poor farmers. Small scale irrigation farming can also increase the level of resilience for farming communities by reducing rural-urban migration, or discourage unsustainable land use practices, such as shifting cultivation and forest degradation which are important key element for combating climate change and fostering economic development (Deressa et al. 2008; Gitz and Meybeck, 2012). Despite playing a key role in enhancing food security and household income as well as economic growth in many rural families, irrigation farming practices have been faced with many challenges too as described below.

2.1.4 Challenges Facing Small-scale Irrigation Farming Schemes

Small scale irrigation farming schemes often function as a development 'pole' in rural areas, where supplemental increased output and income earning can be achieved during the dry season (World Bank, 2007; FAO, 2011b). Kangalawe et al. (2011) and Sanga et al. (2013) noted similar findings in Tanzania along the Great Ruaha and Pangani River Basin respectively. Although the farming practices contributes to increased food security and household incomes for many rural poor families; various studies conducted on small-scale irrigation farming schemes revealed that the practices is also affected by many factors such as climate variability (for example, increased temperature) and soil salinity due to excessive evaporation which affects crop performance at farm level. Other scholars have indicated various challenges through different literature sources (Table 2.4 below) with extreme temperatures and poor land use/farming practices ranked first while hidden cost (land preparation, seeds, pesticides, transport) and health related problems such as infectious diseases (*e.g* Bilharzia) taking last position.

Table 2.4: Challenges facing small-scale irrigation farming

S/N	Challenges facing irrigation farming	Source
1	Extreme temperature and dry condition	Mutui et al. 2012
2	Poor land use changes and poor farming practices	Liu, 2016
3	Unsustainable irrigation water withdrawals	Rockström et al. 2010
4	Low technological innovation	Mercer, 2011
5	Poor technological innovation and adoption	Lowitt et al. 2015
6	Increasing water effluents-use of manure, pesticides	Etteieb et al. 2015
7	Water logging and health problems	Jaleta et al. 2013
8	Hidden costs, public health impacts	IUCN, 2014

These challenges affect the farming practices at different levels of household or farming during vegetable production in dry season. Different number of factors (both internal and external) affects irrigation farming disproportionately which impacts households' farm productivity and income earned. These factors exposes irrigation farming to other set of factors that makes it more vulnerable. For example, in their paper on irrigation and water use efficiency in Sub-Saharan Africa; Kadigi et al. (2012) argues that although SSA has ample water resources some of the past schemes have failed due to poor planning, patchy consultation and insufficient maintenance. Similar findings were also reported in traditional and small scale irrigation farming schemes around major river basins in Tanzania (Sokoni and Shechambo, 2005; Shetto et al. 2007; Mary and Majule, 2009; Kangalawe et al. 2011). Other factors include market failure, lack of support from the government, health (increased incidence of water-related diseases) and the environment such as water logging and soil salinity (Angood et al. 2003). Makombe et al. (2007) and Msaky et al. (2010) observed that an increase in soil salinity from time to time in irrigated farms as compared to rain fed agriculture is a major problem thus affecting agricultural productivity around irrigating communities.

Although small scale irrigation farming schemes are affected by many factors as stipulated above, closer examination at local level is necessary since every location has different geographical settings as well as socio-economic, cultural and political aspects which have both positive and negative attributes to irrigation farming practices. For example, crop productivity in many parts of developing countries and particularly Africa is limited primarily by nutrient rather than water availability (Tittonell and Giller, 2013; Gomo et al. 2014); smallholder crop production is often oriented to both consumption and the market (Angood et al. 2003; Beyal and Beyene, 2013); the integration of cropping and livestock activities is already a common denominator to many of these systems (Kristjanson et al. 2012). Angood et al. (2003) and Beyal and Beyene (2013) in their research study argue that in densely populated regions, green manures or agro-forestry practices do not always fit the needs and possibilities of every smallholder farmer. This indicates that there is a greater diversity among rural farming communities, which calls for a closer examination and an in-depth understanding of each irrigation farming schemes. Therefore, small scale irrigation farming schemes in each rural areas of Africa needs a 'uniquely local' strategy for the sustainable farming practices while capitalising on ecological processes and ensuring efficient use of scarce agricultural inputs (Tittonell et al. 2011).

In regards to the above call, Tanzania can also develop a local strategy for sustainable irrigation farming practices through assessing the vulnerability and resilience of irrigation farming practices and thereby provide a way forward to all stakeholders involved in irrigation farming so as to enhance local farmers earning, improve food security and economic growth while conserving the environment. Hence, whether affected by internal or external factors; small scale irrigation farming schemes still constitutes the backbone of smallholder farmers in many rural areas of Tanzania and contribute immensely to the national economy. Therefore, the genuine positive aspects (benefits) that surround small scale irrigation farming schemes (such as dry land irrigation farming schemes) and their ability to sustain Africa's food security and household income during dry season is yet another self-evident to support the importance of the farming practices for sustaining the future generation. In this regard, the fundamental questions being raised is what is the vulnerability and resilience of dry land irrigation farming schemes against climate change impacts? The nature of exposure and sensitivity will be discussed later in the section 2.4 and 2.5 respectively (vulnerability and resilience on dry land irrigation farming schemes).

2.2 Overview of Agricultural Production and Irrigation Farming in Tanzania.

2.2.1 Overview of Agricultural Production in Tanzania

Agricultural sector is the foundation of the Tanzanian's national economy where it plays an important role in poverty reduction particularly in rural areas (MAFSC, 2012). The sector provides livelihoods to more than 80% of the population in Tanzania most of them living in rural areas (MAFSC, 2012) and it's the main pillar to food security at the household and national levels (Mnenwa and Maliti, 2010). Agricultural production is undertaken by small-scale subsistence farmers which comprise more than 90% of the farming population, with medium and large-scale farmers accounting for the rest. The agricultural sector in Tanzania accounts for more than 25% of GDP and provides 85% of exports while employing about 80% of the work force (MAFSC, 2012). On average, crop production contributes about 19.0% of GDP and grows at 4.1% (MAFSC, 2012; URT, 2012) while livestock production contributed about 5.9% of the GDP. According to Tanzania National Food Survey, 2012; food crop production account for about 65% of agricultural GDP while cash crops account for about 10%. Maize is the most important crop accounting for over 20% of total GDP. The importance of agricultural production is amplified through backward and forward linkage effects both at local, regional and national level.

Though at a very slow pace, the average annual agricultural growth grew-up from 2.1% in 1980's to 6% in 2004 (ASDP, 2013). The rate of growth in agriculture is higher than the average annual population growth rate of 2.9%, implying growth in incomes particularly of rural household farmers. The sale of agricultural products (such as food and cash crops, livestock and fish products and other earning and business) accounts for about 70% of rural household incomes. According to MAFSC (2012); the major crops for export include coffee, cotton, cashew nut, sesame, tobacco, sisal, tea, cloves, oil seeds, spices and flowers whereas major food crops are maize, sorghum, millet, paddy, wheat, sweet potato, cassava, pulses and bananas. Crops such as rice, maize and wheat are also imported to supplement food shortages in periods of harsh condition such as droughts or low yields.

Tanzania is endowed with abundance land resources, however out of 94.5 Mha of land, only 44 Mha classified as suitable for agriculture (MAFSC, 2012). Recent reports show that only 10.1 Mha (23%) of the arable land is under cultivation (URT, 2005b; MAFSC, 2012; ASDP, 2013). According to URT (2008) and URT (2010); despite all the achievements in agricultural sector; the sector has been faced with major constraint such as low land utilization and productivity due to application of poor technology (ICRISAT, 2003), dependence on local knowledge farming systems and unreliable and irregular weather conditions (URT, 2007). The low land utilization has been dominating the industry where smallholder farmers (peasants) cultivate an average farm sizes of between 0.9 ha and 3.0 ha each (Kilemwa, 1999; FAO, 2006 and URT, 2012) while relying on local farming methods (hand-hoe) and rain-fed agricultural farming systems (ASDP, 2013). It is estimated that the average per capita land holding for majority of smallholder farmers is only 0.12 ha.

According to Shetto and Owenya (2007); agricultural yields in Tanzania are generally low - for example, averaging below 1 t/ha for maize and 2.5 t/ha for rice paddy. Yields have been mostly stagnant for the last ten years and agricultural productivity gains have been based more on the expansion of cultivated land, which is one of the major drivers of deforestation and land degradation in the country. Findings from Shetto and Owenya (2007) in three selected districts in Northern Tanzania shows that low yield has been contributed by factors such as low and generally declining soil fertility, soil and water loss through erosion, drought, erratic and unreliable rainfall. Furthermore, Kakeya et al. (1998) observed that conventional farming practices such as burning or removing crop residue and intensive tillage coupled with climate change often make these problems worse. The Millennium Ecosystem Assessment (2005) concludes that the on-farm productivity (for the majority of the Tanzania local farmers) is limited both by the challenging hydro-climate and by land degradation.

Despite these challenges, local farmers and GoT (through Ministry of Agriculture, Food Security and Cooperatives) as well as various actors/stakeholders have developed various strategies and program to safeguard agricultural production and improve productivity and income earning of the local farmers. According to ASDP (2013); some of the strategies include improved farming, agricultural intensification and irrigation farming. These strategies and various initiatives to advance towards sustainable agriculture development within the sector have shown promising results by enhancing research and extension services (ASDP, 2013; MAFSC, 2012) while increasing on-farm productivity and income earnings for many rural farmers. Current government initiatives, such a *Kilimo Kwanza Programme* (Agricultural First Initiatives) and the *Southern Agricultural Growth Corridor* (SAGCOT) have tested several projects in efforts to address some of the challenges mentioned above and contribute to sustainability in agricultural production and economic growth. One of the Kilimo Kwanza initiative's aim is to increase irrigated area from 227, 000 ha in 2002 to 7 million ha by 2017 and improve paddy yields from 1.8 t/ha to 8 t/ha by 2015 (MAFSC, 2012). These programmes have been initiated by the GoT through the Ministry of Agriculture, Food Security and Cooperatives in efforts to modernize and improve agricultural productivity and increase earnings while conserving the environments in the country especially in rural areas.

The Kilimo Kwanza Programme was initiated for overthrowing failure that existed in agricultural sector with its major objectives to transform subsistence farming (small scale) to commercial agriculture; sensitize local investors to engage in large scale commercial farming and adding value to existing agricultural production system (URT, 2008; URT, 2009; MAFSC, 2012). However, inadequate implementation capacity and lack of investment capital for local farmers to buy agricultural inputs needed for mechanized agricultural farming systems such as improved traditional irrigation and medium and large scale irrigation farming; has resulted into serious failure in implementation of the programme at local level. In most cases, local farmers continue to use local methods (such as hand-hoe) in agricultural production in rural areas during rain seasons and supplement their harvest and income during dry season by relying on irrigation such as dry land irrigation farming schemes.

Generally, several factors have contributed to the modest performance of the agricultural sector in Tanzania. Among the major reasons for failure has been heavy dependence on rain-fed agriculture and climate variability, use of hand hoe and low level of mechanization for most of the Agricultural operations (URT, 2009). This list of challenges facing Tanzania's agriculture and farmers is not exhaustive. However, these challenges can be solved if the factors exposing different units of agricultural production to vulnerable condition can be identified and effectively addressed by extension and advisory services through accommodating various local farmers' adaption strategies.

2.2.2 Irrigation Farming Practices in Tanzania

There is growing evidence and concern within and beyond the scientific community that agricultural food production and food security will be additionally threatened by global environmental change (GEC) especially for rural poor who depends on rain-fed agriculture (World Bank, 2007; Calzadilla et al. 2008; FAO, 2009; IFAD, 2012; ASDP, 2013; Devkota et al. 2015). In Tanzania, more than 80% of the population resides in rural areas depending solely on rain-fed agriculture as a means of livelihoods (Mnenwa and Maliti, 2010; MAFSC, 2012). This results into low seasonal crop yield and poor productivity which reduces the potential harvest and income of many poor farmers in rural Tanzania. Thus, irrigation farming is the only viable option for ensuring sustained food availability throughout the year while generating enough needed income for the majority of the poor families in the rural areas.

The National Irrigation Master Plan (2002) and National Irrigation Policy (2009); strengthen that irrigation farming practice is one of the effective means in increasing and stabilising food and cash crop production and productivity for curbing food shortages and increasing export of cash crop and its products. This will not only increase crop productivity but also increase farmers earning as well as creating many indirect job and contribute to economic growth. In order to support and implements various policy and programmes related to agricultural production, the Tanzania National Strategy for Growth and Reduction of Poverty – NSGRP (2005b) provide similar goals and targets of improving food availability and accessibility under cluster I. One of the NSGRP's strategies is to develop irrigation in the country by increasing area under irrigation and promote water use efficiency in irrigation schemes and encourage utilization of low cost technologies. The NSGRP goal is to cut food insecurity from 27% in 2000/01 to 14% in 2010 and to double agricultural growth from 5% in 2002/03 to 10% in 2010 (ASDP, 2013). The Kilimo Kwanza Initiatives and SAGCOT gives the core strategic direction for the agricultural sector, including priority to irrigation development with an emphasis on smallholder traditional irrigation schemes that are based on run-of-river and rainwater harvesting technologies (MAFSC, 2012).

In Tanzania, most of the irrigated areas are under surface irrigation, mostly used by smallholders (traditional irrigation) whereas utilization of groundwater covers only 0.2% of all irrigated areas (MAFSC, 2012). Keraita (2011) and Evans et al. (2012); describe that water distribution for irrigation in the country is usually by lined and unlined canals, and furrows while wetland and basins irrigations are widely used. Sprinkler and drip irrigation is not common amongst smallholders and it's only used by few large-scale commercial farmers. With numerous rivers, lakes and underground water resources, Tanzania has huge potential for irrigated agriculture. Within the country, of the total arable land area available, 29.4 Mha have varying degree of development potential for irrigation (NIMP, 2002). According to NIMP (2002) cited in Evans et al. (2012) and ASDIP (2013); it is estimated that out of 29.4 Mha, 2.3 Mha (7.8%) have a high development potential, 4.8 Mha (16.3%) have medium development potential, and 22.3 Mha (75.9%) have low development potential land for irrigation. The total area currently under irrigation is less than 0.5 Mha, of which only 0.4 Mha (1.2% of the total irrigation potential area) has good irrigation infrastructure, while another 0.1 Mha is still under traditional irrigation practice (Evans et al. 2012; ASDIP, 2013) signifying the importance of developing small scale and traditional irrigation schemes.

The NIMP (2002) sets a more realistically achievable development program and target that 405,421 ha covering 626 smallholder's schemes will be developed for irrigated agriculture by 2017 compared to 191,922 ha that were developed as of June 2002 (Table 2.5). This was initiated to help to improve productivity of smallholder farmers and ensuring the livelihoods in most rural areas as well as contributing to the country's food security.

Table 2.5: Irrigation Development Plan 2002-2017 as indicated in URT, 2002.

Type of water management	**Existing 2002 (ha)**	**New Development until 2017 (ha)**	**Total in 2017 (ha)**
Traditional and Improved traditional	148,141	126,524	274,665
New (modern) small holder schemes	35,847	26,734	62,581
Water harvesting	7,934	60,241	68,175
Total	**191,922**	**213,499**	**405,421**

According to URT (2011); irrigation farming scheme means the area where crops are grown under irrigation through any method including flood recession; gravity or pump fed canal systems supplying either surface or groundwater; water harvesting and pressurised systems such as drip and sprinkler. Irrigation schemes include traditional schemes, rehabilitated or upgraded schemes, new smallholder investment and purely private commercial investment. Several types of irrigation farming schemes exists around the country, however the common types of irrigation identified by National Irrigation Master Plan (2002); District Irrigation and Water Harvesting Support Project (2005a) and Tanzania National Irrigation Policy (2009) are as follow:-

i. *Small, Medium and large commercial irrigation farms:-* The small scale irrigation schemes covers up to 500 ha; medium scale irrigation schemes covers an area between 500 ha and 2000 ha; while large scale irrigation schemes consists of an areas of over 2000 ha.
ii. *Traditional irrigation farming schemes:-* Including variety of schemes such as community river diversion. They are developed and managed by farmers themselves using local skills and materials.
iii. *Improved traditional irrigation schemes:-* These have concrete diversion weirs, gated canal intakes and water diversion boxes.

Other irrigation farming schemes include furrows and basins are widely used in water harvesting schemes such as capturing floods from seasonal rivers via bunds, dams or flood diversion for gravity. Usually main crop includes paddy rice grown on the banks of the rivers and are watered by frequent river flooding. The National Irrigation Master Plan-NIMP (2002) cited in Evans et al. (2012) estimated that of the 1,428 irrigation schemes inventoried; 1,328 were traditional smallholder schemes, 85 private schemes and 15 government-managed schemes (Table 2.6).

Table 2.6:Irrigation schemes by types of irrigation and management type (URT, 2002)

Type of Irrigation	**Area (ha)**	**Number of Scheme by Management Type**		
		Smallholder	**Private**	**Government**
Modern irrigation	35,847	95	25	8
Traditional irrigation	122,630	924	52	6
Improved trad. irrigation	25,511	105	7	1
Sub-total irrigation	183,988	1,124	84	15
Water harvesting	7,934	204	1	0
Total	**191,922**	**1,328**	**85**	**15**

According to Lankford (2004); most traditional irrigation farming schemes are managed by community using temporary diversion weirs with no canal intake gate. Evans et al (2012); estimate that river diversion irrigation could cover 0.15 to 0.51 million ha and 153,000 to 509,000 households or 2% to 8% of rural households could benefit from community managed river diversion schemes (CMRD) if adoption rate of CMRD is only 50% in the area suitable for such technology. Keraita (2011) and Evans et al (2012) describe further that about 3% of the total area is covered by traditional small schemes with an area of less than 50 ha each, while 58% is covered by schemes of over 500 ha each. Difference variations that exist in irrigation farming schemes are attributed by several factors including historical development (Tagseth, 2010; Keraita, 2011), available water source (ASDP, 2013), technology employed (Evans et al, 2012) and type of crops grown as well as cultural background. For example, according to Evans et al. (2012); banded flood irrigation is not regarded as irrigation in the MAFSC traditional irrigation database. ICID (2012); observed that the main irrigated crops are paddy rice and maize, accounting for about 48% and 31% of the irrigated areas in 2002. Other irrigated crops under traditional irrigation schemes account for 44% of the irrigated areas are beans, vegetables including onion, tomato and leaf vegetables, grapes, bananas and flowers.

Selected literature reports and research studies in Tanzania such as a study on the national irrigation master plan (URT, 2003b); district irrigation and water harvesting support project (URT, 2005a), investment in community managed river diversion (Keraita, 2011) and investment in agricultural water management to benefit smallholder farmers in Tanzania (Evan et al. 2012); propose how irrigation farming could be developed so as to benefit rural famers and the country in general. According to National Irrigation Master Plan (2002) and National Irrigation Policy (2009) cited in ASDP (2013); GoT had begun to focus on smallholders farmers contribution on agricultural production by promoting small scale and traditional irrigation farming schemes mainly in areas with little annual rainfall total in order to supplement water shortages. The aim of the Agricultural Sector Development Programme (ASDP) is to support reduction in over-dependence on rain-fed agriculture for local farmers by rehabilitation and management of low cost smallholder irrigation schemes, including rainwater harvesting. The primary reason for embarking on small scale and traditional irrigation farming scheme is to enhance agricultural productivity and increase earnings of the smallholder farmers in areas where surface soils are naturally drier.

In Tanzania, traditional irrigation schemes are those with temporary infrastructure that are not technically constructed and use crude methods of harvesting water from different water sources (URT 2009; Keraita, 2011). The country's irrigation database obtained from the ministry of agriculture and food security (MAFSC, 2012) inventory show that there were 1,137 traditional irrigation schemes covering 117,000 ha only, with Kilimanjaro irrigation zone reported to have the largest irrigated area as percent of irrigable area (ASDP, 2013). According to MAFSC (2012); the development trend of irrigated agriculture has been increasing for the past 20 year (figure 2.1 below) with more traditional irrigation schemes improving their productivity and water use efficiency through varieties of low cost technological inputs (rain water harvesting system, lined-up canals). Most of the improved traditional farming schemes are supported by all stakeholders (farmers, GoT through responsible ministries and other donors).

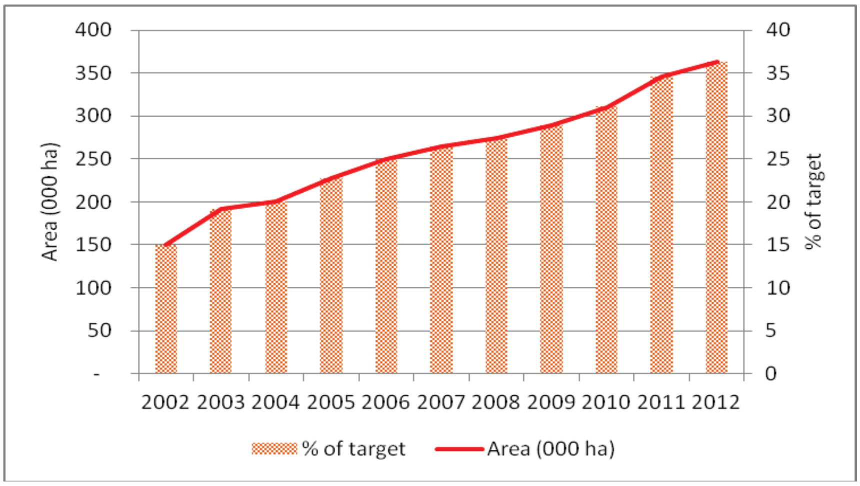

Figure 2.1: Trend of area developed for irrigation in Tanzania (MAFSC, 2012).

Most of traditional irrigation farming practices are carried out by small scale farmers around wetlands, river basins and many valleys by exploiting fertile soil and available moisture. For example in the Pangani basin, irrigated agriculture is mainly practised by smallholder farmers and they utilise most of the available water for crop production (Komakech et al. 2012; Sanga et al. 2003). Similar findings have been reported around the country such as traditional irrigation farming and poverty alleviation (Mkavidanda and Kaswamila, 2001; Majule and Mwalyosi, 2007); changes in the upland Irrigation system (Sokoni and Shechambo, 2005); climate change impact and small scale irrigation (Kangalawe et al. 2011; Liwenga et al. 2012). Mkivanda and Kaswamila, 2001 argues that valley bottom dry period farming practice (*vinyungu*) where farmers harvest water from rivers and or springs for agricultural production have potential ability to provide both food and cash crops at subsistence level using traditional irrigation techniques.

Although traditional irrigation farming practices play a major role in contributing increased food security, income of many poor families and various indirect benefits (employment and economic growth); the farming practice has also been affected by many challenges including the impact of climate change, lack of support - inputs and low yield in many parts of the country. Findings from the field show that under traditional irrigation systems, crop production is low where maize and paddy yields are averaged at 0.8–1.0 t/ha and 1.8–2.0 t/ha respectively (Liwenga et al. 2012; ASDP, 2013; Fischer et al. 2013). This is mostly attributed by poor efficiencies in water consumption which leading to water stress and crop failure. However, under improved irrigation farming schemes and good crop management, yields can rise to 5 t/ha to 8 t/ha (ASDP, 2013). For example, Working Group 2 of ASDP Task Force 1 found that farmers in Bahi and Chikuyu reported yield of paddy increases up to 4.5 t/ha, Ruvu Farm at 6.2 t/ha and Lower Moshi at 8 t/ha (this also depend on the variety used).

Furthermore, out of the total area under irrigation, 80% is under traditional irrigation schemes with low level of water use efficiencies and the remaining 20% is centrally managed irrigation schemes owned by public and private institutions and individuals (TARP II – SUA Project, 2004). Lankford (2004) describes that water use efficiency is very low since most of the traditional irrigation farming schemes managed by community use temporary diversion weirs with no canal intake gate. Water use efficiency estimates range from less than 15% to 0% (World Bank, 2007; IFAD, 2007; Ikeno, 2011; Kangalawe et al. 2012). These reports indicate that because of the large water losses in the intake and conveyance canals, water allocations for farmers at the tail end are often uncertain. Poor on-field water management due to inadequate infrastructure reduces yields and increase labour cost (time needed to irrigate crops).

Consequently, the area served under the traditional schemes and crop productivity can be substantially increased by improving infrastructure, water management and sustainable agricultural practices (World Bank, 2007; Keraita, 2011).

Although local farmers in Tanzania are currently facing several challenges by relying on local farming methods such rain fed agriculture and traditional irrigation; the dry land irrigation farming schemes have proved fruitfully results in many areas of the country. For example, where there is availability of water sources (Iringa-Ruaha River Basin and Coast-Rufiji River Basin); dry land irrigation farming schemes have been documented to increase productivity and income during dry season since the crops (especially vegetables) fetch higher price during this time of the year (Mkavidanda and Kaswamila, 2001; Majule and Mwalyosi, 2003; Sokoni and Shechambo, 2005). As a result, various *policies* (National Water Policy, 2002; National Irrigation Policy, 2009); *programmes* (Kilimo Kwanza, District Irrigation Support Project, Agricultural Sector Development Programme) and *strategies* (NIMP, 2002; NSGRP, 2005) support the substantive contribution of traditional irrigation farming so as to increase agricultural productivity and income earning while ensuring food security for its growing population. According to ASDP (2013); in the past 15 years, various efforts have been made by the GoT through responsible ministries to expand community-based irrigation development, particularly small-scale irrigation around dry land areas (dry land irrigation farming schemes).

2.2.3 Dry Land Irrigation Farming Schemes Along the Ruvuma River Basin and Southern Coast Waters.

The primary reason for irrigation is to improve agricultural productivity in areas where surface soils are naturally drier (Fischer et al, 2013). Studies show that most of the semi-arid regions in Tanzania often have higher agricultural productivity if irrigated (Banzi et al. 1992; Kaswamila and Masuruli, 2004; Mary and Majule, 2009; Ikeno, 2011; Liwenga et al. 2012; Fischer et al. 2013). Irrigation farming practice is carried out around these dry land areas during dry season by exploiting water around rivers, shallow aquifers and wetlands. The term dry land irrigation farming schemes is the farming practice in which farmers harness water from rivers, wetlands, ponds or rainfall (rainwater harvest) to produce both food and cash crops at subsistence level using local irrigation techniques (Mkavidanda and Kaswamila, 2001). Pachpute et al. (2009) point out that the uncertainty of rainfall and high evapotranspiration around dry land areas makes crop production almost impossible unless the soil moisture deficit in the root zone is met through supplemental measures such as irrigation via various rainwater harvesting systems.

According to Matekere and Lema (2012) cited in ASDP (2013); the irrigation development in Tanzania divides the country into seven irrigation zones. The seven zones (though not well-aligned with the agro-ecological zones) include East, North, South, West, Southern highlands, Lake Zone, Dodoma zone. Some of these zones have drier or sub-humid climate while others have humid or wet climate with fertile soil and cool temperatures suitable for a variety of crop production. The study area falls under the Southern Zone (Mtwara Zone) which includes Ruvuma, Lindi and Mtwara Regions. Most of the Eastern part of Ruvuma River Basin and Southern Coast waters falls under sub-humid arid zone which have abundant untapped water resources and often have higher agricultural productivity due to fertile soil around river banks and valleys brought by erosion and sediments from upland.

The National Irrigation Master Plan (2002) and Tanzania District Irrigation and Water Harvesting Support Project (2003b) reports show that many of the productive dry land areas in Tanzania have untapped fresh water resources such as rivers, streams, wetland and aquifers that can be used for developing various irrigation farming schemes. Using various fresh water resources for irrigation development is a key strategy to diversify agricultural production and enhance productivity, increase family income and food security as well as stimulating economic growth in many rural areas. Ruvuma Basin and Coastal waters have potential areas suitable for irrigation development both traditional and improved traditional irrigation schemes, small scale and large scale irrigation farming schemes. The National Irrigation Master Plan (2002) and cited in Agricultural Sector Development Programme (2013) indicates that a survey of irrigation potential conducted around Ruvuma River Basin and Southern Coast waters as part of the integrated development plan shows that Mtwara and Lindi Regions have potential suitable area (about 78,000 ha) for irrigation development (table 2.7 below).

Table 2.7: Irrigable and Irrigated area around the study area

Zone	Region	Irrigable Area	Developed	Traditional	Total	No. of Traditional Schemes	Irrigated areas as % of Irrigable area
		Irrigated area ('000)					
Mtwara	Ruvuma	38	5	6	10	162	26
	Lindi	29	3	3	5	28	17
	Mtwara	49	2	2	5	18	10
Zonal Total		**116**	**10**	**11**	**20**	**108**	**17**

Source: Irrigation database, MAFSC, 2012

The Southern Zonal Irrigation Office and Naliendele Agricultural Research Institutes have identified some of the areas potential for medium and small scale irrigation development projects which includes Kitere and Mahurunga valleys in Mtwara Rural District and Kinyope and Milola valleys in Lindi Rural District. For example, Mtwara region, the area of annual crops under irrigation is 2,717 ha representing 0.6% of the total area utilized (URT-vi, 2012) whereas Lindi is estimated to have more than 24,000 ha that are potential for irrigation, of these only 3,661 ha or 17% is under irrigation (URT-vh, 2012). According to URT-vi (2012); the planted area with irrigation in Mtwara region appears to have increased in a 12 year period from 1,901 ha in 1995 to 2,717 ha in 2007 representing a 42% increase. In Lindi region, the use of irrigation for agricultural activities in the region is negligible where the area planted under irrigation is 2,523 ha equivalent to 0.84% of the total planted area in the region (URT-hi, 2012). The leading district with area planted under irrigations are Nachingwea district (66.4%) followed by Ruangwa district (21.7%).

The main source of water for irrigation around Ruvuma Basin are rivers (*e.g.* Ruvuma, Mnazi moja, Mpapura, Lukuledi and Mkwaya rivers) followed by artificial or natural ponds (Kitere, Mbuo village) and wetlands as well as boreholes from shallow aquifer (Chimbile A and Chiheko village). Reports from national agricultural census (URT-vi, 2012 and URT-hi, 2012) indicates that in both villages studied; earth canals, handy bucket and watering can are the most common method of getting water for irrigation with 76% of households practicing irrigation. Furthermore, the report shows that places with gentle slope, households use gravity water (earth canals, flooded basin) which account for 10% of households while households with diverse income and resources use hand-pump (9%) and motor-pump (5%). Report from ASDP (2013) shows that Mtwara and Lindi contribute only 4% of the total irrigated area but each account for about 10% of the rural agricultural households. Lindi had the largest irrigated area per agricultural rural households while Mtwara had the smallest areas (the average irrigated area is about 0.03 ha per agricultural rural household).

Other existing smaller river basins, wetlands and valleys around the two regions potential for irrigation development includes Mpapura river, Lipwedi valley, Mkwaya river, Mnazi moja valley, and valleys of Chimbile, Mwiti, Mbwinji, Mkungu, Ndanda and Mkululu rivers. In most villages around the two regions, irrigation farming is carried out by smallholder farmers using hand hoe and buckets as well as local seeds. Major crops grown in Lindi and Mtwara regions are maize, rice, millet, sesame, cassava, cowpeas, coconut, and cashew nut (URT-vi, 2012; URT-hi, 2012). According to ASDP (2013); Ruvuma River Basin is a potential area for agriculture for rice, maize, sugarcane, wheat, millet, beans, tomatoes, onions, okra, green pea, pumpkins, pineapple, watermelon, groundnuts and potatoes. Despite this potential, there is a lack of serious private sector investors in irrigated agriculture something that calls for a deeper understanding of how vulnerable and resilience irrigation farming scheme are against climate change.

As the dry land irrigation farming schemes seen as a potential measures of supplemental moisture/water supply for crop production (Majule and Mwalyosi, 2003; Hanjra and Qureshi, 2010); so does the farming schemes been faced with problem of water scarcity and variability in rainfall due to climate change impacts (Ikeno, 2011; Turral et al. 2011; Mutui et al. 2012). The problem is even worse for areas located in arid and semi-arid regions with local farmers depending on local and traditional methods of irrigating their crops (food and cash crops). For example, in many rural areas in Tanzania (Mkavidanda and Kaswamila, 2001; Majule and Mwalyosi, 2003; Sokoni and Shechambo, 2005; Ikeno, 2011; Liwenga et al. 2012; ASDP, 2013); rarely do local farmers afford to produce food and cash crops under mechanised irrigation farming systems. Most of them depends on rainfed agriculture during wet season while during the dry season supplement their food and income by practising dry land irrigation farming which rely on poor technology and seasonal rivers or wetlands as sources of water for their agricultural activities.

Most of the dry land irrigation farming schemes (traditional irrigation schemes in Pangani, Rufiji, Ruaha basins) in Tanzania that have been documented to operate for many decades yield positive results in terms of productivity (ASDP, 2013). However; research findings show that the environments under which they operate are gradually changing and adjusting according to socio-economic and ecological changes such as climate change (Mkavidanda and Kaswamila, 2001; Majule and Mwalyosi, 2003; Sokoni and Shechambo, 2005; Liwenga et al. 2012). As dry land irrigation farming schemes in Tanzania remain the key to food production (food security) and socio-economic development, the main key question remains how vulnerable and resilient the dry land irrigation farming schemes are to climate change and its variability? The research findings described in chapter 5 show that the dry land irrigation farming schemes are affected by climate change at different level and scales while farmers are adjusting and coping with climate change. The research findings suggest that intensification of dry land irrigation farming schemes needs a careful understanding of basin ecology (hydrology) and soil management so as to enhance sustainability without affecting the environmental flow of water especially for downstream users.

2.3 Impact of Climate Change on Irrigation Farming

Climate refers to the characteristic conditions (such as temperature, precipitation, wind or atmospheric air) of the earth's lower surface atmosphere at a specific location over long period of time (FAO, 2008; IPCC, 2001; IPCC, 2014). The changes in these essential climatic variables over a period span of 30 years is termed as climatic change (FAO, 2008) whereas climate variability refers only to the year-to-year variations of atmospheric conditions around a mean state (IPCC, 2014). The IPCC 4th Assessment report described climate change as a change in the state of the climate that can be identified (*e.g.,* by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC, 2014). The report explains further that climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. However, climate change is accelerated by anthropogenic activities taking place at a high rate causing impact on earth's ecological systems while rendering the species (including socio-ecological systems) vulnerable to adapt to that change.

In their Article 1, the Framework Convention on Climate Change (UNFCCC), defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between climate change attributable to human activities (socio-economic activities) altering the atmospheric composition, and climate variability attributable to natural causes such as biophysical processes (IPCC, 2001; IPCC, 2014). The climate change attributes both biophysical processes (such as droughts, floods) and socio-economic activities (such as burning fossil fuel, deforestation) cause various impacts to the earth's ecosystems at different regions or location on the earth's planet. However, various studies indicate that an increase in human activities accelerates climate change and sometimes exposes poor communities who lack resources and knowledge to the risk of climate change impacts (URT, 2007; Mary and Majule, 2009; Shemsanga et al. 2010; Yanda and Mubaya, 2011; IPCC, 2014; Kihupi et al. 2015). Apart from underlying drivers of socio-economic changes (such as population and economic growth); there is likely to be considerable resource pressures on water in future years (Watkiss et al. 2011). Thus climate change (for example changes in precipitation, pattern, variability, runoffs, salt water intrusion) has the potential to exacerbate any water deficit affecting the whole water cycle and water ecosystems.

The impacts of climate change (as results can be observed on various natural and human systems. For example, increased amount of rainfall can cause heavy floods and cause severe soil erosion while an increase in extreme temperature can result into droughts or crop wilting. For irrigation farmers, heavy floods can cause the fertile soil on river banks to be inundated and water logged (hence unusable for vegetable production) while extreme temperature cause excessive evaporation (reducing the available water) and consequently crop wilting. This in turn affects the ability of poor farmers who are exposed and lack social safety nets, to respond and cope with the ongoing changes. According to IPCC (2014); the impacts of climate change is generally due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes of climate change attributes. In this research, the impacts of climate change are used primarily to refer to the effects it pose on irrigation farming schemes and livelihoods among the farming communities around Ruvuma Basin in South Eastern Tanzania as well as the consequences and outcomes thereof.

In Tanzania like any other LDC, climate change impacts have also been observed in various socio-ecological systems as well as climatic variables. For example changes in increased mean annual temperature (1 ^{0}C) have been recorded since 1960 and rainfall decreased at an average rate of 2.8 mm per month and 3.3% per decade (Yanda and Mubaya, 2011; IPCC, 2014). More increased temperature and decrease in amount of rainfall has occurred in southern part of Tanzania since 1980's (Shemsanga et al. 2010). According to Fischer et al. (2013) and Cioffi et al. (2014); predicted extreme events (in different parts of Tanzania) such as frequent dry spell, drought, floods, tropical storms and cyclones are expected to become more frequent, intense and unpredictable in the future. In recent years, Tanzania has witnessed a number of climate related disasters namely; flooding and droughts (Shemsanga et al. 2010), widespread crop failures and livestock deaths (Msaky et al. 2010; Kangalawe et al. 2011; Mbilinyi et al. 2013) and intensification of climate sensitive diseases among others (Mahoo, 2009; Mary and Majule, 2009; Shemsanga et al. 2010; EAC, 2014).

The agricultural production and food security in many regions of Tanzania (particularly rural arid and semi-arid areas) will likely be severely compromised by climate change and climate variability (Shemsanga et al. 2010; Kihupi et al. 2015). Various country reports suggest that the existing yields for different crops such as maize, coconuts, banana, millets, sorghum and cassava have declined during the past two decades with rice increasing only slightly (URT, 2010; FAO, 2012; ASDP, 2013). The declining yields possibly reflect the impacts of climate change (decrease in rainfall amount, increase in temperature and dry spells) which affect crop moisture and temperature requirement and thereby impair plant's growth. Other factors that may account to the existing low yields includes expansion into marginal lands with lower soil fertility, post-harvest losses, diseases and poor farming practices.

As described above, the impact of climate change is two-fold, biophysical (such as floods, droughts) and socio-economic (such as burning fossil fuel, deforestation, and agricultural production) whereby there is close linkage between biophysical and socio-economic impacts of climate change (Mubaya et al. 2010). In this case the environmental degradation caused by biophysical impacts creates socio-economic impacts where the changes in the former creates interwoven effects which affects the later and thereby causing a sustained impacts which creates a vicious cycle of poverty among poor households that have no knowledge and resources to adapt. This is mainly true for example on agricultural sector where areas suitable for agriculture; the length of growing seasons is altered by biophysical attributes of climate change (Mubaya et al. 2010) and thereby causing a decrease in yield potential (of a certain crop), particularly along the margins of arid and semi-arid areas and eventually affects the income and livelihoods of the farmers (Mbilinyi et al. 2013).

According to Fischer et al. (2013); most of the dry land areas in Tanzania, although receive moderate rainfall; are affected by high evaporation compared to amount of rainfall received and land use changes (shifting cultivation, slash and burn, deforestation) can increase the rate of surface runoffs and thereby reducing moisture availability. The low amount of rainfall and high evaporation rates in dry land areas coupled with land degradation (such as overgrazing, forest fire and deforestation) and poor farming practices (shifting cultivation) have consequences on climate as well as water availability/requirement for the crop production due to reduction in soil moisture recharge. The inevitable description of the impacts of climate change is that it affects both rich and poor, however poor farmers are severely affected due to lack of knowledge and resources they need to respond and adapt to the existing and ongoing changes. For example, the consequence of the impact of climate change (biophysical or socio-economic attributes) affects small scale subsistence farmers particularly dry land irrigation farmers in terms of productivity, food security and family income as they merely depend on surface water for irrigation using local crude methods of farming.

Furthermore, Shemsanga et al. (2010) observed that among the cost of climate changes incurred by different sectors in Tanzania, agricultural and water sectors were more vulnerable to climate change compared to other sectors. Kangalawe et al. (2011) described the available freshwater across the Great Ruaha River Basin is questionable under the ongoing climate change impacts where irrigation and live-stock production were affected more compared to other production units. This is due to differences in observed changes in rainfall amount and pattern across the country associated with changes in climate. According to Cioffi et al. (2014); rainfall has decreased considerably during the last 10 – 30 years, and characterised by high inter-annual variability, seasonal shifts and variable seasonal distribution with unpredictable onset and ending of rains and shortened growing seasons. The changes in rainfall variability (pattern and amount) have profound impacts on irrigation farming practices in terms of water needed for crop production as most of the farmers around Ruvuma Basin uses surface water for irrigating crops.

Similar changes across a small scale was observed in Makanya sub-catchment area, where Fischer et al. (2013) discern a great variation in dry spell across a small areas which in turn affects agricultural productivity and yield for different crops within that particular area. The impacts of increased frequent dry spells and extreme temperature (as a results of climate change) has concealed implication particularly for irrigation farming practices as it causes water reduction and soil salinity (due to evaporation) and wilting of crops for many poor farmers who depend on surface water for irrigating crops. The effects of climate change in the country are widespread and significantly interfere with agricultural production, while at the same time, reducing the ability of the poor farmers, usually with limited resources to cope with climate change in many ways. The consequences of climate change in Tanzania have even taken a gender dimension in which women are seen to be more vulnerable on account of deep-rooted socio-economical, historical and cultural barriers across the country (Shemsanga et al. 2010; Kangalawe et al. 2011).

Climate change is expected to affect rains, increase the frequency of droughts, and raise average temperatures, threatening the availability of fresh water for agricultural production in Tanzania (URT, 2007). The changes have profound implications for managing freshwater resources and species dependent on the aforementioned resources (Mubaya et al. 2010; Kangalawe et al. 2011). The changes will worsen the water stress currently faced in arid and semi-arid areas of Tanzania. For example, the freshwater of Ruvuma River Basin and Southern Coast are vulnerable to changing climate, such as frequent drought and floods which negatively impacts the livelihoods of the people through decreased crop and livestock production, increased diseases and pests outbreak and impacts on local biodiversity (UNEP and WIOMSA, 2009).

The changing climate has had negative impacts particularly on water shortages for irrigation due to decreased amount of rainfall which reduce the reservoirs recharge. According to Fischer et al. (2013); irrigation farming is very much sensitive to weather and climate variables, including temperature, precipitation and weather extremes, such as droughts, floods and frequent dry spells. The continuous increase in temperature and occurrence of frequent dry spells lengthen the situation by reducing the water level in various reservoirs in the study area (figure 2.2).

Figure 2.2: Dry river bed in Mpapura and reduced water level at Mkwaya Village (Note the water level marks on the bridge supporting pillar-Source: Mhagama, 2014).

In few cases, the climate change impacts have brought positive impacts to the farmers especially on the lower course of the rivers through increasing sediments and siltation which brings about fertile soil along the riverbanks and flooded valleys. These flooded valleys and river banks provides fertile soil (nutrients) required by different plants during vegetable or crop production. Apart from impact of climate change on fresh water resources, the country's diverse climatic zones creates pressure on arid and semi-arid areas already experiencing low rainfall and water shortage. According to URT (2003) and URT (2007); Tanzania has four main climatic zones, namely; the tropical coastal area and immediate hinterland; the hot and dry central plateau; the semi-temperate highland areas and the high moist lake regions with little variations in rainfall and temperature throughout the year. In general, the climate in the tropical and coastal areas is hot and humid with varying temperature and rainfall amount and the north-western highlands are cool and temperate while the central part is cool and dry. Though Tanzania has different climatic zone and ecological zones; the impact of climate change also depends on the climatic zones of each area (URT, 2007; Shemsanga et al. 2010). This means farmers in different zones will experience the impact of climate change differently and will need different adaptation measures and strategies to cope with the changes in addition to the existing knowledge. According to Kangalawe et al. 2011; in addition to the different climatic zones, cultural norms and traditions of different local farmers also influence the response and adaptation strategies and their level of success. Hence, addressing the impact of climate change on irrigation farming, this research has covered three districts in an attempt to assess the vulnerability and resilience of dry land irrigation farming schemes against climate change across different farming communities.

Kotir, 2010; describes further that the impacts of climate change such as rising global average temperature and changes in precipitation are undeniably clear with impacts already affecting ecosystems, biodiversity and human systems throughout the world. Future impacts are projected to worsen as the temperature continues to rise and as precipitation pattern and amount becomes more unpredictable and unreliable. Among the many adverse impacts of climate change, the risk to agriculture is considered most significant (Shemsanga et al. 2010; Kangalawe et al. 2011; Liwenga et al. 2012) as majority of the world's population; especially those in the developing countries highly depend on agriculture for their livelihoods (World Bank, 2007). For example, in Tanzania, the changes in climate and climate variability poses worst impact through interfering food security to the country are growing population. According to the MAFSC, 2012; majority of the affected population in the country are 80% of the population living in rural areas whereas Shemsanga et al. 2010 noted that 19% of that population segment live below the food poverty line and 36% lives below the wider poverty line.

Generally, climate change is a concern which necessitates two types of responses-mitigation in terms of controlling greenhouse gas emissions and adaptation to reduce the vulnerability to climate change impacts (Shemsanga et al. 2010; Kangalawe et al. 2011). Tanzania like any other developing country is most vulnerable to impact of climate change as majority of its population is closely dependent on natural resources for livelihoods. Thus considering that climate change impacts are already being felt in most parts of the country particularly irrigating communities, understanding the vulnerability and resilience of irrigation farmers and their farming practices is of paramount important in order to effectively address proper interventions aimed at reducing negative impacts and risks associated with climate change.

2.4 Vulnerability of Dry Land Irrigation Farming Schemes to Climate Change.

According to IPCC (2014); climate change will affect rainfall, temperature and water availability for agriculture in vulnerable areas of SSA particularly arid and semi-arid areas in Eastern Africa. Tanzania is one of the countries in East Africa with arid and semi-arid area where irrigation farming is playing a potential role in livelihoods in terms of supplementing food security and household income particularly during dry season. Due to impacts described above, irrigation farming is vulnerable to the climate change as it's exposed to various stimuli (external and internal stressors). External stressors (or biophysical vulnerability) results from biophysical processes while internal stressors (or socio/existing vulnerability) results from socio-economic processes and lack of entitlements (Adger et al. 2006; Gbetibouo and Ringler, 2009; IPCC, 2014). According to IPCC (2001) and IPCC (2007); major climate stimuli such as temperature (drought, dry spell), precipitation (rainfall, flooding), salinization and tropical storms show different biophysical and socio-economic impacts on key agricultural crops such as rice, maize, millet, sorghum, and coffee. For example in rice production, erratic rainfall, flooding during ripening, salinization cause major biophysical impacts on rice in terms of germination, growth/flowering/fruit setting or ripening which influence potential yield (Devkota et al. 2015).

Therefore agricultural production particularly irrigation farming is very sensitive (degree to which a system is adversely affected) to climate stimuli as it's exposed (the nature and degree to which a system is revealed/unprotected to climate variations) to climate change impact (IPCC 2001; IPCC, 2007). For example, the agricultural sector's sensitivity to climate change is represented by the exposure to frequency of climate extremes such as temperature and rainfall variability and frequency of droughts, floods and dry spell which makes the farming practices such as irrigation vulnerable to climate change impacts (as the sector responds negatively *i.e.* crop failure or reduction in yield). For the purposes of this study; vulnerability is described by studying the effects extreme climatic events (*temperature and rainfall variability*) on a socio-ecological systems (*dry land irrigation farming schemes*) and its (in) ability of a systems or people (*dry land irrigation farmers*) to cope with the stress/disturbance (*stressors*) along the Ruvuma Basin in South Eastern Tanzania.

The *first aspects* of vulnerability of irrigation farming practices to climate change is its exposure and sensitivity to climate change and climate variability. According to URT, 2003 also cited in Shemsanga et al. 2010 and Yanda and Mubaya, 2011; the climate and weather in Tanzania varies from place to place in accordance with geographical location, altitude, relief and vegetation cover. As climate (weather elements) from the country varies throughout, it is also expected to change in the near future. For example, predictions from climate models (such as Global Climate Change Scenarios) show that the projected mean daily temperature will rise by 3 ^{0}C – 5 ^{0}C throughout the country and the mean annual temperature by 2 ^{0}C – 4 ^{0}C (URT, 2003; Watkiss et al. 2011; Yanda and Mubaya, 2011; URT, 2012). Extreme cases (such as high temperature and heavy rainfalls) have already been documented in various parts of the country. In 2005, Tumbi Meteorological Station in Tabora reported the highest temperatures of 35.2 ^{0}C since it started recording over 30 years ago (TMA, 2009), which indicates an increasing trend in temperature records. Temperature changes especially along the coastal area in terms of duration and intensity affects water/moisture availability and crop performance (for example extreme temperature cause wilting) and hence reduce yield potential making the farming vulnerable to climate change impacts.

Watkiss et al. (2011) and Cioffi et al. (2014); also reported a projected increase in rainfall in some parts of the country while other parts will experience decreased rainfall. Reports from Initial Communication Strategies, 2003 and other studies (such as Shemsanga et al. 2010; URT, 2007; Watkiss et al. 2011; URT, 2012) predicted further that areas with bimodal rainfall pattern will experience increased rainfall of

5% – 45% and those with unimodal rainfall pattern will experience decreased rainfall of 5% – 15% (figure 2.3 below).

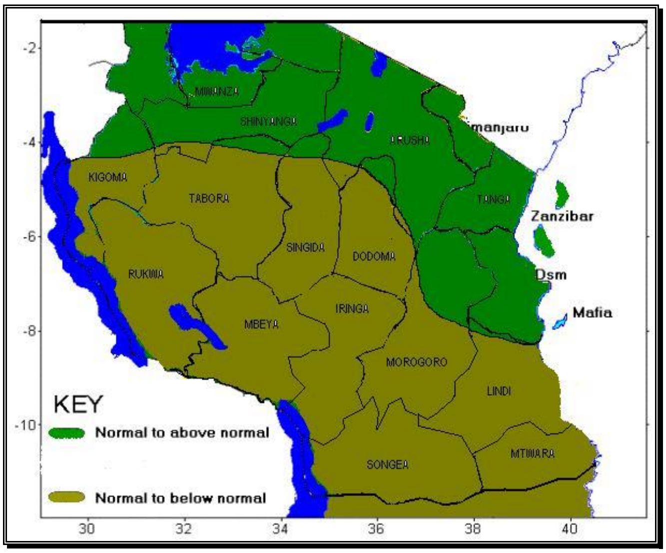

Figure 2.3: Rainfall distribution in Tanzania (Northern part-bimodal while Central and Southern part-unimodal pattern of rainfall). Source: TMA, 2012.

Mtwara and Lindi regions are areas that receive a unimodal type of rainfall, hence making farming very difficult as it relys on one rain season only. Any decrease in amount of rainfall affects the available water in reservours for irrigation farming during dry season. According to URT (2007) and MAFSC (2012); Tanzania's rainfall follows two regimes namely unimodal and bimodal patterns. The unimodal rainfall (including Central, South Western highlands, Southern region and Southern coast) have a single rainfall season between November and April (NA) and normally experienced less rainfall during the whole period while the bimodal rainfall (including Northern coast and Zanzibar, North Eastern highlands and Lake Victoria basin) have two rainy seasons with long rains between March and May (MAM) and short rains between October and December (OND) (URT, 2007; TMA, 2012; URT, 2012).

The projected changes in climate (*i.e.* temperature and rainfall) have consequences for agricultural production in Tanzania where majority of the farmers depends highly on rainfed agriculture while irrigating communities depends on surface water for crop production during dry season. For example, Watkiss et al. (2011) and URT (2012) estimated that with increase in temperature and reduced rainfall as well as change in rainfall patterns will cause the average yield of maize to decrease by 33% country wide. Furthermore, yield of the same crop will decrease by up to 84% in the central regions, 22% in North-eastern highlands, 17% in the Lake Victoria region, and 10 – 15% in the Southern highland making agricultural production one of the risk business in the future if there are no mitigation measures (URT, 2012). Quantifying this impact; Watkiss et al. (2011) cited in URT (2012) argued that climate change will trigger a 0.6 to 1% decline in GDP by 2030; and by 2085, the decline in GDP will range from 5 to 68% depending on the severity of climate impacts (URT, 2007; IIED, 2009; Watkiss et al. 2011).

The *second aspects* of vulnerability of irrigation farming practices to climate change is its exposure and sensitivity to occurrence of climate extreme events such as *frequent droughts, dry spells and floods*. Furthermore; it is estimated that that majority of people in Tanzania lives in areas prone to more than one type of the physical manifestations of climate change which include; floods, storms and droughts (FAO, 2006; Shemsanga et al. 2010; Watkiss et al. 2011; URT, 2012). For example, analysis by Hatibu et al. 2000 revealed that more than 33% of disasters in Tanzania over 100 years period were related to drought, which is a major pre-cursor of agro-hydrological problems in the semi-arid regions. Empirical analysis showed that Tanzania had recorded 37 occurrences of drought between 1872 and 1990 (URT, 1998). Such a situation has serious impact on food security and people's livelihood living in drought prone areas and marginal land such as dry land as their farming productions is affected by the frequency occurrence of droughts. According to Watkiss et al. (2011); the (La-Niña) event of 1996/97 was responsible for the severe drought that occurred in most parts of Tanzania leading to insufficient rainfall and water supplies resulting in widespread crop failure and rangelands could not support livestock resulting in large production shortfalls. Similar cases were reported during the drought occurring in 2005/2006 and affected most parts of the country, triggering food shortages, power crisis, and reducing economic growth to a halt (URT, 2012).

Most vulnerable people in Tanzania lives in arid and semi-arid areas (Boko et al. 2007; Yanda and Mubaya, 2011) such as Dodoma, Same, Shinyanga regions and coastal low land areas. These areas are frequently affected by frequent climatic hazards (droughts) and climatic problem (dry spells). Their dependency on the irregular input of precipitation cause a high shortage of water, commonly known as droughts and or dry spells. Droughts occur in virtually all climatic zones, such as high as well as low rainfall areas and are mostly related to the reduction in the amount of precipitation received over an extended period of time, such as a season or a year. Each discipline (meteorological, hydrological and agricultural) has its user-specific thresholds for declaring a drought (Bicanli et al. 2011; Mishra and Singh, 2010; Rockström et al. 2010). It's important for farmers to know each type of drought so they can address the problem effectively and manage their crop during drought condition.

For a drought condition not only the amount of water in terms of volume is relevant, but also its availability at the time it is mostly needed. Especially for rainfed agriculture and particularly irrigation farming, the knowledge of alteration of wet and dry periods and water fluxes during dry season is essential for crop production. For example, Tilya and Mhita, 2007 analysed the spatial and temporal frequency of wet and dry spells with 22 rain gauges spread over Tanzania. This study shows that the spatial structure of dry spells of Tanzania where long wet spells are located in the north-eastern highlands while long dry spells in the central part and coastal areas of the country (Tilya and Mhita, 2007). At the same time, Mul et al. (2009) shows that precipitation can be very localised and highly variable across a small geographical area which in turn affects the reliability of interpolating precipitation estimates from long but coarse spatial resolution rain gauge data. Many local farmers with limited knowledge on occurrence, intensity and duration of drought and dry spells suffer seriously as they fail to predict when to plant and which crop they plant to withstand such harsh condition.

For the *case of floods*, Watkiss et al. (2011) noted that Tanzania is subject to periodic extremes with serious floods or prolonged drought, associated primarily with El Niño – Southern Oscillation (ENSO) events. For example, the 1997/98 El Niño event, resulted in cereal deficit of almost 1 million tonnes in Tanzania, leading to a national food crisis (Watkiss et al. 2011). According to URT (2012); the livestock sector also underwent severe losses due to increased disease infection, drowning, damaged water facilities (dams, boreholes, water troughs), and disruptions in market infrastructure and road systems, though in some marginal agriculturally areas, the additional rainfall led to higher production. The country is also affected by climatic variability and extremes due to its tie to the movement of the Inter-tropical Convergence Zone (ITCZ) which often results in a double rain season that can be seen at a number of locations in Tanzania during rain seasons (Watkiss et al. 2011; URT, 2012; Cioffi et al. 2013). Similar reports by National Initial Communication Strategies (2003) and Tanzania Meteorological Agency (2012); indicates that the country has been frequently affected by frequent floods due to heavy rainfall particularly along the coastal area since 2012.

Studies by Mwandosya et al. (1998); Cioffi et al. (2013); predicted an increase in rainfall along the coastal areas; however, report from Tanzania Meteorological Station, 2012 indicates that rainfall patterns will become less reliable and less predictable as well as erratic including heavy down pour in a short period of time which cause havoc floods. The Citizen Newspaper of 3rd Feb, 2016 reported over 500 households in Mtwara Municipality were submerged in water following ongoing heavy rains in the region while scores of people have been rendered homeless and crops have been washed away by heavy floods in lowland areas. The Tanzania Meteorological Agency (2012) had issued several weather alert (early warning) warning the public of expected heavy rains across most of coastal areas including Mtwara and Lindi region for the year 2014/15 and 2015/16. The early warning systems predicted heavy rains, strong winds and sea storms which were expected to storm the coastal regions for three days consecutively during long rain, requesting people living in the region to take necessary precautions against the extreme weather events.

Though the regions (Mtwara and Lindi) is prone to recent frequent flash floods, the rainfall is erratic and sporadic affecting the farmers ability to reorganize the farming systems. Thus, with such changes, it is likely to result in delays in onsets as well as shortening of rainy seasons (which affects crop productivity) and thereby affecting the whole farming practices including potential harvests (both rainfed and dry land irrigation farming). According to Mwandosya et al. 1998; these changes would likely results in season shifting in which people organise their farming activities as well as increased incidence and severity of drought thereby making agricultural and irrigation farming more vulnerable to other sets of stimuli. Poor rainfall distribution coupled with drought periods, particularly inter-seasonal dry spells have amplified the problem of moisture stress (Tillya and Mhita, 2007) and put at risk between 20% and 30% of human population living in semi-arid areas (DFID, 2001) while making poor household vulnerable by exposing them to other external stressors. Any decrease in rainfall amount is a challenge as most of the agricultural systems in arid and semi-arid areas of Tanzania depends entirely on rainfed agriculture and irrigation systems are not well developed to cater crop production for the whole dry season period.

The loss of rain water through surface runoffs and lack of storage infrastructure such as artificial reservoirs is another factor exposing irrigation farming to risk of climate extreme *i.e.* lack of moisture for crops and exposure to high temperature. Few villages with limited capacities to adapt to recurring droughts, floods and dry spells have often abandon farming practices and resorted to other income generating activities such as charcoal making and quarrying so as to diversify their income sources (Mwandosya et al. 1998; URT, 2007).

According to Nyamadzawo et al. (2013); in addition to decreased rainfall, in semi-arid regions most of the rainfall received is lost as runoffs, and very little water is harvested for plant growth or future use due to lack of knowledge and support for constructing reservoirs or rainwater harvest schemes. In many cases, the surface runoffs affects agricultural production as most of the top fertile soil and nutrients are washed away reducing the available nutrients/fertile soil for crop requirement or crop production. EI-Swaify et al. (1982) describe that the high runoff rates and associated soil losses of nearly 137 Tm/ha/yr (98 m^3/ha) have been documented around Mpwapwa, indicating seriousness of soil erosion in central Tanzania. Similar studies of soil losses through erosion from surface runoffs as a result of >50% of received rainfall have been reported in Northern and Western Pare in Kilimanjaro region (Mul et al. 2009; Ikeno, 2011; Fischer et al. 2013). According to Mlingano ARI (2006) around two-thirds of the Mtwara district has less fertile soil that cannot sustainably support intensive agriculture (maize production) as a results of soil erosion. Naliendele Agricultural Research Institutes in Mtwara, reported similar findings for ecologically sensitive habitats that are prone to serious gully erosion including the escarpments on the edges of the Makonde (Mtwara region) and Rondo Plateaux (Lindi region). Most of the sloping lands with bare vegetation (due to deforestation and shifting cultivation) are vulnerable to soil erosion.

The loss of soils nutrient triggered by soil erosion (as a result of heavy rainfall) and continuous poor cropping without adequate restorative practices have negative impact as declining in soil fertility (nutrient loss) affects potential yield of various crops in the field. For example Savini et al. (2016) estimated that a loss of potassium and phosphorus of about 3–13 kg/ha results in low and declining soil fertility and consequently average maize production is <1.0 t/ha. Many smallholder farmers in the Tanzania find it increasingly difficult to afford commercial fertilizers because of high purchasing cost. High levels of surface runoffs losses in smallholder farming areas do not only limit water availability, but also cause an erosion hazard and nutrient losses which in turn makes agricultural farming more vulnerable. However, erosion from the uplands creates fertile soil for irrigation farming along the river banks and in most valleys in lower course of the river.

Another aspect of vulnerability of irrigation farming schemes to climate change is poor infrastructure development for irrigation farming. In the Ruvuma basin irrigated agriculture is mainly practised by smallholder farmers utilising most of the available surface water but with very low efficiencies (due to crude methods of water extractions) leading to water stress. Field observation results show that most of the irrigation farmers use earth canals, flooded basin, handy bucket and watering can as a common method of getting water for irrigation from various water sources. Keraita (2011) reported that due to poor infrastructure, the water use efficiency (WUE) of the traditional irrigation schemes ranges from 15% to 30%, which creates conflicts among farmers around water scarce regions in Tanzania. The low WUE underscores the need to invest in improving the traditional irrigation schemes (Keraita, 2011). Some of the lowland irrigation production (such as rice) uses largely traditional irrigation called bunded basin flood irrigation (majaluba). One major problem involves the location of the interceptor jaluba (basin) and canals (Mary and Mwalyozi, 2003; Maketere, 2012). Some of these (interceptors) are not located along the contour, leading to their collapse and loss of harvested rain water. Most of the canals that intercept and convey runoff water into the rice fields have no control structures as well as no drainage structures for disposing excess water from the fields. Field observation in Mpapura, Mkwaya and Mnazi moja villages noted similar structure for farmers using *mfereji* (canal) irrigations. The *majaluba* (basin) rain water harvesting structures lose a lot of water and do not efficiently capture water from runoff, due to poor construction

(Mary and Majule, 2009). Despite their low WUE, the banded basin flood irrigation accounts for 74% of rice production in Tanzania (ASDP, 2013).

Apart from external vulnerability due to exposure to biophysical processes (such as droughts, floods), irrigation farming schemes are also vulnerable to internal stressors or exposure to existing socio-economic processes. In sub-Saharan Africa, although rainfed agriculture is responsible for 90% of the food production and 80% of the population rely on it for a living (Rockström et al. 2010); it has a high risk of crop failure with water as a main limiting factor. Irrigation farming is even becoming more vulnerability because of high dependence on surface water for irrigating crops where the surface water is highly susceptible to evaporation and eutrophication as well as competition from other human activities such as construction, livestock and industrial or household consumption (socio-economic processes). Unsustainable socio-economic activities (poor land uses) such as shifting cultivation, deforestation and overgrazing exacerbate the effects of climate change on various ecological systems and expose other means of livelihoods (such as irrigation farming) to the risk of climate change impacts while rendering poor farming communities unable to respond, adapt and cope with ongoing changes.

The high levels of vulnerability in the developing worlds are linked to a range of factors including a high reliance on natural resources (Adger et al. 2007) which are already impacted by climate change and in turn it constrains community's adaptive options. Adger et al. 2007 explain further that whatever the effects of climate change will be (sea level rise, increased floods, drought, disease), the most vulnerable groups will be the poor people (depending solely on natural resources) whose ability to withstand environmental shocks and stresses to their livelihoods are low (Adger et al. 2007; Boko et al. 2007; Yanda and Mubaya, 2011). In developing countries like Tanzania, major pressing issues like food security, poverty, and water availability are all interconnected with climate change. However, the level of vulnerability effects (exposure to climate stimuli) affects different groups of the societies (such as individual farmers) differently within the same range of geographical location. The research study site is found along the areas that receive unimodal type of rainfall, an area that is expected to experience a decrease in rainfall in the future. Apart from the fact that Ruvuma basin receives unimodal type of rainfall, it's also found along the high temperature variable zone (coastal area); thus makes the irrigation farming even more vulnerable to climate change impacts (such as dry spells) particularly for farmers who do not have enough resources (such as manual pump; information-crops that withstand drought or moisture availability). According to Watkiss et al. 2011 cited in National Climate Change Strategies, 2012; concluded that all socio-economic changes will aggravate the situation leading to increased vulnerability of the communities (farmers) to the impacts of climate change and also affecting the various sectors of economy particularly irrigation and water sectors.

The existing socio-economic vulnerabilities and variation in climate change described above makes agricultural farming practices (particularly irrigation farming) very vulnerable as the farming practices depends solely on one type of natural resources (surface rain water) to irrigate their crops. Various country reports (Initial Communication Strategies, 2003; National Adaptation Programme of Action, 2007 and National Climate Change Strategies, 2012) indicate that Tanzania is among the SSA country's most vulnerable to climate change impact and climate variability. According to Tanzania National Climate Change Strategies and National Adaptation Programme of Action; agriculture has been identified to be the second most vulnerable sector to the impacts of climate change (URT, 2003; URT, 2007; URT, 2012) particularly irrigation farming (ASDP, 2013). For example, majority of farmers depends on rainfed agriculture and 80% of irrigation farmers practice traditional irrigation farming while the remaining 20% are semi-mechanized irrigation depending on both surface and ground water for irrigating their crops.

NEPAD (2005) describe further that although the country is divided into nine different major river basins and annual renewable water resources are currently estimated to be 2,700 m^3 each year; more than half of the country receives less than 800 mm in an average year (compared to wetter region 1500 mm) due to seasonal and unreliable rainfall as a result of climate change (URT, 2007; Watkiss et al. 2011; URT, 2012). The estimated annual recharge, which is affected by climate variability coupled with socio-economic pressures (poor land use and degradation), limits the soil storage capacity or underground recharge resulting in some aquifers subsiding or drying up due to high utilisation rates and slower rates of recharge. This scarcity creates negative impacts on irrigation farming that depends on surface water and shallow water table for irrigating crops. For example, MAFSC (2012) cited in ICID (2012); indicated that although total water withdrawal in mainland Tanzania was estimated for the year 2002 to be 5,142 million m^3; agriculture consumed the largest share with 4,624 million m^3 (almost 90% of total) of which 4,417 million m^3 was for irrigation and 207 million m^3 for livestock, while the domestic sector uses 493 million m^3 creating high dependence of irrigation farming from rainfall (surface water).

The last socio-aspect of vulnerability in irrigation farming is lack of agricultural extension services, entitlements and agricultural inputs and poor land use which both render irrigation farming vulnerable as they reduce the capacity of the farmers to adapt and cope with the existing climate change impacts. ASDP (2013) observed that Mkindo rice farmers (Mvomero district, Morogoro region) who attended farmer's agricultural training and frequently receiving agricultural extension services in rice cultivation achieved 20% - 200% higher yields than the other farmers in the same irrigation scheme. Local farmers with no relevant information on climate change are exposed to various effects of climate change such as moisture availability, intensity and duration of sunshine during dry season which can affect planted crops negatively. Such lack of advisory agricultural services is serious particularly in dry irrigation farming where water fluxes, temperature variability and pest control are issues of concerns for maximizing crop productivity and yield. Similar situation exists along the Ruvuma river basin where local farmers have been practising dry land irrigation farming.

In terms of lack of entitlements, climate change and variability has increased the burden on food security and income among poor farming families. Lack of food security and income means farmers has to diversify the available income needed for purchasing agricultural inputs and use it for buying food. According to the national survey on trends in the food security in mainland Tanzania; although food insecurity was forecasted mainly in the northern part of the country, other areas that received inadequate and sporadic rains, their households reported food shortage and chronic income limitations (URT, 2010). For example, in spite of the fact that Mtwara and Lindi region receives an overall average of about 1000mm of rainfall per year (TMA, 2012); but rainfall patterns are very erratic with considerable annual variation and slightly lower rainfall in inland than on the coast areas (URT-vh, 2012; URT-vi, 2012). This variation is normally coupled with dry spells of one to two weeks which often occurs at the end of January or at the beginning of February. This is reflected in a decrease in the 20% probability of exceedance on the plateaux and the coastal plain, and in the 80% probability of exceedance in the central plains (TMA, 2012).

Both inadequate and sporadic rains, coupled with dry spells affects food security (availability) and income that is generated via irrigation farming (selling vegetables). In Newala district (Mtwara region) and Lindi rural district (Lindi region); the erratic and below normal rainfall intensities caused significant reductions in food crop production, consequently reducing farmers' ability to retain part of their harvest (URT-vh, 2012; URT-vi, 2012). FAO (2006) noted food insecurity period was foreseen to be November 2004 through February 2005, if *vuli* rains (which fall in the bimodal rainfall areas from October to January) happened to be good otherwise, a longer food insecurity period would be expected. Furthermore, the limited cash earning opportunities and price hike creates obstacles for farmers from accessing agricultural inputs such as improved seeds, fertilizer and farm equipment's.

In a summary, irrigation farming is vulnerable to both external stressors resulting from biophysical processes such as floods and droughts as well as internal stressors resulting from socio-vulnerability such as poor land use, overdependence on natural resources (rain water), lack of resources and information. All factors described above make irrigation farming very vulnerable to climate change impacts and resulted in food crop shortages (food insecurity) due to insufficient rainfall which causes poor yields. Tanzania like any other SSA countries is vulnerable to the effects of climate change because of the over dependence of rain-fed agriculture, recurrent droughts, frequent dry spells, inadequate land distribution and policies, and widespread poverty (Watkiss et al. 2011). Recurrent droughts and frequent dry spells have often resulted in severe crop damage, decreased livestock production and widespread food shortages whereas heavy floods have continued to cause havoc, damaging irrigation infrastructure and crops while cause severe impacts to the agro-based economies particularly irrigation farming communities. Farmers with limited capacities to adapt to climate change impacts (recurring droughts, floods and dry spells) have often abandoned farming practices and resorted to other income generating activities such as charcoal making and quarrying so as to diversify their income sources.

In addition, as crop yields decline with increasing changing climate, pressure to cultivate unsuitable (marginal) land will rise. This is a major challenge, as productivity from land and water in many tropical regions will decline due to land degradation. However, the farming schemes have been frequently faced with problem of climate change and climate variability which draws attention to many stakeholders to solve the problem. Kangalawe et al. (2011) argues that vulnerability to negative impacts of climate change is influenced by the inadequate adaptive capacities of the communities to respond and cope with the ongoing changes. Thus, assessment of vulnerability need to focus more on adaptive capacity and resilience amongst communities and/or related institutions, while considering the nature of available freshwater resources in each geographical area. Irrigation farming schemes differ in their relative vulnerability to climate change impacts. For example, large and medium scale irrigation will respond less rapidly than smaller traditional irrigation schemes exposed to the same extent, type, and rate of climate change. Similarly, individual farmers will respond and adapt to the ongoing changes differently, thus requires a better understanding of adaptive capacity and resilience mechanisms at households and farm levels.

2.5 Resilience of Dry Land Irrigation Farming Schemes to Climate Change.

The concept of resilience was first defined by Holling (1973) as a measure of how far the system could be disturbed without shifting to a different regime. Other scholars such as Gunderson and Holling (2001) define resilience as the capacity of a system to undergo disturbance and maintain its functions and controls. Walker et al. (2004) added that while the system (such as socio-ecological systems) is disturbed, it has to reorganize and undergo change so as to still retain essentially the same function, structure, identity, and feedbacks. Similar definition were provided by Stockholm Resilience Centre (2007); where they describe resilience as the capacity of a social-ecological system both to withstand perturbations from, for instance, climate or economic shocks and to rebuild and renew itself afterwards (Stockholm Resilience Centre, 2007). The IPCC (2007) provided comprehensive definition on the same framework as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.

The 5th Assessment Report added that the socio-ecological systems has to adapt (process of adjustment to actual or expected climate and its effects) and transformation itself (change in the fundamental attributes of natural and human systems). It explain that in some natural systems, human intervention may facilitate adjustment to expected climate and its effects so as to ensure the socio-ecological systems reflects the strength and add values towards promoting adaptation for sustainable development, including poverty reduction. This will ensure the resilient or capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance while responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

The impacts of climate change has resulted in increased vulnerability of irrigation farming for smallholder farmers in marginal areas of Tanzania where farmers have limited capacity to adapt to changing climate impacts (Mahoo, 2009; Mary and Majule, 2009; URT, 2012; Fischer et al. 2013; Kihupi et al. 2015). As irrigation farming schemes (dry land irrigations) increasingly being affected by climate change and become more vulnerable, so does the farming schemes and farmers respond and adapt to these changes. Several approaches have been used by the dry land irrigation farmers to respond, adapt and cope with these changes to provide the required outputs. Most of the literature suggests that different approaches have been used by different irrigation farmers to respond, adapt and cope with climate change impacts in vulnerable and affected areas by climate change impacts. For example, one approach that has been used to adapt to changing climate is in-field water harvesting for improved crop yields in the semi-arid regions of Makanya Sub-catchment area (Fischer et al. 2013). Different management techniques have been suggested to improve water productivity and produce “more crop per drop of rain” (Rockström et al. 2010). Water harvesting systems are among the technologies that have shown substantial productivity improvements in different arid and semi-arid regions in Tanzania (Hatibu et al. 2000; Tagseth, 2010; Fischer et al. 2013).

Similar technology (on farm rain water harvesting systems) has been used elsewhere in Tanzania where there is low rainfall to cater for moisture deficits required for crop production (Hatibu et al. 2000; Mary and Majule, 2009). A good example of climate change adaptation strategy is the more efficient use of available rain water, such as rainwater harvesting system to reduce drought vulnerability for communities living in the impacted arid and semi-arid areas of Tanzania (Kangalawe et al. 2011). With improved in-field water harvesting, harvested rainfall can possibly sustain crop production during the dry season and this will reduce crop failures and may ultimately lead to improved household food security. In areas where it has applied, water harvesting systems has proved to build resilience to climate variability and thereby result in sustainable agricultural intensification.

Nyamadzawo et al (2013) argues that in order to reduce the vulnerability to smallholder farmers in arid and semi-arid regions to climate change and climate variability, and to increase the resilience to climate change there is need to optimize in-field water harvesting techniques so as to maintain moisture require for crop production and improve crop yields. The efforts of improving soil moisture by harvesting rain water is driven by farmer's own innovations, simple and available water harvesting technologies from other regions, and future directions of water harvesting in arid and semi-arid marginal areas of Tanzania. For example, Shetto and Owenya (2007) reported on use of improved farming systems such as conservation tillage and mulching as a means of conserving soil moisture and improving crop productivity in areas affected by low rainfall. Kangalawe et al (2011) suggest that due to highly variable rainfall, long dry seasons, recurrent droughts and dry spells as well as floods, water management is often a key determinant for agricultural production and productivity in arid and semi-arid regions in Tanzania. Yields can be significantly enhanced by improved water management. Thus, in the global water crisis and scarcity due to increased climate change impacts and variability, water and soil moisture management in irrigated agriculture is not only to secure the water required for food production during dry season, but also to build resilience for coping with future water related risks and uncertainties.

Other scholars such as Carretta et al. (2015) observed the use of intercropping (different crops such as maize with beans and cowpeas on the same field) as a strategy used by local farmers in Engaruka, Tanzania to adapt to the changing weather and to improve soil moisture and fertility. The strategy for intercropping is to increase soil cover and harvest (more than single crop on the same field) while maintaining soil moisture especially in drought prone areas. Mmbaga and Friesen (2003) observed that moisture measurements taken at different maize stages indicated higher moisture retention in intercropped field (with maize/legume) compared to maize alone and bare land. The study suggest that intercropping in arid and semi-arid regions is a way to grow a staple crop and retain more moisture, especially during critical moisture requirements by crops while obtaining several benefits/yield from the additional crop per a small area of land. Having a variety of crops in one field means reduction in weed populations and soil moisture loss, however care should be taken during choice of crops so as to reduce competition for water and nutrients uptake. Furthermore, mixing different crops means increased development to crop pests and disease attacks in the future. Another coping strategy used by local farmers includes planting of drought tolerant crops/varieties like sweet potatoes, sunflower, cassava and planting early maturing varieties of sorghum, maize and beans. Majule et al. 2013 adds that the emergence of more crops tolerant to drought seem to be good options for farmers in the area affected by rainfall variability and drought.

In major river basin of Tanzania where there are different competing end users, water allocation has been reported as an important strategy to cope with water scarcity and deficit (Shemsanga et al. 2010; URT, 2012; ASDP, 2013). Kangalawe et al. (2011) observed that farming communities around Great Ruaha river basin have devised different coping strategies including practicing irrigation to provide supplementary water to crops, using drought tolerant crop varieties, rationing of irrigation water in farmlands, wetland cultivation, and diversification to non-agricultural activities. Tagseth (2010) observed that although water management has been a traditional practice for generation along the slopes of Mount Kilimanjaro, water allocation and rationing has been frequently used as a means to save water due to decreasing rainfall and increasing competition from farmers as a result of growing population. Due to increasing end users, water rights, water transfer and water allocation and rationing has been also practiced along Pangani river basin (Komakech et al. 2012). Similar findings were reported by farmers in arid and semi-arid areas of Northern and Western Pare in Kilimanjaro region where water allocation and rationing is a common practice to cater the impact of water shortage (Mul et al. 2009; Ikeno, 2011). The introduction of irrigation timetables for all members of the community to ensure every farmer gets water (in traditional canals) according to specified rounds was reported as an important attribute of farmers coping with water scarcity particularly in rice fields in Great Ruaha River Basin (Kangalawe et al. 2011; ASDP, 2013).

Many small scale irrigation farmers adopt different strategies to avoid, mitigate or minimize risk arising from climate change impacts particularly scarcity of water. For example, irrigation farmers have even resorted to the use of waste water as a measure to counteract the lack of moisture during dry season. A research study by Ngowi et al. (2015) observed that the use of low-quality irrigation water in Morogoro for vegetable production has several benefits. The study revealed that the perception of irrigation farmers on waste water includes several benefits such as the availability of water throughout the year, highest soil and crop nutrients in irrigation water, less costs of buying commercial fertilizers, vegetable production all year round, sustainable income generation from selling vegetables and also jobs creation in the community among farmers and vegetable sellers.

Other strategies adopted by irrigation farmers to cope with climate change includes engaging in various socio-economic activities to diversify their income sources. Kangalawe et al. (2011) reported that wetland cultivation and migration to other areas (in search of casual labour/jobs and water) such as Morogoro (Kilombero, Mbingu area), have become common among community members in the Mpolo catchment as a strategy to cope with ongoing decreasing water for irrigation around Great Ruaha River Basin. Kangalawe et al. (2011) adds that other local coping strategies reported in Tanzania include engagement in alternative enterprises that are not climate dependent such as raising and selling poultry-chickens as well as quarrying so as diversify income during harsh climatic condition. In study area, narration for individual farmers and key informants supported the argument of poultry farming as well as animal husbandry. Report from agricultural census survey indicates that most farmers in the affected villages (where there is decrease in rainfall) were also reported to sell livestock (including chickens), providing agricultural and casual labour in large scale farms, and selling charcoal and handcraft products (URT-vh, 2012; URT-vi, 2012) as a means of generating income needed for the family.

The availability of timely relevant information (from relevant authority) on climate change have been seen as a strategy to cope with impact of climate change during disaster, for example in the event of drought or floods (URT, 2007; Shemsanga et al. 2010; Watkiss et al. 2011). Farmers who receive relevant information (including local knowledge) prior to the onset of farming season have been reported to cope better with any adverse effects of climate change compared to farmers with little or no information (Kangalawe et al. 2011; Majule et al. 2013). Thus proper information (from agricultural extension services and meteorological agency) on planting date, crop variety, water fluxes, temperature variability and pest control are important for irrigation farmers to adapt and cope with the impacts of climate change. Majule et al. (2013); suggest that timely availability of relevant information on climate change had positively reduced vulnerabilities of the farmers to climate change impacts and resulted in increased crop yields and income generation.

The coping and adaptation strategies of the smallholder farmers depend, to a very large extent on their perception knowledge level and sources of information about climate change available to them (Kangalawe et al. 2011; Majule et al. 2013; Kihupi et al. 2015). However, perceptions are influenced not only by actual conditions and changes, but also by other factors such as socioeconomic, environmental and institutional factors as well as the economic structure. Weber, 2010 believes that most farmers' knowledge and exposure to climate change have been influenced indirectly by the media reporting various events on climate change occurring elsewhere. Deressa et al. (2008) concluded that farmers' education, access to extension and credits, climate information, social capital and agro-ecological settings have great influence in farmers' choice of adaptation methods to climate change while financial constraints and lack of information about adaptation methods hinders the farmers' uptake of other adaptation methods. According to Majule *et al.* 2013 most farmers are aware of the adaptive strategies to put in place in their fields, however they are limited in implementing them because of lack of information for example about the on-set of the rain season (Mubaya et al. 2010), lack of information about appropriate seeds to plant and types of new crops to grow (Kangalawe et al. 2011) and also on how to appropriately manage soils and water under dry conditions.

For the irrigation farming schemes to adapt and cope with climate change impacts; the choice of adaptation methods depends on a range of variables which are considered important for the availability, accessibility and affordability of particular adaptation methods. The key lesson from the above descriptions is that integrated adaptive management to climate change interventions may help build a more resilience irrigation farming schemes and reduce vulnerability of irrigation farming to climate change impacts while improving yields and income of poor farmers. URT, 2012 suggest that in order to forge adaptive capacity in agriculture through irrigation, the government and other key stakeholders should continuously strive to increase the investment in irrigation development over the National irrigation Master Plan target of 5.4% to reach at least 15% area growth rate per annum.

2.6 Research Gap

Generally, based on the literature study, there are scant data available about irrigation farming schemes and food security as well as climate change impacts but these data do not complement each other (Mkavidanda and Kaswamila, 2001; Majule and Mwalyosi, 2003; Sokoni and Shechambo, 2005; Deressa et al. 2008; Fische et al. 2013; Sanga et al. 2013; Ngowo et al. 2015). Most research has tended to be generalised or limited in terms of geographical coverage and culture (Mkavidanda and Kaswamila, 2001; Majule and Mwalyosi, 2003; Sokoni and Shechambo, 2005; Mary and Majule, 2009; Tagseth, 2010; Carretta et al. 2015). Some studies focus on particular scope or field with limited knowledge or interrelationships on vulnerability and resilience of irrigation farming to climate change. Few researches provide solution (technological innovation and intervention) (Kangalawe et al. 2011; Kihupi et al. 2015), however without a deeper understanding of how vulnerable and resilient the dry land irrigation farming schemes is to climate change; any intervention or technology innovation would be too difficult for local farmers to adapt or too costly for farmers to purchase. As a result this will contribute to poor productivity; thus calling for an in-depth understanding of the issue at local level since best practices (lessons) such as dry land irrigation farming schemes can be easily transferred across a small scales of agricultural production in many rural areas which have similar geographical, socio-economic and cultural conditions.

Various information that have been collected from study and analysed; have provided some of the missing in-depth knowledge and understanding on how dry land irrigation farming schemes is vulnerable to climate change impacts. The information also share a light on few how other factors interplay and render the dry land irrigation farming schemes more vulnerability to climate change. Responses from local farmers and field observation have also indicated the ability (resilience) of the farming practices to cope with the already ongoing climate change impacts.

The climate change impact is a global phenomenon while adaptation is largely site-specific (IPCC, 2007; IPCC, 2014). A common disadvantage for most local adaptation and coping strategies is that they are often not documented, but rather handed down through oral history and local expertise. With increasing levels of adverse effects of climate change such as drought and floods (Shemsanga et al. 2010; Yanda and Mubaya, 2011; IPCC, 2012), dry land irrigation farming schemes will likely be facing with a new bigger problem of vulnerability and resilience against climate change impacts. Worldwide, there is an increasing literature on vulnerability and resilience to climate change (Mary and Majule, 2009; Ekblom, 2012; PROLINNOVA, 2012; Tropentag, 2012; Sanga et al. 2013; Kihupi et al. 2015). However, the lessons on vulnerability and resilience from one country do not necessarily apply to other countries with similar biophysical systems (Adger et al. 2007; Boko et al. 2007; Ekblom, 2012; Gitz and Meybeck, 2012). However, as described above best practices (best lessons at local level) such as dry land irrigation farming schemes can be easily transferred across small scales of agricultural production due to many factors such as similar geographical condition, socio-economic and cultural factors. To address these challenges at regional and local level, a careful understanding of how vulnerable and resilient dry land irrigation farming schemes is to climate change is of paramount importance so as to enhance food security, reduce poverty and mitigate climate change. The productivity and sustainability of dry land irrigation farming schemes is of great concern due to increasing impact of climate change as well as how to mitigate the problem in rural areas of arid and semi-arid with little or no access to technology and funds (IPCC, 2012).

2.7 Summary

This chapter provided general overview of agricultural production worldwide and in Tanzania. The main focus was small scale irrigation farming practices and its vulnerability and resilience. Several challenges facing agricultural production and particularly irrigation farming practices such as overdependence on rainfalls, unsustainable water withdraw, poor farming practices, technological innovation, poor markets and poor policy were clearly described. Attention was given on the impacts of climate change on irrigation farming and how exposure (vulnerability) to the adverse effects of climate change impacts affects small-scale irrigation farming schemes such as dry land irrigation farming. At the same time many features of the vulnerability (such as exposure and sensitivity to climate change impacts) and resilience (adaptive capacity of farmers) with respect to irrigation farming schemes were described and elaborated here. Finally, in this chapter, the research gap on vulnerability and resilience of dry land irrigation farming schemes against climate change impacts were described to elaborate how other scholars failed to address the problem.

CHAPTER 3: CONCEPTUAL FRAMEWORK AND KEY CONCEPTS

3.0 Introduction

The focus of this chapter is on the conceptual framework and key concepts used in the current thesis. Theories, concepts and terms discussed here aim to provide a theoretical framework for the analysis of this study. In this chapter, several elements related to climate change adaptation process within the context of vulnerability, adaptation and resilience, for example, are examined, analysed and explained with the view to broadening understanding of their linkage to irrigation farming practices in South Eastern Tanzania. The chapter starts by providing an overview and conceptual development of vulnerability and resilience in the framework of climate change impacts and adaptation. The chapter define the concepts of vulnerability by build-up on historical evolution and development of concepts and its uses in various aspects of socio-ecological context. Additionally, the chapter explain different causes and approaches to vulnerability, their critique and provide a pathway for vulnerability assessment in this study.

The conceptualization of term vulnerability and its variations across research domains have been clearly described in this chapter. The chapter advances the understanding of vulnerability as flexible, diverse and adaptive in both time and space by considering the notions of vulnerability assessment and pathways. The basic components of vulnerability are described here while vulnerability framework for dry land irrigation farming scheme is drawn and constructed here. Later in the Chapter, attention is given to the adaptive capacity, interconnectedness and the way various elements within socio-ecological resilience framework can possibly explain the situation in this research. Finally, the chapter describes resilience of dry land irrigation farming schemes and possible factors affecting farming practices (exposure and sensitivity), different changes in the farming practices (adaptation options) and the efforts farmers use to encounter the effects of climate change impacts (coping strategies) which are portrayed in the conceptual framework developed to guide this study.

3.1 Defining the Concept of Vulnerability.

The concept of vulnerability has many meanings as it is being used in a wide variety of contexts and in many different fields; however a traditional definition of vulnerability is rooted in the context of natural hazards and sustainability science (Füssel, 2005). The concept of vulnerability was first introduced within the discourse on natural hazards and disaster in 1970's (O´Keefe et al. 1976). During this time many natural hazards and disasters caused serious damage to ecosystem and people with irreversible damage as some of the ecosystems fail to absorb shock/stress while people fail to predict and manage the aftermath of the disaster impact. White (1974) explained the concept of vulnerability as inability of a modern society to cope effectively with natural hazards in the environments by relying solely upon technological solutions instead (must be) the skilful sensitive use of a wide range of adjustments such as land management and social regulation.

Since its inception in the 1970's; several definitions of vulnerability have emerged relating the term with global environmental change and human society. Although different definitions of the term vulnerability exist with different meanings; Füssel (2005) emphasized that the term 'vulnerability' can only be used meaningfully with reference to a particular vulnerable situation (i.e., assessment context). Examples of such assessment context can be earth quakes, famine, drought, floods, deforestation, insecurity and civil unrest among others. According to Amit et al. (2007) vulnerability is also understood as being connected with social and economic conditions relating to people's livelihoods such as people with few or fragile resources, low caste or class, poor education, lack of savings and so on. Timmermann (1981) explained that since the term has a broad use; if not careful described to indicate areas of greatest concern or focus the term will be useless and meaningless. Other scholars define vulnerability as exposure to contingencies and stress, and the difficulty of coping with these exposures (Chambers, 1989; Mitchell et al. 1989; Swift, 1989). The term has also been related or equated to concepts such as resilience, marginality, susceptibility, adaptability, fragility, and risk (Liverman, 1990). A leading definition of vulnerability from natural hazards was developed by Blaikie et al. (1994) incorporating characteristics such as capacity to anticipate, cope with, resist and recover from the impacts of natural hazard.

In both cases above, vulnerability is seen as exposure to natural hazard/event and inability to cope with unpredictable changes or consequences. The above definitions (Watts and Bohle, 1993; Blaikie et al. 1994) fit with current studies on vulnerabilities (Gbetibouo and Ringler, 2009; Pasteur, 2011; Cardona et al. 2012; Chikodzi et al. 2012); however there are other hazards that are not natural and may render the system or society exposed and become more vulnerable. Adger (1996) for example identifies two components of vulnerability as the effects that an event may have on humans (referred to as capacity or social vulnerability), and the risk that such an event may occur (referred to as exposure). Exposure, susceptibility and capacity explain the vulnerability of a system or society but still there are missing information about the complete and specific definition of term vulnerability as to what system or group is exposed to what hazard/event and the likelihoods of the system or group to fail in sustaining that exposure to natural hazard/event. Scholars such as Brooks (2003) suggests that one "can only talk meaningfully about the vulnerability of a specified system to a specified hazard or range of hazards", and to distinguish between 'current' and 'future' vulnerability. According to Edger et al. (2004) a system or exposure unit may be a region, population groups, community, ecosystem, country, economic sector, household, business or individual.

According to Adger (2006); although a number of traditions and disciplines, from economics and anthropology to psychology and engineering, use the term vulnerability; it is only in the area of human – environment relationships that vulnerability has common, though contested, meaning. Definitions of vulnerability to global environmental stress and natural disasters vary considerably, however a formal definition of the concept of vulnerability can be taken from the literature on sustainability science where "Vulnerability is defined as the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation of stress/stressor (Turner et al. 2003; Füssel, 2005; Adger, 2006)". The term vulnerability can be understood in terms of physical exposure to specific hazards such as people living in low lying areas or river banks are vulnerable to flooding while people living in mountainous areas are prone to soil erosion and loss of soil fertility. Vulnerability can also be described based on the characteristics of the vulnerable system, the type and number of stressors and their root causes, their effects on the system, and the time horizon of the assessment

(Füssel, 2004). Luers (2005) explains that the primary objective of vulnerability assessment is to identify people, systems or places that are most susceptible to harm and to identify vulnerability reducing actions.

In this study I particularly focused on the vulnerability and resilience of dry land irrigation farmers and their farming schemes against climate change impact along the Ruvuma Basin, South Eastern Tanzania. Combining Füssel (2007) (*sustainability science*) and Luers (2005) (*global environmental change*); definition on vulnerability; this study focused on effects of climate change (here referring to *temperature and rainfall*) on dry land irrigation farming schemes (here referring to *socio-ecological system*) and (in) ability of dry land irrigation farmers (here referring to *people*) to cope with the stress/disturbance along the Ruvuma Basin (referring to *place*) in South Eastern Tanzania. Although there is considerable diversity of theories and definition of the term *vulnerability* in the existing literature; this study define the term as the sensitivity or exposure of an *irrigation farming schemes* to climate variability (*temperature and rainfall*) relative to a threshold of damage (stress/disturbance), and (in) ability of *dry land irrigation farmer's* to adapt and cope with changing conditions (Adopted from Turner et al. 2003; Luers et al. 2005; Füssel, 2007 and IPCC, 2007).

The IPCC (2007) 4th assessment report prescribed a definition of vulnerability that relates almost entirely to climate change: "The degree to which a system is susceptible to or unable to cope with, adverse effects of climate change, including climate variability and extremes". By focusing on the above definitions, the character, magnitude, and rate of climate change and variation to which a dry land irrigation farmers and their irrigation farming schemes are exposed to, their sensitivity and their adaptive capacity will be a major concern (adapted from IPCC, 2007). In a summary (see table 3.1 below); vulnerability research has largely evolved from three academic communities *i.e:* natural hazards (White, 1974; O´Keefe et al. 1976; Mitchell et al. 1989; Blaikie et al. 1994); development and food security (Sen, 1981; Chambers, 1989; Bankoff, 2004; Watts and Bohle, 1993; FAO, 2001) and climate change (Luers et al. 2003; Turner et al. 2003; O'Brien, 2004; IPCC, 2007 and Füssel, 2007).

Table 3.1: Summary of approaches to vulnerability definition

S/N	Category	Definition of Vulnerability	Scholars
1	Natural hazard	The characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard.	White, 1974; O´Keefe et al. 1976; Blaikie et al. 1994 ; Bankoff, 2004
2	Development and food security	The exposure to contingencies and stress, and difficulty coping with them. (*external* side of risks, shocks and stress to which an individual or household is subject; and an *internal* side which is defencelessness, meaning a lack of means to cope without damaging loss."	Sen, 1981; Watts and Bohle, 1993; Adger, 1996; FAO, 2001; Agder, 2006; Fraser, 2006; Gbetibouo and Ringler, 2009; Cardona et al. 2012
3	Climate Change	The degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor	Turner et al. 2003; O'Brien, 2004; Luers, 2005; Füssel, 2007 and IPCC, 2007
4	IPCC 4th Assessment Report	The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and the variation to which a system is exposed, its sensitivity and its adaptive capacity.	IPCC, 2007
5	Adopted definition (for the purpose of the study	The sensitivity or exposure of an *irrigation farming schemes* to climate variability (*temperature and rainfall*) relative to a threshold of damage and (in) ability of *irrigation farmer's* to adapt and cope with changing conditions	Adopted from (Turner et al. 2003; Luers et al. 2005; Füssel, 2005 ; IPCC, 2007).

3.2 Causes of Vulnerability.

Vulnerability as a concept is rooted in the context of natural hazards and sustainability science (Turner et al. 2003; Füssel, 2005). Traditionally, the causes of vulnerability were exposure to contingencies and stress such as natural hazards (earth quakes, drought and floods) and the difficulty of coping with these exposures (Chambers, 1989; Mitchell et al. 1989). The exposure to natural hazard/event and inability to cope with unpredictable changes has been seen as the major cause of vulnerability; however there are other hazards that are not natural and may render the system or society exposed and become more vulnerable (Sen, 1981; Watts and Bohle, 1993). Other factors that are additional sources of vulnerability to any society or ecological systems include famine, deforestation, insecurity and civil unrest among others.

In recent times, vulnerability has become a major issue to consider for research on the human dimensions of global environmental change (Obrien et al. 2004) due to the fact that human population, their activities and various socio-ecological systems have been exposed to various external forces apart from natural hazards/events. Current literature on vulnerability and climate change impact have changed the focus from external factors (*bio-physical*) to include internal factors such as social (*systems*) and political (*decisions*) causes of vulnerability to a specified socio-ecological system, region, sector or people (Luers et al. 2003; Turner et al. 2003; Füssel, 2004; IPCC, 2007; Malone, 2009; Chikodzi et al. 2012). This study focused on both external factors (*bio-physical such as temperature and rainfall*) and internal factors (*social system-farming schemes*) as the causes of vulnerability. According to Pasteur (2011); the causes of vulnerability are multi-dimensional due to the exposure of socio-ecological systems and people to various internal and external forces or stimuli (see figure 3.1 below).

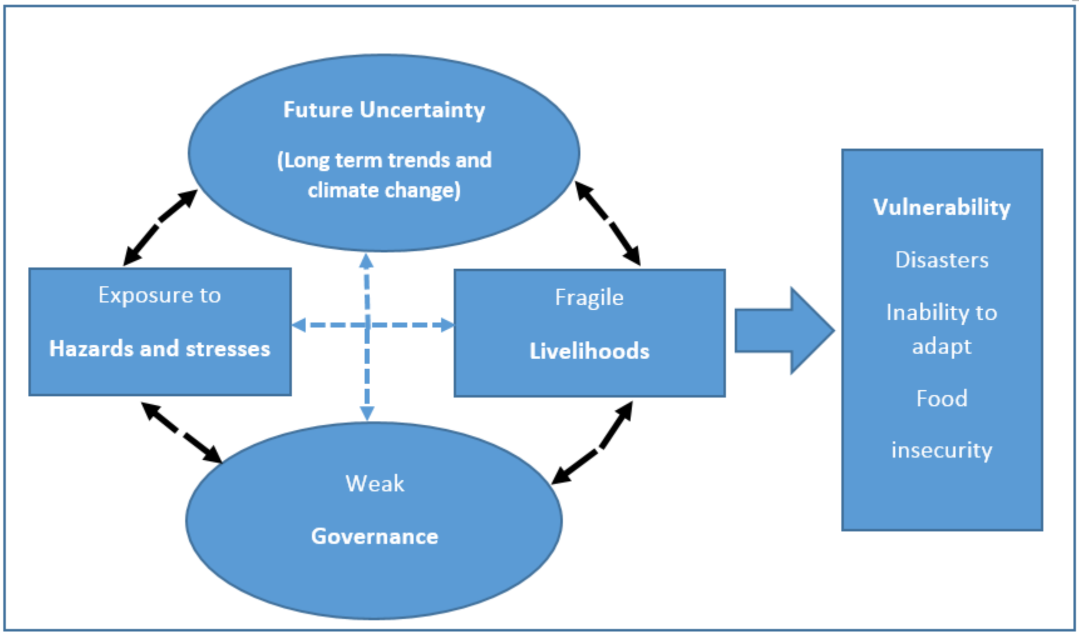

Figure 3.1: Vulnerability Framework. Source: Pasteur, 2011.

The causes of vulnerability becomes vital important when attempting to assess vulnerable groups or socio-ecological systems as the causes vary between communities or social systems, between social groups in a community, between households and between people within a household and the effect of vulnerability are unevenly distributed in time and space (Adger et al. 2004). In order to effectively address and manage vulnerability, it is essential to understand how vulnerability is generated, how it increases, and how it builds up (Obrien et al. 2004; Cardona et al. 2012). For example on the same geographical location; people living in marginal land are vulnerable to poor productivity due to lack of soil fertility/moisture while people living along the river embankments or flood plains areas are vulnerable to poor productivity due to exposure to frequent floods and not due to lack of fertile soil.

Though in the study area, the causes of vulnerability are multidimensional, this study focused on impact of climate change (*temperature and rainfall*) and social systems/attributes (*farming practices*) as the causes of farmer's vulnerability and its associated consequences on dry land irrigation farming schemes. Other factors and conditions determining the vulnerability of dry land farmers and their farming schemes in the study area such as socio-ecological condition and political factors have been considered so as to find out more about the interconnectedness of climate change impact and other influencing factors. According to Cardona et al. (2012);

vulnerability describes a set of conditions of people that derive from the historical and prevailing cultural, social, environmental, political, and economic contexts. In this sense, vulnerable groups are not only at risk because they are exposed to a hazard but as a result of marginality, of everyday patterns of social interaction and organization, and access to resources (Watts and Bohle, 1993; Bankoff, 2004). Malone, 2009 argued that for poor people, vulnerability is both a condition and a determinant of poverty, and refers to the (in) ability of people to avoid, cope with or recover from the harmful impacts of factors that disrupt their lives and that are beyond their immediate control. This includes the impacts of shocks (sudden changes such as natural hazards, collapsing market prices) and trends (for example, gradual environmental degradation, or access to information). For example, Krone et al. 2014 posited that the increasing use of mobile phones results in positive contributions to the economic activities of horticultural farmers in the Mwanza region as it allows farmers to access different vital types of knowledge such as transaction (payment, market price for vegetables), farm supplies/inputs and how to identify crop diseases or pests. This means that farmers without access to frequent information and knowledge are increasingly becoming vulnerable and their farming schemes are exposed to other set of stressors such as pests or high cost of production. Therefore, integrated and multidimensional approaches are highly important to understanding causes of vulnerability. Table 3.2 indicate summary of evolution of the causes of vulnerability.

Table 3.2: Summary of approaches to vulnerability definition

S/N	Vulnerability	Causes	Scholars/Source
1	Natural vulnerability	Exposure to natural hazards such as earth quakes, volcanic eruption)	White, 1974; O´Keefe et al. 1976;
2	Social vulnerability	The exposure to insecurities (famine, conflicts) and lack of entitlements (assets, knowledge, income) and difficulty coping with changes.	Sen, 1981; Watts and Bohle, 1993; Adger et al. 2004; FAO, 2001; Malone, 2009
3	Biophysical or climate change vulnerability	Exposure to continuous climatic stimuli (mean increase in temperature or rainfall) and discrete climatic hazard such as drought or floods	O'Brien, 2004; Luers, 2005; Füssel, 2007 and IPCC, 2007

3.3 Conceptual Approach for Vulnerability Assessment.

The conceptualization of term vulnerability varies significantly across research domains, and it has evolved over time and space (Füssel, 2007); however many assessment approaches characterize vulnerability according to the degree of susceptibility or fragility of communities, systems or elements at risk and their capacity to cope under hazardous conditions (Birkmann et al. 2015). The existence of variation has been contributed by scholars from different fields of specialization having a tendency to conceptualize vulnerability differently based on the objectives to be achieved and the methodologies employed in a particular research (Adger, 2000; Luers et al. 2003; Turner et al. 2003; O'Brien et al. 2004; Füssel, 2005; Malone, 2009; Chikodzi et al. 2012; Cardona et al. 2012). For example in the natural science research communities often focus on the quantification of different factors of vulnerability (Turner et al. 2003; Kienberger et al. 2009) while in social science approaches often encompass a broad focus and examine, in particular, the likelihood that an individual household or a community will suffer harm or experience losses related to environmental hazards, as well as the context conditions that influence social vulnerability (Kok et al. 2015; Tucker et al. 2015; Wisner et al. 2004). These differences limit the possibility of having a universally accepted definition and methodological approach to assessing vulnerability against which the appropriateness of a given concept or method can be judged (Deressa et al. 2008). The diversity of conceptualizations is seen primarily as a consequence of the term 'vulnerability' being used in different research domain and policy contexts, referring to different systems being exposed to different hazards over time and across different geographical conditions. The multidisciplinary vulnerability framework developed by various researchers (such as Turner et al. 2003; Luers, 2005; Füssel, 2005; Nelson, et al. 2010; Cardona et al. 2012) illustrates the complexity and interactions involved in vulnerability analysis, drawing attention to the way in which multiple socio-political and physical processes, operating at different spatial and temporal scales, produce vulnerability within the coupled human – environment system (Thomalla and Zou, 2008). The knowledge of the existing conceptual and methodological approaches can act as a guide and help the researcher to choose one of the methods, or combinations of existing methods when analysing vulnerability for a specific area of interest. Although a consistent framework and terminology is needed for assessing vulnerability of dry land irrigation farmers to climate change; this study assumes that there is no single ‘correct’ or ‘best’ conceptualization of vulnerability. According to Deressa et al. (2008); there are three major conceptual approaches to analysing vulnerability to climate change: the *socio-economic* assessment, the *biophysical* (impact assessment), and the *integrated* assessment approaches.

In the case of *socio-economic approach*; here vulnerability assessment is referred as the *“starting point”* (Kelly and Adger, 2000; Watts and Bohle 1993; Füssel, 2007). It is largely pertaining to the social, economic, and political aspects of society and it focuses on the assessment of the socio-economic and political status (such as income, yield, livelihoods, and economics) of individuals or social groups (Singh et al. 2014; Adger, 2000). The first approach considers vulnerability as the “starting point,” *i.e.* as a state that exists within a system before it encounters a hazard event (Kelly and Adger, 2000; Brooks, 2003). Here, the term vulnerability is viewed as (in) ability of a system to respond and cope with that hazard, rather than by what may or may not happen in the future. Kelly and Adger (2000); argues the vulnerability of any individual or social group to some particular form of natural hazard is determined primarily by their existent state, which is their capacity to respond to that hazard, rather than by what may or may not happen in the future. For example; the drought will result in a set of unique impacts to the farming scheme, depending not only on its severity and duration, but also on a society's social, economic and environmental conditions (Singh et al. 2014). The question on sensitivity and exposure as well as resilience of the dry land irrigation farming scheme to climate change was posed in using approach in order to understand the social, economic, and political impacts.

Further studies show that this approach also draws on the entitlement literature regarding access to resources, on the political economy literature in explaining the factors that lead to vulnerability, and on the social capital literature for the means of claiming entitlements and pursuing coping mechanisms (Deressa et al. 2008; Adger 1996). According to Gbetibouo and Ringler (2009); in this approach vulnerability is determined by the internal properties of a system, and is a variable condition generated by multiple environmental and social processes, including climate change impact. Thus, the starting point approach diagnoses inherent social and economic processes of marginalization and inequalities as the causes of climate vulnerability, and seeks to identify ways to address these processes (O'Brien et al. 2004). In general, the socioeconomic approach focuses on identifying the adaptive capacity of individuals or communities based on their internal characteristics. The main limitations of the socio-economic approach are that it focuses only on the variations within society or social groups (Gbetibouo and Ringler, 2009). The approach overlooks exogenous or environmental factors. In reality, societies or household vary not only due to socio-economic and political factors but also to due to environment-based intensities, frequencies, and probabilities of environmental shocks, such as drought and flood (Singh et al. 2014; Deressa et al. 2009). For example, the approach does not account for the availability of natural resource bases to potentially counteract the negative impacts of these environmental shocks – for example, areas with easily accessible underground water can better cope with drought by utilizing this resource (Deressa et al. 2009). In other words, different groups or households in the same location may experience very different levels of vulnerability which calls the need for a wider focus on other approach to vulnerability assessment.

In the case of ***biophysical approach***, here vulnerability assessment is referred as the *"end point";* vulnerability is described in terms of the amount of (potential) damage caused to a system by a particular climate-related event or hazard (O'Brien et al. 2004; Luers, 2005). Füssel (2007) identified this approach as a risk-hazard approach and denoted the vulnerability relationship as a dose-response or exposure-effect relationship in epidemiology, and a damage function in macroeconomics. Gbetibouo and Ringler (2009) explain that in this approach; vulnerability is understood as a residual of climate change impacts minus adaptation; it is therefore the net impact of climate change. The attributes in end point analysis includes the susceptibility, sensitivity or exposure of a system to climatic variables such as rain fall or temperature. In additional to damage caused to a system by a particular climate-related event or hazard; Deressa et al. (2008) add that this approach assesses the level of damage that a given environmental stress causes on both social and biological systems. Kelly and Adger (2000) referred to the biophysical approach as an end-point analysis responding to research questions such as, "What is the extent of the climate change problem?" In this study the question of what are the susceptible conditions (climatic variables-temperature and rainfall) that affect dry land irrigation farmers and exposing the farming schemes to climate change in the study area was posed.

Thus, the end point represents a strong scientific understanding of climate change and other environmental problems (Gbetibouo and Ringler, 2009). An assumed knowledge of future climate is deeply embedded in end-point analyses in terms of both impacts and adaptations. In the end point analysis; Deressa et al. (2008) argues that the yield impacts of climate change can be analysed by modelling the relationships between crop yields and climatic variables. According to O'Brien et al. 2004, in this approach, assessment of vulnerability is the end point of an analytic sequence that begins with projections of future emission trends, moves on to the development of climate scenarios, and then progresses through biophysical impact studies and the identification of adaptive options. In this study, climatic and weather data from Tanzania Meteorological Weather station (Mtwara) have been used to estimate variable projections in climate change scenarios.

Although the end point analysis is very informative and shows/predict the future climate impact scenarios, the approach has its limitations. The major limitation is that the approach focuses mainly on physical damages, such as yield, income, and so on (Deressa et al. 2008). According to Debbie (2014), this perspective neglects the factors such as social, economic, and political, which shape vulnerability as well as overlooking coping strategies enacted by individual and corporate actors. For example, a study on the impact of climate change on yield can show the reduction in yield due to simulated climatic variables, such as increased temperature or reduced precipitation (Nelson et al. 2010; Singh et al. 2014). In this case simulations models can show quantities of yield reduced due to climate change, but it is difficult to interpret or show what that particular reduction means for different people across the society. This means that climate change impact does not affects poor farmers the same way it does for rich farmers. According to Deressa et al. (2008); poor farmers very often cannot cope with marginal changes in their yields or income, whereas richer farmers can buffer their loss (smoothen consumption, in technical terms) by depending on savings or sale of some of their assets. In general, the biophysical approach focuses on sensitivity (change in yield, moisture) to climate change and misses much of the adaptive capacity of individuals or social groups, which is more explained by their inherent or internal characteristics or by the architecture of entitlements, as suggested by Adger (1999). This addresses the need for including other factors or indicators in vulnerability assessment such as socio-economic indicators that might affect the farmers as a result of climate change.

According to Panthi et al. (2014) there are no consensus on methods to assess vulnerability, but most assessments entail considering one or more of exposure to risks, susceptibility to damage and capacity to recover. Vulnerability assessment must integrate and examine interactions between humans and their physical and social surroundings. For the case of *integrated approach*; vulnerability assessment is referred to holistic approach (IPCC, 2007; Deressa et al. 2008; Cardona et al. 2012; Singh et al. 2014). This approach combines both the socio-economic and the biophysical attributes in vulnerability analysis (Füssel, 2007). In this approach the vulnerability analysis conceptualizes vulnerability as a function of sensitivity, exposure and adaptive capacity to events such as drought or floods (Brooks et al. 2005). As describe in the above definition (for the case of study area); this study will combine the two vulnerability approach *e.i.* the *socio-economic* and *biophysical approach.* In this case, vulnerability is defined as the sensitivity or exposure of an *irrigation farming schemes* to climate variability (*temperature and rainfall*) relative to a threshold of damage (stress/disturbance), and (in) ability of *dry land irrigation farmer's* to adapt and cope with changing conditions.

The integrated analysis has also been depicted in the fourth and fifth IPCC assessment reports (IPCC, 2007 and IPCC, 2014). Even though the integrated assessment approach corrects the weaknesses of the other approaches, it also has its limitations. There is no standard method for combining the biophysical and socio-economic indicators (Deressa et al. 2008; Singh et al. 2014; Li et al. 2015). The relative importance of different variables used in this approach has not been taken into account and thus more care is needed in using this approach (Cutter et al. 2000). For example; this approach uses different data sets, ranging from socioeconomic data sets (*e.g.* education, gender and age structures of households) to biophysical factors (*e.g.* frequencies of floods, drought) where these data sets certainly have different and yet unknown weights. The other drawbacks are that it does not take into account the dynamism in vulnerability (Singh et al. 2014). For the purpose of this study, a conceptual and methodological approach to vulnerability analysis based on the literature above (*socio-economic, biophysical and integrated*) approach was adopted in order to develop a conceptual framework of vulnerability for this study (see the summary of approaches in table 3.3). A pragmatic approach to vulnerability assessment involves studying how vulnerable a community is compared to others and which component pushes up the level of vulnerability within the community.

Table 3.3: Summary of approaches to vulnerability to climate change impact

	Biophysical Vulnerability (end point)	**Social Vulnerability (starting point)**	**Socio-ecological resilience**
Focal question	What is the condition exposing irrigation to climate change impact?	Who is vulnerable to climate change and why?	How do farmers deal with changes in climate?
Key attributes	Exposure (temperature and rainfall variability)	Sensitivity and exposure	Capacity to learn and adapt and thresholds
Exposure unit	Dry land irrigation farming schemes	Individual farmers,	Socio-ecological system
Definition	Function of the frequency and severity of exposure to Climate variability	Ability or inability of individuals farmers to respond to, and cope with changes from climate changes	The ability of communities to withstand climate change shocks to their Farming schemes

Adapted and modified from Isabel, 2012

While there are differences in approaches, there are many commonalities in vulnerability research in the environmental arena. *First*, it is widely noted that vulnerability to environmental change does not exist in isolation from the wider political economy of resource use (Neil, 2006). In most rural and marginalised communities; vulnerability is driven by inadvertent or deliberate human action that reinforces self-interest and the distribution of power in addition to interacting with physical and ecological systems. The degree of impact depends on the ways in which the natural triggering event interacts with particular ecosystems and with the specific characteristics of the society affected, including its level of economic development; the types of livelihoods of its members; education levels; and other factors that generally determine both how vulnerable and resilient the affected population is as well as what resources are available for adaptation (Neil, 2006; Malone, 2009).

Second, there are common terms across theoretical approaches: vulnerability is most often conceptualized as being constituted by components that include exposure and sensitivity to perturbations or external stresses, and the capacity to adapt (Neil, 2006). Exposure, sensitivity and capacity to adapt are the three basic block in assessing vulnerability of a system to perturbations or external stresses such as extreme weather events (Luers, 2005; Füssel, 2007; Gbetibouo and Ringler, 2009; Cardon et al. 2012; IPCC, 2014; Birkmann et al. 2015; Kok et al. 2015 and Tucker et al. 2015).

3.3.1 Basic Components of Vulnerability.

Therefore based on integrated approach (4th and 5th IPCC assessment reports); vulnerability can be expressed as the positive function of exposure and sensitivity, but negative function of adaptive capacity (IPCC, 2007; IPCC, 2014; Li et al. 2015).

$$\text{Vulnerability} = f(\text{Exposure, Sensitivity, Adaptive capacity})$$

For the purpose of this study; Sensitivity, Exposure and Adaptive Capacity are three basic components that have been considered in vulnerability assessment (figure 3.2 below). Exposure together with sensitivity represents the propensity and predisposition of the studied system to be adversely affected by climate change, whereas adaptive capacity reduces these effects (Nelson et al. 2010; Li et al. 2015).

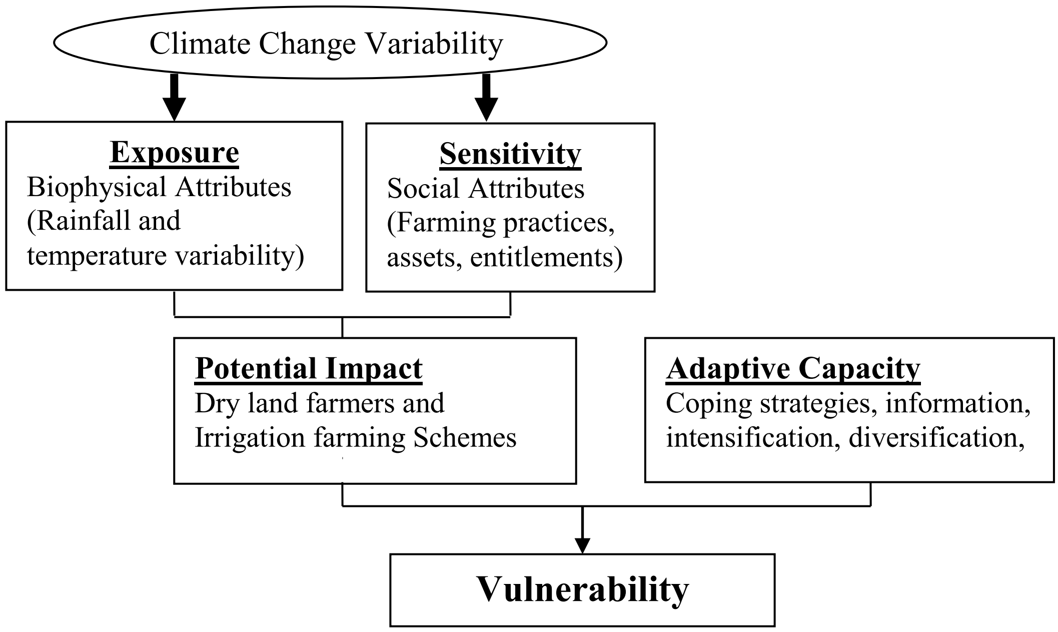

Figure 3.2: Vulnerability framework. Source: Adapted from Fellmann, 2012.

Exposure is defined as 'the extent to which a given system is exposed to climate change-related hazards' (IPCC 2007; IPCC, 2014). It has both a biophysical dimension (the frequency and severity of climate impacts) and a social dimension (the spatial distribution of populations and assets. The IPCC, 2014 indicate that mean annual temperatures in the Tanzania is projected to rise by 2.2°C by 2100, with increases over June, July and August, and lower values (1.9°C) for December, January, February while total annual rainfall is expected to decrease dramatically (during wet seasons-OND), mainly as a consequence of decreasing of seasonal number of wet days. It is generally agreed that increasing temperature and decreasing precipitation are both damaging to the already hot and water scarce Tanzanian agricultural sector. Thus, the country's coastal low lying areas are exposed to climate variability due to increasing temperature (extreme dry condition) and decreasing rainfall (with frequent dry spells). In this study, I focused on dry land irrigation farming scheme being exposed to the impact of climate variability (*rainfall and temperature variability*) as biophysical aspects while in the social dimension I focused on how farmers, their farming practices and their livelihoods are exposed to climate stimuli mentioned above.

Sensitivity is defined as 'the degree to which a system is affected, either adversely or beneficially, by climate variability or climate change' (IPCC, 2014). Effects may be direct or indirect. In Sub-Saharan Africa; the agricultural sector's sensitivity to climate change is represented by the frequency of climate extremes (Paavola, 2004; Li et al. 2015). In the study area, I argued that villages soil condition (dark cotton soil, prone to erosion), poor farming practices and entitlements coupled with greater frequency of dry spell, extreme dry condition and soil erosion from heavy rainfalls makes farming schemes responds negatively (*i.e.,* reduced yield). Thus, agriculture in drought and flood-prone areas is more sensitive in terms of yield reduction. The determinants of sensitivity include also the extent of dependence on natural resources, age and health status of the population and access to alternative livelihoods. Exposure and sensitivity are often considered together in the literature as 'exposure-sensitivity'.

Adaptive capacity is defined as 'the whole of capabilities, resources and institutions to implement effective adaptation measures' (adapted from IPCC 2007; IPCC, 2014). Adaptation to climate change is defined as 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2007; IPCC, 2014). In this study the measures of sensitivity and adaptive capacity can also be used to represent vulnerability to climate variability, as dry land irrigation farmers have been adapting to changes in extreme temperatures and rainfall variability as much as to changes in mean conditions. Different cropping pattern, farming practices, access to information and livelihood diversification have been used to assess the capacity to adapt by different farmers. Determinants of adaptive capacity include assets, institutional arrangements and entitlement security, knowledge and information, ability to innovate and the presence of flexible, forward-looking governance (Cardona et al. 2012; Li et al. 2015). In order to assess the vulnerability of any socio-ecological system; several indicators can be developed to assess the sensitivity, exposure and capacity to adapt and cope to climate change impacts (O'Brien et al. 2004; Tucker et al. 2015).

3.3.2 Indicators of Vulnerability.

Several methods have been proposed to measure vulnerability from a comprehensive and multidisciplinary perspective (Cardona et al. 2012). According to Gbetibouo and Ringler, 2009; the indicator approach uses a specific set or combination of indicators (proxy indicators) and measures vulnerability by computing indices, averages or weighted averages for those selected variables or indicators. In the wider literature, some authors have taken steps towards developing linked indicator sets for vulnerability analysis at different scales (e.g. Turner et al. 2003; Cardona et al. 2012; Tucker et al. 2015). In some cases composite indices or indicators intend to capture favourable conditions for direct physical impacts – such as exposure and susceptibility – as well as indirect or intangible impacts of climatic hazard to socio-ecological systems have been used. The usefulness of indicators depends on how they are employed to make decisions on risk management objectives and goals (Cardona et al. 2012). Indicators vary between studies, and as they are proxies for vulnerability to future changes, it is not possible to test the validity of indicator sets. According to O'Brien et al. (2004); the vulnerability profile is constructed by combining indices for adaptive capacity with sensitivity indices that take into account exposure to climate change.

In additional to socio-economic and biophysical approach to vulnerability assessment; the different key indicators showing vulnerability of dry land irrigation farming schemes against climate change in the study area were identified and studied. In order to measure sensitivity, exposure and adaptive capacity in the study area, I identified significant biophysical, socioeconomic, local innovative farming and political factors that influence dry land irrigation farming schemes (vegetable production). For example by selecting biophysical indicators such as soil conditions (cover, biomass, depth) and surface water availability (estimates of annual availability), I assumed that areas with more productive soil and more surface water available for dry farming irrigation will be more adaptable to adverse climatic conditions and better able to compete and utilize the opportunities of irrigation farming business. For socioeconomic factors, basic indicators such as literacy rates, working force, land ownership, income and adult were measured. The presence of alternative economic activities provides an indicator of the ability of dry land irrigation farmers in the study area to shift to other economic activities in response to reduced yield and income resulting from adverse climatic conditions such as extreme temperature and drought. A review by Eriksen and Kelly (2007) found that the choice of indicators greatly influences the resulting rankings, and composite vulnerability scores alone are not particularly informative. When dealing with indicators choices, a great care must be taken into account. For example Aulong and Kast (2011); cautioned that sensitivity indicators contribute less trivial to vulnerability since some farmers who appears as more sensitive to market shocks, might not be affected by other factors. In addition, the application of indices is limited by considerable subjectivity in the selection of variables and their relative weights, by the availability of data at various scales, and by the difficulty of testing or validating the different metrics (Luers et al. 2005).

3.3.2 Vulnerability of Dry Land Irrigation in the Study Area

The vulnerability concept is still dynamic as it varies across temporal and spatial scales and depends on economic, social, geographic, demographic, cultural, institutional, governance and environmental factors (Folke, 2006). River basins are good examples of dynamic ecological systems that vary across temporal and spatial scales. For example, river basins areas are characteristically wet during the rainy season and characteristically moist during the dry season with variation across the river basin and across the landscapes. In the study area, the characteristics of both six villages studied vary in terms of *landscape* (*marsh land, swamps, and river basins*); *soil type* (*clay, sand, loamy*) and *water availability* (*ponds, river flow, canals and soil moisture*). The opportunity of having alternate wet and dry season allows local farmers to cultivate multiple annual crops based on soil water requirements (Msaky, 2010); however the land across river basins are severely constrained in agricultural activities disproportionately due to unpronounced floods or prolonged dry season as a result of climate change (Smit and Wandel, 2006). These conditions render the farming schemes such as dry land irrigation farming schemes more and more vulnerable (*exposed, susceptible and sensitive condition*) to climate change.

The sensitivity, exposure and adaptive conditions are the central themes to this research and underlie the vulnerability framework approach for this study. Poor *farming practices* coupled with variation in *landscape, water availability* and *soil characteristics* makes the dry land farming scheme susceptible to hazards and expose it to various natural disaster such as drought. As the dry land irrigation farming schemes becomes vulnerable to climate change; so do the systems become resilience with the situation through adaptation (intervention and transformation from local farmers) so as to sustain their farming system throughout. Malone (2009) suggest that understanding the causes of vulnerability will support analysis of policy options to address its underlying causes rather than just its symptoms while understanding resilience and adaptive capacity will provide guidance on where to direct resources to build on existing strengths or open new areas of support.

As described above in the vulnerability approach (*socio-economic approach)*; in order to understand dry land irrigation farmers' vulnerability to climate change, the following important characteristics that dry land irrigation farmers share across the study area has been assessed:-

(i) Dry land farmers that are constrained by poor soil (clay, sand loamy and alluvial) that has been affected by salt accumulation (evaporation) and in some places acidification (water stagnation).

(ii) Lack of entitlements such as subsidies, farm inputs, low price for their vegetables produced, lack of information from extension officers

(iii) Presence of poor land-management practices that can stress the dry land irrigation farming schemes (increased land degradation) and increase its sensitivity to exogenous forces such as floods and drought.

Thus the vulnerability of dry land irrigation farming schemes to climatic variability (*temperature and rainfall*) and its impacts across dry land farming communities in the study area requires exploring the existing knowledge or information of the farmers and the direct/indirect consequences that contribute to vulnerability, and their capacity to adapt and cope. Other characteristics and aspects of dry land irrigation farming schemes (*farming practices, water availability* and *soil characteristics*) that might expose irrigation farming schemes to climate change have been studied and analysed.

In the case of biophysical approach, susceptible conditions that expose dry land irrigation farming scheme to climate change was studied. For a deeper understanding of these conditions; the question of what are the susceptible conditions (climatic variables-*temperature* and *rainfall*) that affect dry land irrigation farmers and exposing the farming schemes to climate change in the study area was posed. This study focused on the climate variables (*temperature* and *rainfall variability*) and how they affect dry land irrigation farming schemes (*e.g* moisture availability and crop yield; temperature and farming pattern) along the Ruvuma basin in the selected six villages. In order to clearly understand dry land irrigation farming schemes' vulnerability to climate change, the following important characteristics that farmers share across the study area has been assessed:-

(i) The unbearable dry season (semi-arid) climatic conditions in the study area where rainfall is unimodal in this area and farming is greatly reliant on its quantity and quality.
(ii) Dry land irrigation farming schemes (vegetable production) that relies mainly on surface and groundwater irrigation.

Although the two vulnerability approach (*socio-economic and biophysical*) analysis are self-explanatory and shows/predict the future climate impact scenarios, the approaches have their own setbacks as described in the above section. For example, the variations within society or social groups and their income status which are depicted in the yield/harvest produced and their (in) ability to withstand shock or adapt to climate change impacts. This indicates that there is no single approach to vulnerability assessment thus calling for a combined or integrated approach to examine interactions between humans and their physical and social surroundings.

3.4 Adaptive Capacity

Productivity of rain-fed agriculture in rural Sub-Saharan Africa is severely constrained by climate variability, particularly in terms of drought and high temperatures (Midega et al. 2015). Under current climatic conditions these regions indicates a significant negative effects on already constrained food production, crop season length, and higher-order social impacts including food security. Most of the poor rural farmers have limited economic and institutional capacity to cope with, and adapt to, climate variability and change; particularly those depending on rainfall and surface water for irrigation (Perez et al. 2015). For example, in the study area the persistence of rain fall and temperature variability (extreme dry condition, frequent floods and dry spells) and their potential to change in frequency and severity indicate the need to develop sound and friendly adaptive strategies to ensure sustainable horticultural and vegetables production and environmental conservation.

Many definitions of adaptive capacity exist (*e.g:* IPCC, 2001; Burton et al. 2002; Adger et al. 2003); broadly speaking it may be described as the ability or capacity of a system to modify or change its characteristics or behaviour so as to cope better with existing or anticipated external stresses. Deressa et al. (2008) defines adaptive capacity as the ability of a system to adjust to actual or expected climate stresses or to cope with the consequences of those stresses. According to Brooks (2003), the adaptive capacity of a system or society reflects its ability to modify its characteristics or behaviour in order to better cope with existing or anticipated external stresses and changes in external conditions. In socio-ecological systems; Perez et al. (2015) define adaptive capacity as related to the ability to respond (moderate or offset) actual or expected climatic and other challenges by altering processes, practices, or structures, including governance and assets, in order to reduce vulnerability.

The common elements exists in all definition above is system's ability and capacity; to adjust or modify or change characteristics; and anticipate or cope with external stresses and changes in external conditions. Both definitions above are in line with the IPCC (2001) which describes adaptive capacity as the potential or ability of a system, region, or community to adjust to the effects or impacts of climate change (including climate variability and extremes). The IPCC (2007) add that the adaptive capacity is the ability (or potential) of a system to adjust successfully to climate change (including climate variability and extremes) to:-

(i) Moderate potential damages;

(ii) To take advantage of opportunities; and/or

(iii) To cope with the consequences

Scholarly knowledge related to capacity to adapt to climate change and adaptation is still limited, and the vague and inconsistent definitions of terminology and concepts used in this academic field have frequently been criticized (Hinkel, 2011; Janssen and Ostrom, 2006). Despite their intention of providing generally applicable guidelines, most studies provide only very limited references to local – level adaptation processes and, especially, to the adaptation of small – scale farmers (Agder et al. 2004; Deressa et al. 2008; Kihupi et al. 2015). The conceptual approaches of Yohe and Tol (2002) and Chambers (1989) provide explanations for the variability of farmers' vulnerability, adaptive capacity, and adaptation at a local scale. Even though Yohe and Tol's (2002) determinants of adaptive capacity are specific enough to explain local adaptation processes, they are not targeted to a particular sector and do not fully explain the realities of small – scale farmers struggling to adapt to climatic variability and changes. Bennett et al. (2015) explain that impacts of climate change can be unevenly experienced by various similarly exposed groups (genders, ages, classes, groups, livelihoods) based on differential sensitivities (O'Brien et al. 2004). The capacity to adapt is context – specific and varies from sector to sector, from community to community, within the sector, among social groups and individuals, and over time (IPCC 2001).

Many approaches for assessing vulnerability rely on an assessment of capacity as a baseline for understanding how vulnerable people are to a specific hazard (Cardona et al. 2012). Cardona et al. (2012) argues that there is a difference in understanding and use of the terms coping and adapting. Although coping capacity is often used interchangeably with adaptive capacity in the climate change literature; the term adaptation means adjustment, whether passive, reactive or anticipatory that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change (Kihupi et al. 2015). Adaptation strategies refer to all responses to climate change that may be used to reduce vulnerability (Burton et al. 1998). Adaptive capacity is the potential or ability of a system, region or community to adapt to the effects or impacts of climate change (Smit and Pilifosova, 2001). In the field of climate change it includes all adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in climatic system (Midega et al. 2015). IPCC (2007) consider the adaptive capacity to be "a function of wealth, technology, information, skills, infrastructure, access to resources, and management capabilities.

For this study, adaptive capacity is represented by different coping strategies, farming practices, wealth-income, land ownership, availability of resources-water and farm inputs, access to information and literacy rate (see vulnerability conceptual framework). Smallholder farmers in different parts of the study area have adapted to impact of climate change through various coping strategies. In Iringa and Morogoro local farmers have been adapted to climate change impact by planting drought resistant seed varieties and crops, intercropping, irrigation, changed planting dates, increased use of water and soil conservation techniques, diversification from farm to non-farm activities such as casual labour and moving to other places (Mary and Majule, 2009; Shemsanga et al. 2010; Kihupi et al. 2015).

In many places, local knowledge and practices have helped communities to cope with and respond to natural hazards and environmental change for generations (Djalante et al. 2011). These local/indigenous knowledge and practices need to be integrated with scientific knowledge when assessing vulnerability and resilience to climate change. Connolly and Smit (2015) argues that in the future, adaptation will be required to alleviate the worst effects of climate change and help build resilience, especially for the poorest and for those who live in the most vulnerable regions of the world. Vulnerability research should directly assess adaptation by seeking to understand who or what adapts, to what stimuli, and how it occurs. The goal is to understand the adaptation process: how people have adapted to past changes, and what changes or conditions are relevant and can provide insight into how they will adapt in the future (Adger et al. 2004).

3.5 Limitation to Adaptive Capacity

According to Preston and Smith (2009); perhaps one of the most neglected aspects of adaptive research and assessment is the evaluation of limitation on adaptation. When discussing vulnerability and capacity to adapt to climate change, care should be taken not to confuse the two concepts in question. For example, in many climate change literature vulnerability describe as among other things, the result of a lack of capacity (O'Brien et al. 2004; Cardona et al. 2012). Vulnerability is viewed as the opposite of capacity, so that increasing capacity means reducing vulnerability, and high vulnerability means low capacity. However, Gaillard (2010) noted that capacity and vulnerability are not necessarily opposites, because communities that are highly vulnerable may in fact display high capacity in certain aspects. Adger et al. (2004) also explains that adaptation does not occur instantaneously; a system requires time to realise its adaptive capacity as adaptive capacity represents potential rather than actual adaptation. There will never be "perfect" adaptation of agriculture to climate change. Some negative impacts are likely to remain (residual damage) even after adaptation actions and investment have taken place. This "residual damage" may result in increased food insecurity and dealing with it requires a degree of resilience to climate change (Pingali et al. 2005); thus resilience is seen as a more robust strategy regardless of the future.

3.6 Resilience to Climate Change

The idea of *"resilience"* originated in the field of ecology (Holling, 1973) as a measure of how far the system could be disturbed without shifting to a different regime. Since then, the concept of resilience is now used in a great variety of interdisciplinary work concerned with the interactions between people and nature (Gunderson and Holling, 2001; Folke et al. 2006). For example, resilience has been connected with ability of a system to return to its state (or dynamics) after a temporary disturbance (Ludwig et al. 1997; Guillaume and Gilbert, 2011). Klein highlight that on top of that the system has to self-re-organize and maintain its functions and services. Few scholars use the term resilience to describe the amount of time needed to recover following an external force or perturbation (see table 3.4).

Table 3.4: Summary of Approach to Resilience Definition

S/N	Category	Definition	Scholar
1	Ecology	A measure of how far the system could be disturbed without shifting to a different regime.	Holling, 1973
		The magnitude of disturbance that can be absorbed before the system redefines its structure by changing the variables and processes that control behaviour.”	Gunderson and Holling, 2001; Gunderson, 2000
2	Ecosystems	Connected with ability of a system to return to its state (or dynamics) after a temporary disturbance such as fire.	Ludwig et al. 1997; Guillaume and Gilbert, 2011
3	Socio-Ecological Systems	i) the amount of change the system can undergo and still retain the same controls on function and structure, or still be in the same state within the same domain of attraction; ii) the degree to which the system is capable of self-organization; iii) the ability to build and increase the capacity for learning and adaptation.	Folke et al. *2006* Carpenter et al. 2001
4	Adopted definition for the purpose of this study	The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks	Walker et al. 2004

Other scholars such as Gunderson and Holling (2001) define “resilience” as the capacity of a system to undergo disturbance and maintain its functions and controls. In their view, resilience is measured by the magnitude of disturbance the system can tolerate and still persist (Carpenter et al. 2001). Adger et al. (2004) define social resilience as the ability of communities to absorb external changes and stresses while maintaining the sustainability (robustness) of their livelihoods. Whereas resilience refers to the ability to recover from stresses, robustness is a characteristic associated with strength or vigorous health, and it describes the degree to which a system is not susceptible to damages from external stresses in the first place (Smit et al. 2000). They contrast this definition with that proposed by Pimm (1984), for whom the appropriate measure is the ability of the system to resist disturbance and the rate at which it returns to equilibrium following disturbance (Pimm 1984; Tilman and Downing, 1994).

Though there are commonalities in the terms used to define resilience above (for example; *ability of a systems* – Ludwig et al. 1997; *self-organise* – Klein, 2002; *disturbance and maintain* – Gunderson and Holling, 2001 and *still persist* – Carpenter et al. 2001); the distinction in above definitions has been useful in the area of socio-ecological research due to variability in this socio-ecological systems and different disturbances perturbed therein. In his research, Holling (1996) distinguished two types of resilience that have been applied by ecologists; one is engineering resilience and the other is ecological resilience. However, when defining resilience we also need to consider which socio-ecological systems are we dealing with so as to be clear on what and how resilient that system is compared to the amount of external pressure exerted and how the system is coping with a given amount of disturbance? The notable definition in the framework includes Walker et al. 2004 who defined resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks." It refers to the capacity of a social-ecological system both to withstand perturbations from, for instance, climate or economic shocks and to rebuild and renew itself afterwards (Stockholm Resilience Centre 2007). The IPCC-WG2 (2007) provided comprehensive definition on the same framework as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.

Based on the above interpretation, Carpenter et al. (2001) noted that resilience has the following three properties: (a) the amount of change the system can undergo (and implicitly, therefore, the amount of extrinsic force the system can sustain) and still remain within the same domain of attraction (that is, retain the same controls on structure and function); (b) the degree to which the system is capable of self-organization (versus lack of organization, or organization forced by external factors); and (c) the degree to which the system can build the capacity to learn and adapt. These properties are brought about due to the fact that resilience is a more difficult property to know and understand because of the patterns of occurrence and its impacts therein. Part of that difficulty is that there are few (if any) direct metrics or measures of ecological resilience (Carpenter et al. 2001). According to Carpenter (2003) one reason is that thresholds (or boundaries) between alternative regimes are the result of multiple factors and are constantly changing. Another reason that it is difficult to measure and assess ecological resilience is because it is an emergent property of the system, and only recognized when it is declined (Carpenter et al. 2001).

The loss of resilience is revealed when a disturbance that had previously been absorbed by the system all of the sudden creates a regime shift. Resilience can also be thought of as the capacity to endure shocks and stresses and bounce back; individuals or communities that can ride out the difficulties that life might bring without their overall situation deteriorating. Even when affected by significant hazard events, or by longer term negative trends, they must be able to recover or adapt their livelihoods and continue to improve their lives and move out of poverty (Pasteur, 2011). Increasing people's resilience means addressing the factors that underlie their vulnerability as illustrated in figure 3.1 above. Carpenter et al. (2001) asserts that improving the ability to manage risk, adapt to new changes and diversify security of their livelihoods. This means that they have more options available, and can chose to live or work in areas less exposed to hazards, or at least have more resources to draw on in order to cope and recover when they are affected by negative events (see figure 3.3 below).

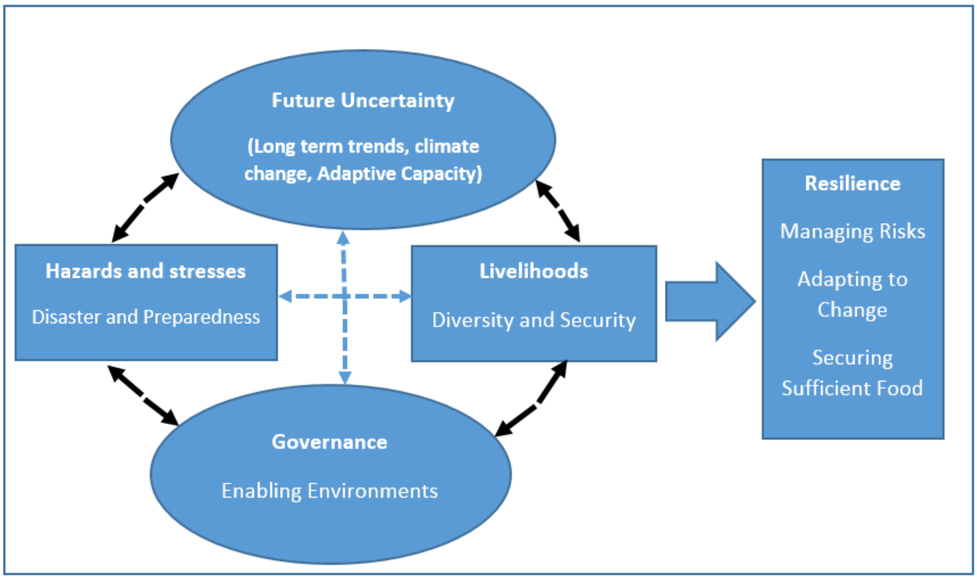

Figure 3.3: Resilience framework. Source: Pasteur, 2011.

Based on the above explanations and illustration; in other words, the scholars are trying to explain resilience as the ability of a systems to *respond, adapt* and *cope* with the situation when exposed to stress/shock (variable agents of changes) and at the same time to continue provide functional services while undergoing *transformation*. Resilience has multiple levels of meaning: as a metaphor related to sustainability, as a property of dynamic models, and as a measurable quantity that can be assessed in field studies of socio-ecological studies (Carpenter et al. 2001). The operational indicators of resilience have, however, received little attention in the literature. To assess a system's resilience, one must specify which system configuration and which disturbances are of interest. In this research, I have focused on Folke (2006); who described the evolution of the concept's meaning in ecology and in social-ecological systems analysis such as dry land irrigation farming schemes. The question of what are the response and coping strategies local farmers use to mitigate climate change impact in the study area was posed? Innovative response mechanisms developed by local farmers to counteract the effects of climate change were studied and analysed to understand how resilient the dry farming scheme is to climate change? Different attributes to resilience such as innovative farming practices, intercropping and using crop varieties; increased use of water and soil conservation techniques; diversification from farm to non-farm activities such as casual labour and migration to other places in search for water have been assessed. Other factors include different coping strategies used by the farmers have been studied as well.

As pointed out by Majule and Mwalyosi (2003); dry land irrigation farming schemes is dynamic process that varies geographically and irrigating communities are capable of assimilating and adapting outside knowledge and experiences so as to improve their own situation. However; with current climate change impacts, the dry farming schemes has become more vulnerable (*exposed, susceptible and sensitive*) and at the same time continue to build resilience (*respond, adapt and cope*) to the situation while providing the required services/output. The combined vulnerability and resilience framework here will also includes economic and social-cultural resources available to different groups of dry farming farmers for adaptation and also provides a capability for assessing synergies and tradeoffs with other environmental conditions and trends (*e.g.* land use, soil characteristics and water availability) that will condition climate-related impacts. In order to fully understand the rationally behind the vulnerability and resilience theory, there are number of crucial terms that needs to be studied and understood in a local context. Some of these terms stated ad defined above include *exposure, sensitivity, susceptibility, response, adapt, cope, and transformation*.

3.7 The Combined Conceptual Framework of Resilience and Vulnerability

Daniel (2011) explains resilience and vulnerability as concepts that are complementary in nature linked through socio-ecological system dynamics in face of disturbances. Miller et al. (2010) strongly advocated that vulnerability and resilience approaches in concert can provide new avenues to tackle uncertainty and environmental change fuelled by global warming (climate change). In a similar light, Walker et al. (2002) highlighted the important role socio-ecological systems could play in face of climate change. The authors highlighted points of convergence in theory, methodology and policy formation wherein resilience and vulnerability can lend support to each other since both concepts evaluate aspects of socio-ecological systems. To understand the above relationships there is a need to design a conceptual framework that can guide this study on which parameters to be assessed in the field. The following diagram (figure 3.4) depicts the conceptual framework that will guide data collection in this study.

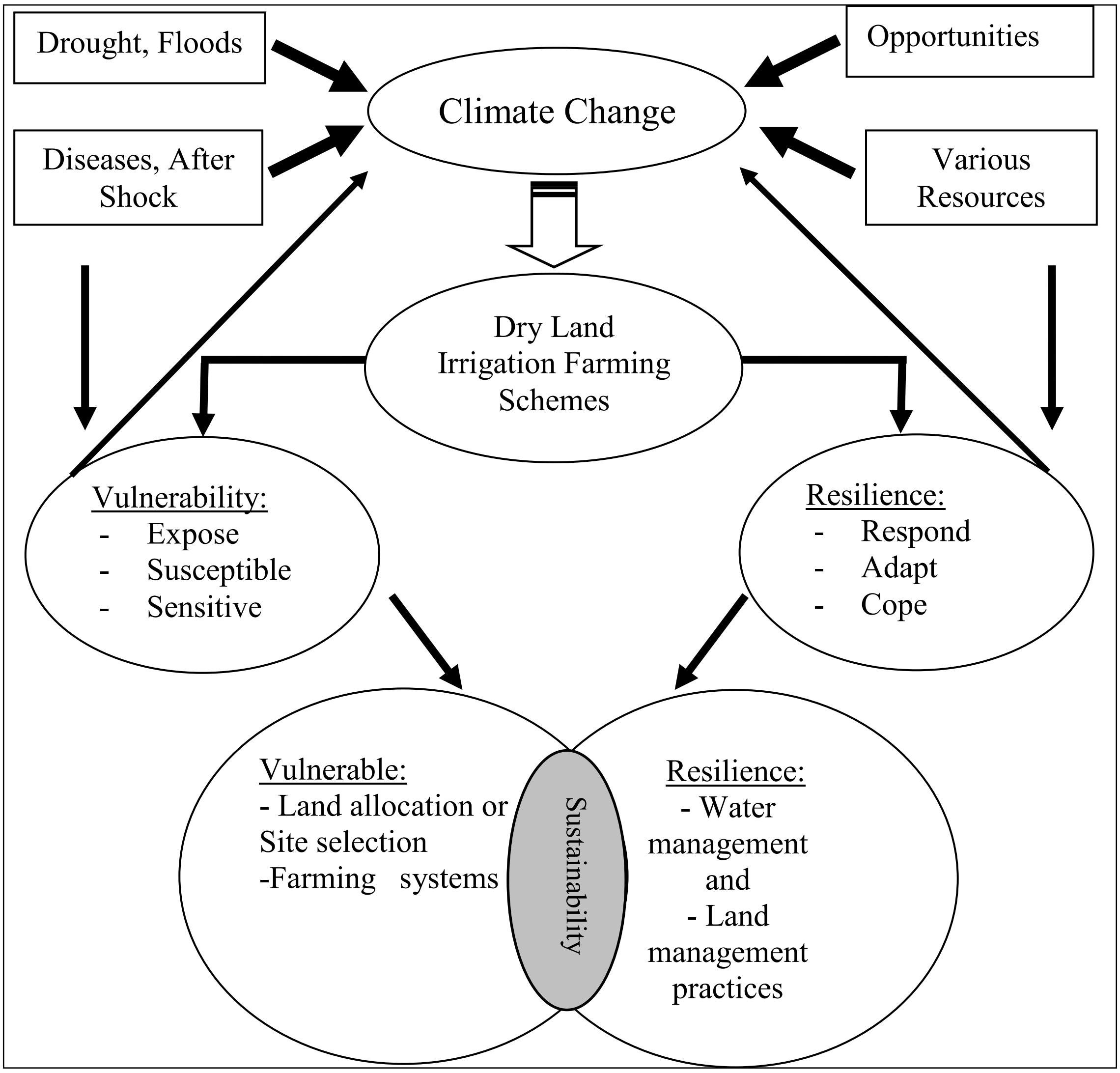

Figure 3.4: The combined conceptual framework for vulnerability and resilience. Source: Mhagama, 2014.

Just like any other socio-ecological systems, dry land irrigation farming schemes can be subjected to many stress/shock by a number of influencing factors (Folke, 2006). The rationale behind this framework is to identify factors contributing to vulnerability and resilience of dry land irrigation farming schemes against climate change. These factors influence dry land irrigation farming schemes in a number of ways such as *exposing* and making the farming schemes *susceptible* and *sensitive* to climate change impact such as drought and floods. However, at the same time local farmer's may use different dry land irrigation farming schemes and management practices to *respond, adapt* and *cope* with the changing climate which make the dry land irrigation farming schemes develop resilience against climate change. By understanding the vulnerability and resilience of dry land irrigation farming schemes against climate change it will be easier to help the local farmers to transform the farming systems and make it a more self-sustainable while continuing to provide the basic function in the face of climate change (Walker et al. 2004).

3.8 Summary

This chapter provided an overview of conceptual framework and key concepts used in vulnerability and resilience assessments. It has attempted to provide a clear and lucid account of the relevant theories and concepts on which this study is conceptualised and based. Different theories of vulnerability were described as discussed by White (1974); Sen (1981); Agder (2006) and Turner et al. (2005). The study adopted the definition provided by Füssel (2005) and IPCC (2014). The cause of vulnerability was described as it is rooted in the context of natural hazards and sustainability science. Furthermore, the multidimensional causes of vulnerability such as exposure to external factors (bio-physical-*temperature* and *rainfall*) and internal factors (social system-*farming schemes*) were also described and elaborated in the context of dry land irrigation farming schemes.

The three major conceptual approaches to analyzing vulnerability to climate change including the socio-economic assessment, the biophysical (impact assessment), and the integrated assessment approaches were clearly described in this chapter. After a clear analysis of these three elements; the chapter focused on integrated approach to vulnerability assessment to climate change impacts as it provides an idepth analysis of both the human systems (farmers) and socio-ecological systems (dry land irrigation farming schemes). The basic components of vulnerability expressed in integrated approach in IPCC (2014); as the positive function of exposure and sensitivity and negative function of adaptive capacity were described here. Additionally, advances the understanding of vulnerability and attention were given to the adaptive capacity, interconnectedness, links and the way various elements within socio-ecological resilience framework have possibly explained vulnerability and resilience in the study area. Finally, the chapter descibed resilience of dry land irrigation farming schemes and used different factors such as exposure and sensitivity and adaptation strategies as well as coping strategiesto portray the combined conceptual framework which guided this study.

CHAPTER 4: RESEARCH METHODOLOGY

4.0 Introduction.

This chapter presents Research Methodology employed in this study. It provides detailed description of the research area from a broader perspective, Tanzania, to a narrow specific overview South Eastern Tanzania capturing the dry land irrigation farming schemes along the Ruvuma Basin. The chapter starts by providing details of research design and research approaches that have been undertaken in this study. It provided detailed analysis of both approaches (quantitative, qualitative and mixed research approaches) and the final pathway for the research study. It also captures various aspects related to research methods, techniques and methodology employed in this study including: design and approach of the research; sampling; data collection methods as well as instruments; reliability and validity issues; and data processing, analysis and presentation. The chapter described how to assess vulnerability and resilience uing different methods. It further describe the geographical location of the study area and provided socio-demographic characteristics of the households in the study area.

4.1 Research Design

Research designs are important because they provide road maps for how to rigorously conduct studies to best meet certain objectives as well as guiding the researchers during data interpretations and reporting at the end of studies (Criswell, 2003; Bazely, 2004; Driscoll et al. 2007; Terrell, 2012). Creswell (2014) define research design as a comprehensive description of the plan that indicates how systematically a scientific study is going to be conducted. He explains further that research design describes the research methodology, which includes approaches and research styles such as survey; descriptive, exploratory, case study, longitudinal, cross-sectional, correlation and so forth; and kinds of data required (quantitative, qualitative or both); the population and sampling process (for example, sample size and access, type and so on). Cohen et al. (2007) describes other aspects of research design which includes data collection methods to be used like questionnaires; interviews; observation, and documentary reviews; validity and reliability issues and data analysis plan (Jackson, 2009).

Generally, there is no single blueprint for a research design (Cohen et al. 2007). For example, Creswell et al. (2003) argues that in one study, research design may reflect the entire research process, from conceptualizing a problem to the literature review, research questions, methods, and conclusions; whereas in another study, research design refers only to the methodology of a study (*e.g.,* data collection and analysis) (Aliaga and Gunderson, 2002). In this study, the conceptual framework and research questions addressed in chapter 2 were used as the driving force behind the choice of a research design and any changes that were made to the elements of the design during field data collection. The study used a case study as a research design. The design allows data to be collected at a single point in time without repetition from the target population (Yin, 2003; Wynsberghe and Khan, 2007; Babbie, 2010).

According to Yin (2003); case study involves the detailed description and analysis of a single person, group, system, process, or other entity at one point in time and in great detail. It is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Gomm et al. 2000; George and Bennett, 2005; Yin, 2009). The objective is often to determine how the object of study works and to identify the factors or dynamics that lead to success or failure. The case study research design was adopted in this research so as to understand how dry land irrigation farming schemes are exposed to climate variability and why deference levels of exposure and sensitivity exists within different irrigation farmers at a particular point in time (farm level/village). In the study area, the research design consisted of two parts: collection of bio-physical data (temperature and rainfall data from Tanzania Meteorological Weather Station and future climate projections from IPCC) and social attributes/data from dry land irrigation farmers. Field observation and interviews were also scheduled to supplement information collected in both cases. Apart from its ability to be used for data collection on relevant variables within a short time frame, the research design was also opted due its advantages. Some of these advantages include the ability to collect data on many variables at a time, data collection from a large number of a sample population, data collection from a dispersed study population, data collection on attitudes and behaviours of a study population (Gomm et al. 2000; Wynsberghe and Khan, 2007; Yin, 2009; Babbie, 2010).

Other benefits of case study research design includes ability to use more than one research methods for data collection in the field accommodating different data collection techniques (Yin, 2003; George and Bennett, 2005; Wynsberghe and Khan, 2007). George and Bennett (2005); explains that case studies typically employ more than one research method and for this reason they tend to fit the definition of "Multiple Method Research". For example in a case study, a researcher might conduct a trend analysis, cross sectional study, a survey, an observational study, and an experiment, or some combination of all of these methods (Yin, 2003). Yin (2009) explains further that one part of a case study may use quantitative methods while another part uses qualitative or naturalistic methods approach. Because of the use of multiple methods, case study designs are closely connected to ethnographic designs and to anthropological designs, even though the latter are generally thought of as "qualitative research". However, when dealing with case study research design, essential research skills and great care should be observed as both types of data can be highly complex, demanding analytic techniques going well beyond simple coding and tallies (Yin, 2003; Baxter and Jack, 2008).

4.2 Research Approaches.

Research approaches are plans and the procedures for research studies that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation (Creswell, 2003). The common traditional research methodology or approach includes quantitative research and qualitative research (Bailey, 2004; Creswell, 2014). Johnson and Onwuegbuzie (2004); argues that for many years, quantitative and qualitative research approaches have been in debate challenging each other on positivist and constructivist philosophical approach as well as practical deficiencies and strengths for each research approach. The debates also stems from traditional definitions (Creswell, 2003), nature of knowledge inquiry (Babbie, 2010); methods of data collection (Bailey, 1994) as well as data analysis (Johnson and Christensen, 2004). For example Aliaga and Gunderson (2002); define quantitative research approach as, "explaining phenomena by collecting numerical data that are analysed using mathematically based methods". Here the quantitative collection of information is in form of numbers and using quantitative analysis to addresses the question of "what, where and when (Cohen et al. 2007). The methodology employed is based on the testing of hypotheses deduced from theory and using statistical inference the results may be generalised to the population.

Qualitative research approach, on the other hand, involves collecting non-numerical data and using qualitative form of analysis to explain phenomena (Creswell, 2012). Qualitative research method aims to provide an in-depth understanding of why things are the way they are, why people for example behave the way they do and other similar questions that can explain behaviours and attributes of an object under study (Babbie, 2010). Creswell (2014) adds that its aim is not to impose preordained concepts; hypotheses and theory that are generated during the course of conducting the research as the meaning emerges from the data. Statistical inference is not the objective, although within government, results are used to inform policy and therefore some form of generalisation or transferability is implicit (Cohen et al. 2007; Babbie, 2010).

Both quantitative and qualitative research approach may employ similar methods during data collection, such as interviews or observations (Babbie, 2010). However, quantitative approaches use more closed-ended approaches in which the researcher identifies set response categories (Creswell, 2003); whereas qualitative approaches use more open-ended approaches in which the researcher asks general questions of participants, and the participants shape the response possibilities (Aliaga and Gunderson, 2002). Several differences have been noted, for example it's difficult to explain why things behave the way they do in quantitative research while at the same time it is difficult for qualitative research to separate into clear steps mainly because various parts of the research process are interrelated and interlinked (Creswell, 2014). Depending on the subject of inquiry and application, both quantitative and qualitative approaches have their strengths and weaknesses but can lead to fruitful answers by addressing the right questions. To address those limitations, using them in combination is the best way to bring in the best qualities for each one of them (Johnson and Onwuegbuzie, 2004). This enhances flexibility of the researcher to use different investigative techniques and ability to address several emerging questions well without being bound by the myth of either qualitative research approach or quantitative research approach.

Several authors indicate that there is no single blueprint that exists for a research methodology (Bazely, 2004; Stange et al. 2006; Creswell and Garrett, 2008; Venkatesh, et. al. 2013). Today, there is still a broad range of approaches and strategies for undertaking research (Creswell, 2014), which on one hand, they offer the researcher an opportunity to choose the best among many available options while on the other hand, they may pose a great challenge for the researcher due to the fact that having many options may lead to confusion (Creswell and Clark, 2011) or if one is not careful, there is a risk of choosing an inappropriate option (Bazely, 1994). This can be achieved by proper research design which is governed by the notion of 'fitness for purpose'. Cohen et al. (2007) further explains that the purposes of the research determine the methodology and design of the research. For example, if the purpose of the research is to map the field, or to make generalizable comments then a survey approach might be desirable (de Vaus, 2002), using some form of stratified sample; if the effects of a specific intervention are to be evaluated then an experimental or action research model may be appropriate (Aliaga and Gunderson, 2002); if an in-depth study of a particular situation or group is important then an ethnographic model might be suitable (Crotty, 1998).

Furthermore in order to avoid possible confusion during research planning, Crotty (1998) suggest that one needs to consider, the theory of knowledge rooted in the theoretical perspective (epistemology); the methodology intended to be used (such as case study, survey research); and the methods, the techniques as well as data collection procedures to be used (for example, questionnaire, interview, focus group and the like). Thus, there is wide consensus that mixing different types of research methods can strengthen a research study. This calls for a need to combine more than one research methodology or using multiple research methodology such as multi-research methods (Stange et al. 2006) and mixed research methods (Terrell, 2012). Venkatesh et al. (2013) define a *multi-research method* as one which uses two or more research methods, with or without being restricted to a single research paradigm while *mixed research method* involves mixing both qualitative and quantitative methods of data collection and analysis in a single study (Terrell, 2012). It involves integrating quantitative and qualitative approaches to generating new knowledge and can involve either concurrent or sequential use of these two classes of methods to follow a line of inquiry (Stange et al. 2006; Cohen et al. 2007). The table 4.1 below provides details on the three research approaches described above.

Table 4.1: Features of a quantitative, qualitative and mixed research approaches

Criteria	**Quantitative Approach**	**Qualitative Approach**	**Mixed Approach**
Scientific Method	Deductive or "top-down" *Test theory with data.*	Inductive or *"bottom-up" Generate new hypotheses and theory from data collected.*	*Deductive and Inductive*
Most common research objectives	Description Explanation *Prediction*	Description *Exploration* Discovery	*Multiple objectives*
Focus	Narrow-angle lens Testing specific hypotheses.	Wide and deep-angle lenses *Examine the breadth and depth of phenomenon* to learn more about them.	Multi-lens
Nature of study	Study behaviour under artificial, controlled conditions.	Study behaviour in its *natural environment* or context.	Study behaviour in *more than one context* or condition
Form of data collected	Collect *numeric data* using structured and validated instruments (*closed-ended survey items*, rating scales, measurable behavioural responses)	Collect narrative data using semi- or unstructured instruments (*open-ended survey items, interviews, observation, focus groups*)	Multiple forms
Nature of data	Numeric variables.	Words, images, themes, And categories	Mixture of numeric variables words, images
Data analysis	*Identify statistical relationships.*	*Holistically identify patterns*, categories, and themes.	*Statistical and holistic*
Results	Generalizable findings. *General understanding of respondent's* viewpoint. Researcher framed results	Particularistic findings. *In-depth understanding of respondent's* viewpoint. Respondent framed results.	*Corroborated findings that may be generalizable.*
Form of final report	Statistical report including *correlations, comparisons of means*, *and statistically significant* findings.	Narrative report including *contextual description*, categories, themes, and *supporting respondent.*	Statistical findings with *in-depth narrative description* and identification of overall themes.

Source: Adapted from Johnson and Christensen, 2004.

Though there is a great need to use multiple research methods, it is vital to pick a research approach and methods which are relevant, depending on the problem addressed and research question (s) employed in the research study. A more elaborate definition would specify the nature of data collection (*e.g.* whether data are concurrent or sequentially), the priority each form of data receives in the research report (*e.g.* equal or unequal), and the place in the research process in which "mixing" of the data occurs such as in the data collection, analysis, or interpretation phase of inquiry (Stange et al. 2006; Cohen et al. 2007; Terrell, 2012; Venkatesh et al. 2013). Combining all of these features into a single definition, Creswell et al. (2003) suggests the following definition:- "A mixed methods study involves the collection or analysis of both quantitative and/or qualitative data in a single study in which the data are collected concurrently or sequentially, are given a priority, and involve the integration of the data at one or more stages in the process of research". In this study; I used a mixed research approach which involves mixing both quantitative and qualitative methods of data collection and analysis in a single case study using concurrent mode of data collection, analysis and presentation of results (refer to the definition of mixed research methods above).

The actual terms used to denote a mixed methods study vary considerably in the planning and procedures of any research design and has evolved over time. For example; different writers for example have referred to it as multi - methodological research (Hugentobler et al, 1992); combining qualitative and quantitative research (Creswell, 2003); integrating qualitative and quantitative approaches (Bazely, 2004); merging qualitative and quantitative data in a mixed method research (Driscoll et al. 2007; Creswell and Garrett, 2008) and mixed methods research (Terrell, 2012; Creswell, 2015). Central to all of these terms is the idea of combining or integrating different research methods so as to provide an umbrella term to cover the multifaceted procedures of combining, integrating, linking, and employing different methods in one case study (Bazely, 2004; Terrell, 2012; Venkatesh et al. 2013). Combining multiple methods (mixed research method approach) have been proved to be beneficial as it provides a better understanding of a research problem than either quantitative or qualitative data by itself. Several authors (Creswell, 2003; Bazely, 2004; Terrell, 2012; Venkatesh et al. 2013; Creswell, 2015) have increasingly recognized the advantages of mixing both quantitative and qualitative data collection in a single case study. Numerous mixed methods studies have been reported in the scholarly journals for social scientists to see and use as models for their own studies. In addition, authors have delineated more carefully a definition for mixed methods research, although consensus has been slow to develop for a single definition recognized by all inquirers (Creswell et al. 2003).

Several authors recommend that using mixed methods approach allows a researcher to the following purposes: looks for convergence as well as substantiation of results from different methods studying the same phenomenon (Driscoll et al. 2007); makes elaboration, enhancement, illustration and clarification of results from one method with results from the other method (Vekantesh et al. 2013); uses results from one method to help inform the other method (Bazely, 2004); discovers paradoxes and contradictions (Johnson and Onwuegbuzie, 2004) that lead to re-framing of the research question(s) (Caruth, 2013); and seeks to expand the breadth and range of inquiry by using different methods for different inquiry components. Venkatesh et al. (2013) presented seven purposes for a mixed research method. These seven purposes are: complementarity, completeness, developmental, expansion, corroboration or confirmation, compensation, and diversity (Table 4.2).

Table 4.2 Purposes of Mixed Methods Research

Purposes	**Description**
Complementarity	Mixed methods are used in order to gain complementary views about the same phenomena or relationships.
Completeness	Mixed methods designs are used to make sure a complete picture of a phenomenon is obtained.
Developmental	Questions for one strand emerge from the inferences of a previous one (sequential mixed methods), or one strand provides hypotheses to be tested in the next one.
Expansion	Mixed methods are used in order to explain or expand upon the understanding obtained in a previous strand of a study.
Corroboration or Confirmation	Mixed methods are used in order to assess the credibility of inferences obtained from one approach (strand).
Compensation	Mixed methods enable to compensate for weaknesses of one approach by using the other.
Diversity	Mixed methods are used with the hope of obtaining divergent views of the same phenomenon.

Source: *Adapted from Venkatesh et al. 2013.*

4.3 Case Study Research Methods.

Case study method has attained routine status as a viable method for doing social science and education research (Yin, 2003). The concept of case study has been broadly used in research context in connection with the term “case” which is defined as a spatially delineated phenomenon or a unit observed at a single point in time or over some period of time (Gerring, 2007). According to Yin (1994); a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. Gerring (2004) add-up that case study as research design is best defined as an intensive study of a single unit (a relatively bounded phenomenon) where the scholar’s aim is to elucidate features of a larger class of similar phenomenon. Other scholars such as Woodside (2010) had broadened the definition to include description, understanding, prediction and/or controlling individual case, which can be a person, household, village, group, process, organization, culture, nationality and so forth. Wynsberghe and Khan (2007) redefine case study as a relevant and trans-disciplinary heuristic that involves the careful delineation of the phenomena for which evidence is being collected (event, concept, scheme, program, process, etc.). Here by trans-disciplinary, case study is described as no particular disciplinary orientation; that is, it can be used in social science, science, applied science, business, fine arts, and humanities research while heuristic is viewed as an approach that focuses one’s attention during learning, construction, discovery, or problem solving (Wynsberghe and Khan, 2007).

Case study research enables the researcher to investigate important topics not easily covered by other methods such as survey and experiment. Woodside (2010) proposes that the principal objective of the case study researcher is to develop deep understanding of actors (in a specific case), interactions, sentiments, and behaviours occurring for a specific process through time. Through case study, a researcher investigates intensely at an individual or small participant pool, drawing conclusions only about that participant or group and only in that specific context. In brief the case study method allows investigators to retain the holistic and meaningful characteristics of real-life events (Yin, 2004); while enabling them to describe and understand individual or group (Woodside, 2010) and predict or draw conclusion about the case being studied or observed (Onatu, 2013) at a single point in time or over a short period of time. A case study is especially suitable for learning more about a little known or poorly understood situation such as climate change variability. Leedy and Ormrod (2005) argue that case study, as a research methodology may also be useful for investigating how an individual or programme changes overtime, perhaps as the result of certain circumstances or interventions.

The most notable features of case study research design are the use of small number of unit studied (Woodside, 2010); the contextual and natural setting (Wynsberghe and Khan, 2007); deeply and thoroughly study of a social unit (Yin, 2003); ability to combine qualitative and quantitative data (Yin, 2004); covering sufficient wide cycle of time (Onatu, 2013) as well as boundedness and extendability (Gerring, 2007). One of the salient key feature of the case study research design is the use of multiple sources of evidence, each with its strengths and weaknesses because no one kind or source of evidence is likely to be sufficient on its own (Gillham, 2000). This feature becomes very important in ensuring validity of data collected (Baker et. al. 2012); however many research investigators nevertheless have disdain for the strategy (Flyvbjerg, 2004). This is because, case studies have been criticized by some scholars as lacking scientific rigour and reliability and that they do not address the issues of generalizability (Flyvbjerg, 2004; Mohd Noor, 2008). Woodside (2010) and Onatu (2013) dispute the above argument and substantiate that there are some strengths of case study as it enables the researcher to gain a holistic view of a certain phenomenon or series of events and can provide a round picture since many sources of evidence are used. According to Flyvberg (2004); case study seek to transcend this problem of relevance by anchoring their research in the context studied. Furthermore, case studies are relevant to solve a problem that seeks a holistic understanding of the event or situation in question using inductive logic-reasoning from specific to more general terms (Becker et al. 2012).

For case studies research, four major types of designs are relevant, following a 2 x 2 matrix (Yin, 2009). Barkley (2006) identified four main types of case study research designs, namely, single-case against multiple-case studies and holistic against embedded case studies. The first pair of categories is based on the number of cases in the research design (single-case vs. multiple-case) while the second pair, can occur in combination with either of the first pair, is based on the unit or units of analysis to be covered, and distinguishes between holistic and embedded designs (Barkley, 2006). According to Yin (2003), a researcher can choose to use either a holistic case study or to have embedded sub-cases within an overall holistic case depending on the research design and type of data to be generated. Other scholars such as (Hancock and Algozzine, 2006; Baxter and Jack, 2008; Becker et al. 2012) identified four types of case studies, namely, illustrative (which are basically descriptive, utilizing one or two instances of an event to describe how a situation is like); exploratory (condensed type of case studies undertaken prior to implementing a large scale investigation of a phenomenon); critical instance case studies, which examine one or more sites for various purposes such as generalizability or challenging a highly generalized or universal assertion; and cumulative case studies, which, as the name suggests, they aggregate information from several sites collected at different times to see if it is possible to allow for generalization without additional cost to a new study on a particular phenomenon.

Baxter and Jack (2008); explain that case study research is concerned with investigating single or multiple units of study, using familiar research methods for data collection such as interviews or surveys. Case studies are empirical investigations, in that they are based on knowledge and experience, or more practically speaking involve the collection and analysis of data (Hancock and Algozzine, 2006; Yin, 2009). By circumscribing the area of a study to a small number of units, the case study researcher is able to look in depth at a topic of interest or phenomenon. According to Onatu (2013); case study use a logical model of proof that allows the researcher to draw inferences concerning causal relations among the variables under investigation. Another way of thinking about a case study research design is as a “blueprint” of research, dealing with at least four problems: what questions to study, what data are relevant, what data to collect, and how to analyze the results (Baxter and Jack, 2008; Woodside, 2010). Case study research is versatile in that the variety of data collection methods at the disposal of the case study researcher can be adapted to particular situations and conditions (Yin, 2009). There are several advantages of using case study research design in comparison to other research strategies (Table 4.3).

Table 4.3. Comparison of case study research (experimental and survey approaches).

Experimental	**Case Study**	**Survey**
Small number of units	Small number of units (sometimes one)	Larger number of units
Data collected and analysed about small number of predetermined features of each unit	Data collected and analysed about large and often not predetermined features of each unit	Data collected and analysed about a small number of features of each case
Study of units organized in such a way as to control variables of interest	Interest in naturally occurring features or the variables in context	Units selected to represent characteristics of the study's population
Data usually quantified	Data can be quantitative, qualitative or both	Data usually quantified
Aim is of testing theory or evaluation of an intervention	Aim is to understand and theorize through enfolding the literature	Aim is to generalize findings from sample to population

Source: *Adapted from Gomm et al. 2000.*

However, like in other research designs case study method has its own strengths and weaknesses. The following table 4.4 indicates some strength and weakness of case study research design.

Table 4.4. Strength and weakness case study research design.

Strength	**Weakness**
Investigates a contemporary phenomenon within its real-life context.	Different relevant actors had different values which can limit access to information.
Identify and measure the indicators that best represent the theoretical concepts the researcher intends to measure.	May be prone to versions of "selection bias" that concern statistical researchers.
Comparatively flexible method of scientific research allowing the researcher freedom to discover and address issues as they arise in the real context.	They are challenged that they are difficult to generalize because of inherent subjectivity and because they are based on qualitative subjective data, generalizable only to a particular context.
Emphasize on deep data or thick description, information is based on particular contexts, giving rise to research results with a more human face.	They can also be time consuming since a deep understanding of the case is sought hence requiring more time for the study.
They are much appropriate in dealing with creativity, innovation, and context unlike homogeneous and routine behaviours.	They may also require more resources because they normally involve learning more about the subjects being tested than most researchers would care to know, for example, educational background.
Case studies produce much more detailed information than what is available through a statistical analysis.	Time consuming and multiple skills are required

Source: *George and Bennett, 2005; Yin, 2009 and Dawidowicz, 2011.*

In many researches as case studies include both single and multiple-case studies (Yin, 2009; Berkley, 2006); some case study research goes beyond being a type of qualitative research, by using a mix of quantitative and qualitative evidence (Baxter and Jack, 2008). In this study I used a mixed research approach with case study methods, combining both quantitative and qualitative research methods of data collection and analysis. This in turn allows data to be collected at a single point in time without repetition from the target population and reduces time. The conceptual framework and research questions in this study were used as the driving force behind the choice of a research design and any changes that were made to the elements of the design during field data collection. Both quantitative and qualitative methods were concurrently used to collect data in a single phase of data collection. Based on Creswell (2003) and Terrell (2012); triangulation strategy was used in the concurrent mixed research method approach where equal priority was given during quantitative and qualitative data collection phases.

The research design consisted of two parts: the first part included collection of quantitative data i.e. Bio-physical data (long term temperature and rainfall records from Naliendele Agricultural Research Institutes – part of Tanzania Meteorological Weather Station in Mtwara region and future climate projections from IPCC) and collection of social attributes/data through a questionnaire survey administered to smallholder dry land irrigation farmers from six villages in the study area. The second part consisted of qualitative methods collecting data from interviews conducted to experts, selected elders and local leaders, while Focus Group Discussions (FGDs) were also conducted to selected smallholder dry land irrigation farmers. In some cases field observation was conducted concurrently during field interviews with farmers so as to supplement information collected in both cases. Three districts each with two villages were selected based on dry land irrigation farming schemes. The irrigation farming schemes are small scale, constituting less than one ha in size planting single or mixed variety of green vegetable crops.

Use of mixed methods is normally credited for generating comprehensive research data (Yin, 2003; Bazely, 2004); which was also found to be a useful approach for the same purpose in this research study. The primary purpose of using concurrent mixed research approach is confirmation, corroboration or cross-validation within a single study (ensuring better data quality, validity and reliability). The methods incorporate shorter data collection time when compared to sequential methods. Triangulation was necessary as means to strive for convergence and validation of results from quantitative and qualitative research approaches (Terrell, 2012). The mixed method research approach helped to ensure that research questions were comprehensively answered through use of many sources of information. Furthermore, in order to address weaknesses inherent in the use of a single study research method using mixed research approach (quantitative and qualitative) in combination is the best way to bring in the best qualities for each one of them (Bazely, 2004; Johnson and Onwuegbuzie, 2004). Mixed research method approach also enhances flexibility of the researcher to use different investigative techniques and ability to address several emerging questions well without being bound by the myth of either qualitative research approach or quantitative research approach. Using this level of flexibility, it is possible for a researcher to adjust case studies to effectively address various research situations and contexts (Dawidowicz, 2011). Teddlie and Tashakkori (2008); strengthen the argument that studies that combine both aspects (quantitative and qualitative) can provide comprehensive insights into all types and levels of questions.

The adoption mixed research methods with a case study research was relevant so as to have a comprehensive understanding of how dry land irrigation farming schemes are exposed to climate variability in the study area and why deference levels of exposure and sensitivity exists among different irrigation farmers at a particular point in time (farm level/village). Using this broad, multiple data sources allow researchers to gain in-depth knowledge about a given bounded case (Bazely, 2004; Stange et al. 2006). According to Caruth (2013) and Venkatesh et al. (2013); the use of a wide variety of data sources such as observations, interviews, questionnaire *etc.,* in a mixed research methods through a case study design can help a researcher to have a comprehensive view of factors involved in a phenomenon studied. The use of mixed research approach with a case study design in turn, was helpful in explaining different social attributes or factors which makes the dry land farming schemes in the study area more vulnerable to climate change apart from climate variability alone. Generally, use of mixed research method (both quantitative and qualitative methods) in form of triangulation was helpful in supporting this research study as it helped the researcher in various aspects such as obtaining a variety of information on vulnerability and resilience of dry land irrigation farming schemes; use strengths of each method to overcome deficiencies of each other; achieve a higher degree of validity and reliability of results; and overcome deficiencies of a single method.

4.4 Measuring Vulnerability and Resilience

Tanzania like other third world countries has started to experience significant climate variability and climate change impact (IPCC, 2014). Researches done by Yanda and Mubaya (2011) and NAPA (2007); have shown that over the past years the climate in regions throughout the country has changed significantly affecting various aspects of human life and different ecosystems. These studies indicates that by the end of the century, average temperatures are projected to increase between 1.9 ^{0}C and 3.6 ^{0}C while rainfall is said to decrease in the dry season and it is expected to increase during the rainy season, leading to a growing risk of floods, water shortage and related conflicts. According to Shemsanga et al. (2010); these changes will affect many key sectors, possibly affecting agricultural production, health, water availability, coastal zones, energy use, infrastructure, and biodiversity and ecosystem services (including forestry and tourism). Any effects and impacts of climate change posited on a region or sector is likely to have disproportionately strong effects on the poor, as such vulnerable groups who have fewer resources to adapt to climatic change (O'Brien et al. 2005; URT, 2007; Deressa et al. 2008). For example, the rising temperature and changing rainfall pattern can affects agricultural production differently (rainfed agriculture versus irrigation famers) as a result of exposure to extreme climate change events such as drought or floods and availability of resource to cope and adapt to these changes. This implies that it is difficult to measure and quantify vulnerability and resilience by generalizing the concept without focusing on its specific aspects and variable of concerns.

Many researches in climate change fields have struggled to find suitable metrics for vulnerability and resilient of various socio-ecological systems (Luers et al. 2003; Adger, 2006; Deressa et al. 2008). The common form of vulnerability and resilient measurement is by using econometric or indicator methods through assessment of biophysical and social-economic aspects of a socio-ecological system (Deressa et al. 2008). The struggle to find suitable measurement is contributed by the fact that the term vulnerability and resilience are dynamic phenomenon, often in a continuous state of flux by both biophysical and social processes that shape local conditions and the ability to cope (O'Brien et al. 2005). Carpenter et al. 2001; cautioned that vulnerability and resilient indicators are both fluid and flexible, since indicators that are appropriate for the current regime may become useless as ecological and social conditions shift.

The existence of variation in vulnerability and resilient assessment has been also contributed by scholars from different fields of specialization having a tendency to conceptualize the terms differently based on the objectives to be achieved and the methodologies employed in a particular research (Luers et al. 2003; Turner et al. 2003; O'Brien et al. 2004; Adger, 2006; Cardona et al. 2012). Other researchers suggested different forms of vulnerability assessment and measurements such as using stakeholder participatory assessment (Isabel, 2012); mapping vulnerability using selected variables of concern to specific sets of stressors (Gbetibouo, and Ringler, 2009) and measuring vulnerability using integrated/mixed method approach (Deressa et al. 2008).

Edger (2006) argue that vulnerability and resilience can not easily be reduced into a single metric and not easily quantifiable using a single aspect of measurement unit such as exposure to external stimuli or availability of resource to cope with stresses. Clearly, there are advantages and drawbacks to each methods or approach used in vulnerability and resilient assessment for different socio-ecological systems. CAADIP (2011) suggested that the task is to choose an appropriate approach that corresponds best with the objective of the research, research methodology and data analysis and its intended use of the research results/application, time available for conducting the research, the scale and unit of analysis, and the resources available. Measurement of vulnerability and resilient of any socio-ecological systems must therefore reflect biophysical and social processes as well as the coping strategies within socio-ecological systems that appear complicated and with many linkages that are difficult to pin down (Adger, 2006).

For the purpose of this study, a conceptual and methodological approach to vulnerability analysis based on both biophysical and socioeconomic approach was adopted in order to develop a conceptual framework of vulnerability for this study. The study uses the three basic blocks in vulnerability assessment i.e. exposure to climate variability (temperature and rainfall variability), sensitivity (water, crops or soil) and capacity to adapt (farming practices, resources) for dry land irrigation farming schemes to extreme weather events (high temperature and floods) resulting from climate variability. In additional to both socio-economic and biophysical approach to vulnerability assessment; the different key indicators showing vulnerability (water availability, crop productivity) and resilience (improved farming, resource owned) of dry land irrigation farming schemes against climate change in the study area were identified and assessed. Therefore, vulnerability and resilience assessment is a useful tool for understanding the impact of climate change and effectively adhere responding mechanism to the community to cope with any unanticipated changes within a society. Understanding vulnerability and resilience of dry land irrigation farming schemes in the study area is a critical step towards developing strategies and measures that will be taken by local farmers to reduce the risk of climate change impact or increase capacity to adapt in the future.

4.5 Description of Study Area

4.5.1Geographical Location

Tanzania covers a total area of 945,234 km^2 made up 942,832 km^2 of mainland Tanzania (formerly Tanganyika) and 2,400 km^2 of Zanzibar (consisting of the Islands of Unguja and Pemba) (URT, 2013c). The country is located in East Africa, between longitude 39^0 18′ East and latitude 6^0 50′ South of the Equator (figure 4.1). The country has a wide variety of physical features extending from a narrow coastal belt of the Western Indian Ocean with sandy beaches to an extensive plateau with altitude ranging from 1000m to 2000m above sea level (URT, 2013c).

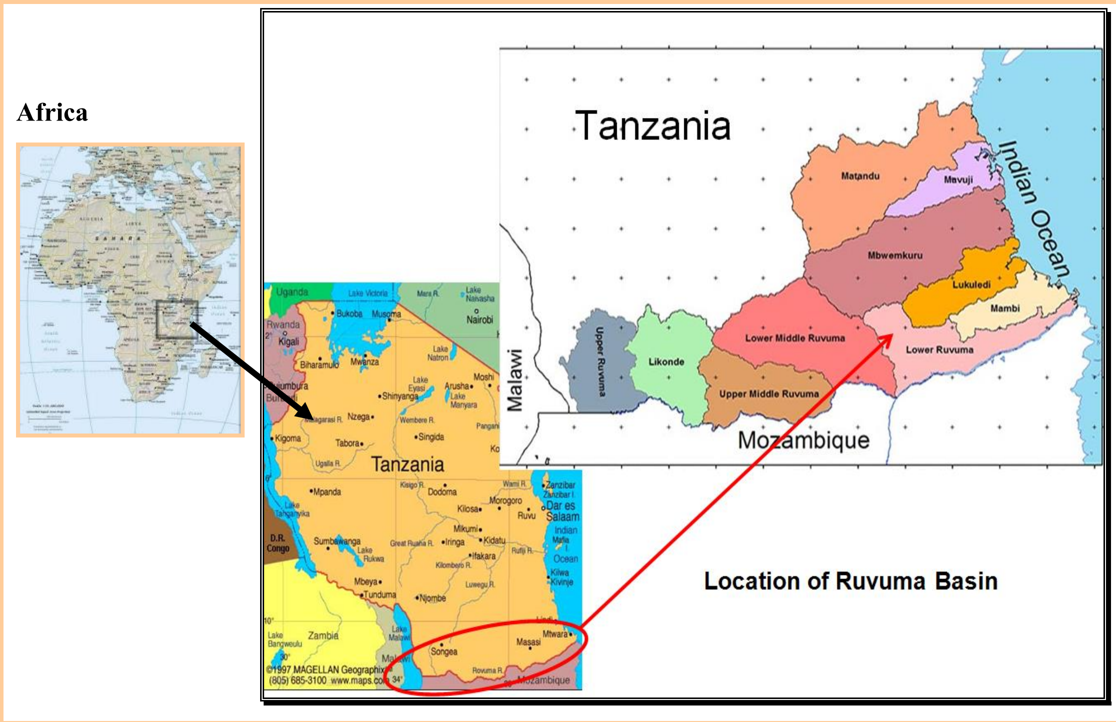

Figure 4.1: Location of Study Area from the Map of Tanzania. Source: URT, 2013a

Other features include vegetation wood lands, forest and marine reserves, lakes (Lake Victoria) and rivers. According to URT (2013a); Tanzania has major nine river basins namely: Pangani River Basin, Ruvu/Wami River Basin, Rufiji River Basin, Ruvuma River and Southern Coast Basin, Lake Nyasa Basin, Lake Rukwa Basin, Lake Tanganyika Basin, Lake Victoria Basin, Internal Drainage Basins of Lake Eyasi, Manyara and Bubu depression. The Ruvuma River and Southern Coast Basin is found in the South Eastern Tanzania where the research was carried out in the selected villages of Mtwara and Lindi Region.

4.5.2 The Ruvuma River and Southern Coast Basin

The research was carried out in Ruvuma River and Southern Coast Basin which is located along the Eastern margin of Northern Mozambique and Southern Eastern Tanzania with a passive margin continental basin type (URT, 2013a). To the South of the Ruvuma Basin, the Ruvuma River separates Tanzania from Mozambique country and to the East the Ruvuma basin boarder Indian Ocean while to Makonde Plateau is found to the West of the basin and to the North are Lukuledi and Mbemkuru River and Selous Game Reserves (URT, 2013a). According to URT (2013a); the total land area around Ruvuma River Basin is approximately 152,200 km^2 where by 52,200 km^2 (34.3%) are found in Tanzania and 99,530 km^2 (65.39%) are found in Mozambique and 470 km^2 (0.31%) in Malawi.

A study by UNEP and WIOMSA (2009) indicates that Ruvuma River has a length of 800 km. The report estimated that the annual mean precipitation for the basin is 800 mm to 1,200mm with a total estimates mean annual runoff of 15 km^3. Floods normally occur in the flood pain of Ruvuma river where crops may be destroyed and occasionally occur on Matandu, Mbwemkuru and Mavuji river systems. Sediment transport in the basin varies from $2.5m^3/km^2$/year in Lukuledi river system to $185m^3/km^2$/year in Lumesule, a tributary of the Ruvuma river system (UNEP and WIOMSA, 2009). The Ruvuma Basin and its Coastal waters have also five major rivers that empty their water into Indian Ocean (URT, 2013b). These rivers include River Matandu having 18,565 km^2; River Mavuji with 5,600 km^2; River Mbwemkuru with 16,255 km^2; River Lukuledi 12950 km^2 and the main Ruvuma River (URT, 2013a). All the rivers feeding the Ruvuma basin and associated wetlands are important for dry land irrigation farmers as they provide both water needed for irrigating crops and fertile soil at the river banks or flood plains. They also provide green pasture for farmers and communities practising mixed farming or keeping livestock during dry season.

Ruvuma basin has also small basins with water bodies such as wetlands (Kitele and Rupondo water ponds) and small rivers not directly feeding the main Ruvuma River (UNEP and WIOMSA, 2009). According to the Ministry of Water and Irrigation (URT, 2013b) most of small basin are found along the altitudes ranging from 305 – 710 m A.S.L (Above Sea Level); however in few cases dry land irrigation farming schemes in the study area is carried out in area having low altitude below 300 m A.S.L. In the study area main small rivers (sub-catchment) includes River Mpapura, River Mkwaya and River Lukuledi. The Ruvuma Basin has coastal land surface covers Mtwara Rural and Lindi Rural while Ruangwa District is located along the coastal area although not directly linked with Indian Ocean (figure 4.2). Most of the Ruangwa District is found on high altitudes making it well suitable for agriculture due to cool climate and fertile soil from slopes of Liwale and Ruangwa Mountains (URT, 2013b).

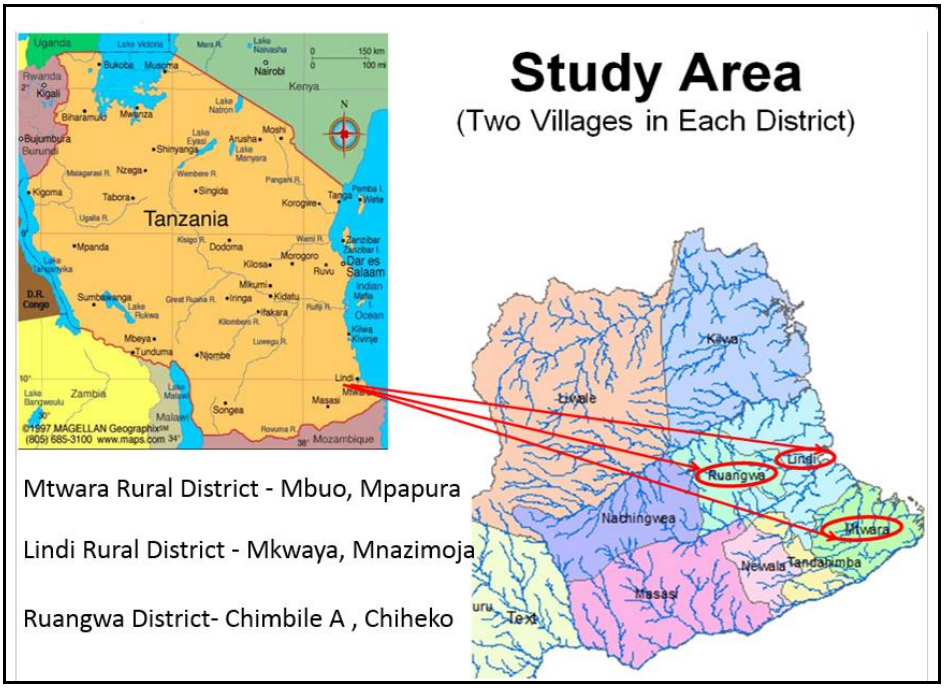

Figure 4.2: Location of Study Area (Ruvuma Basin). Modified from URT, 2013a

The selected villages in the study area are located in Mtwara Rural District (Mbuo and papura) and Lindi Rural District (Mkwaya and Mnazi Mmoja) and Ruangwa District (Chimbile A and Chiheko). The villages are found in the South-Eastern part of Tanzania along the coastal area. Most of the study area if found along coastal low lying area and its elevation is not uniform throughout the region but it ranges between 120m to about 300m A.S.L. The rationale for selecting the villages in the study area is that the three districts are characterized by dry land irrigation farming schemes which that are constrained by low agricultural productivity, flooding and other environmental problems including climate change and rainfall variability. The study findings from this research report can be used improve the livelihood of this vulnerable community and enhance their resilience against climate change and thereby contributing to increase in agricultural output.

4.5.3 Geology and Topography

According to Regional Socio-economic Profile (2007); the geology around the study area is based primarily on sedimentary deposits from the Jurassic and Lower Cretaceous (around 150 million years ago). Geologically, there is a complex interaction between the various elements defining the geology and topography of the study area. The coastal sedimentary formation produces deep, well drained, sandy soils of low fertility and low moisture holding capacity such as valley soils of Mpapura and Mkwaya villages (Artumas, 2005). Some few low lying areas give rise to heavy muddy black clay soils while most of high elevated hills at Ruangwa district give a mixture of poorly drained greyish gravel/soil to red earth, well drained and heavy textured soils (Mattijin, 2010). In general most of the landscape in the study area is characterised by rural settlements, general lands and farm lands with some gentle undulation and flat plains (BirdLife International, 2013). Most of the valleys in Mpapura, Mbuo and Mkwaya Villages consist of alluvial soils with peat type of humus soil which are fertile and easy to cultivate. The soils around Chimbile A and Chiheko are typical cotton soils while at the top of the valleys the soil is changing from red earth into coarsely sandy soil.

4.5.4 Crops Grown and Livestock

Generally, the most important crops grown are: starchy staples notably maize, rice, cassava and millet (URT, 2005). The leguminous crops mainly pigeon pea, cowpea, lablab bean, green gram and bambaranut; oilseeds especially sesame and groundnut (URT, 2009). Vegetables such as onion, tomato, cabbage, carrots, spinach, sweet pepper and lettuce are commonly grown; however local vegetables such as amaranths, cowpea, African eggplant, okra, jute mallow, pumpkin leaves, green peas also common in various dry farming schemes around the study area (URT, 2005). The national sample census of agricultural survey in Lindi region indicates that vegetable crops such as tomato and onion are the most dominant grown in Ruangwa covering an area of about 164ha and 364ha respectively (URT-Vh, 2012). In Mtwara rural district the report indicates that apart from green vegetables being the dominant crops grown under irrigation; the district had the largest planted area of tomatoes (1,335ha) and Okra (328ha) in the region (URT-Vi, 2012). Tree crops particularly grown are cashew, coconut, orange, lemon and banana. Livestock kept in the study areas includes goats, cattle, sheep and local poultry are part of the farming systems. Cashew and sesame are the most important cash crops; however, rice, cassava, groundnut, maize and coconut contribute to some of the households' income in the study area.

4.5.5 Area Under Irrigation

According to URT (2012i); the area of annual crops under irrigation in Mtwara region was 2,717ha representing 0.6% of the total area utilized with Mtwara rural district representing (161 ha, 6%) with total number of 372 households using irrigation. URT (2012i); further explains that the main source of irrigation in Mtwara are rivers; whereby 2,770 ha equivalent to 45% of all irrigated land used this source followed by canals (2,444 ha equivalent to 40%), tap water (554ha equivalent to 9%) and wells (79ha equivalent to 1%). Information from URT (2012h) indicates that the area planted under irrigation in Lindi region is 2,523ha equivalent to 0.84% of the total planted area in the region with Ruangwa district having 548 ha equivalent to 21.7% of the area planted using irrigation with 607 households using irrigation. The report (URT, 2012h) indicates that the main source of water household's use for irrigation is river (40.5%) and canal (7%), tap water (1.9%) and a very small number of households used borehole (0.5%). In both regions, the agricultural reports shows that handy bucket is the most common method getting water for irrigation followed by gravity water, hand pump and motor pump.

4.5.6 Socio-Demographic Profile

There are three main ethnic groups in Mtwara region namely Makonde, Yao and Makua. The original inhabitants in the study areas are Makonde, Yao and Makua with more than 75% of the population being Makonde although there are minor ethnic groups such as Mwera and Maraba (Mtwara Regional Socio-Economic Profile, 2007). According to National Population Census (2012), Mpapura ward has total population of 4,933 of which Males are 2,284 and Females are 2,649 with average growth rate of 1.2 and average household size of 3.7. Mkwaya and Mnazi Moja in Mingoyo ward has a total population of 11,812 of which Males are 5,538 and Females are 6,274 with average growth rate of 0.9 and average household of 3.8 (National Population Census, 2012).

Traditionally, local communities in the study area are subsistence farmers, fishermen and very few hunters (Regional Socio-economic Profile, 2007; URT, 2012i; URT, 2012h) . Main staple foods include cassava, sweet potatoes, millet and maize. Local communities also cultivate coconuts, groundnuts, millet and cashew nuts as cash crops at a very small scale compared to the potential of the land. In the study area, fishermen still make their living relying on fishing from dugout canoes and dhows in the deep outer bay while others within reach of the coast also supplement their meal by collecting other marine resources like shellfish and *sea cucumbers*. The regions have experienced an increase in the number of population and households due to availability of arable land for agriculture; other coastal resources of biological importance and recent discovery and exploration of offshore oil and gas.

4.6 Population and Sampling

According to Visser et al. (2000); population is defined as the complete group of elements to which one wishes to generalize findings obtained from a sample. *de* Vaus (2002) elucidate that the fundamental goal of research is to be able to generalise – to say something reliably about a wider population on the basis of the findings in a particular study. On the other hand Kothari (2009) claims that in order to prepare a suitable description of a population it is essential to distinguish between the population for which the results are ideally required, the desired target population, and the population which is actually studied, the defined target population. Creswell (2012) explains that a sample is a subgroup of the target population that the researcher plans to study for generalizing about the population. When dealing with people, it can be defined as a set of respondents (people) selected from a target population for the purpose of a survey (*de* Vaus, 2002). The sample should be representative of the population to ensure that we can generalise the findings from the research sample to the wider population as a whole. An ideal situation, in which the researcher had complete control over the research environment, would lead to both population and the sample containing the same elements and characteristics (Flowerdew and Martin, 2005; Creswell, 2012).

Depending on the objective of the study and research question; this can be fully achieved by having proper sampling design technique (s). In this study the target population were all dry land irrigation farmers along the Ruvuma basin, whereas the sample population were individual farmers particularly farming during the dry season from which the sample (respondents) were drawn for the research study. The population in the study area involved 2,971 households practising irrigation in three districts, namely Lindi Rural District with 1,612 households; Ruangwa District had 987 households and Mtwara Rural District has 372 households (District Governments Authorities Communication, 2012). The data was later divided further into six villages, each district having two villages selected for study. With the help of Village Chairperson and Ward Executive Officer; village registers in respective villages (in the study area) were used to identify households practising irrigation farming. Village register are official books used by village local authority to record names and other important information of all individuals residing in the village for the purpose of keeping and tracking village records. In addition to these villages, there were five institutions, namely Lindi Rural District Council, Ruangwa District Council, Mtwara Rural District Council, the Ruvuma Water Basin Office and Southern Irrigation Zonal Office. This made the population to have a total of 2,976 units (households, district authorities and institutions).

4.6.1 Sampling Design

Creswell (2012); describe sampling as the act, process, or technique of selecting a suitable sample, or a representative part of a population for the purpose of determining parameters or characteristics of the whole population. Since it is generally impossible to study an entire population (*e.g.* every individual farmer in a country), researchers typically rely on sampling design to acquire a section of the population to perform an experiment or observational study (Flowerdew and Martin, 2005; Babbie, 2010). Creswell (2012) define a sampling design as a set of rules and procedures by which some elements and characteristics of the target population are included in the sample unit. It encompasses all aspects of how to group units on the frame, determine the sample size, allocate the sample to the various classifications of frame units, and finally, select the sample (Babbie, 2010).

Sampling designs can be classified as random/probability sampling designs, non-random/non – probability sampling designs and 'mixed' sampling designs (Cohen et al. 2007; Babbie, 2010). For a sample to be called a random sample, each element in the study population must have an equal and independent chance of being selected in a study (Visser et al. 2002) while in non – probability sampling designs do not follow the theory of probability in the choice of elements from the sampling population (Creswell, 2012). Non – probability sampling designs are used when the number of elements in a population is either unknown or cannot be individually identified. In such situations the selection of elements and its characteristics is dependent upon other considerations based on research objectives and type of data needed (Frankfort-Nachmias and Nachmias, 1996). Cohen et al. (2007) adds that non – probability sample deliberately avoids representing the wider population as it seeks only to represent a particular group of interest such as a group of students who are taking a particular examination in a certain class. Thus, the best method to sample the population for observation or studying in this case is by using non – probability sampling. Here the population of interest can also be sampled from existing records such as village book register, a population census surveys; or be constructed by researcher in the field depending on the objective (s) of the study.

There are four common types of non – probability sampling *i.e,* convenient/accidental sampling, purposive (judgmental) sampling, snowball sampling, and quota sampling (Visser et al. 2002) where each type of sample seeks only to represent itself or instances of itself in a similar population, rather than attempting to represent the whole, undifferentiated population (Cohen et al. 2007). In this study, purposive sampling was used to selected suitable sample for representing the dry land irrigation farmers in the study area. According to Visser et al. (2002); purposive sampling consists of the researcher using their judgement and approaching only those people who they decide are most appropriate to participate in the study. Babbie (2010) further adds that purposive sampling techniques are primarily used in qualitative studies and may be defined as selecting units (*e.g.* individuals, groups of individuals, institutions) based on specific purposes associated with answering a research study's questions. In the study area, dry land irrigation famers were deliberately selected based on their knowledge about dry land irrigation farming schemes which could have not been provided as well from other people. The technique was used because probability sampling was considered less important since, random samples may have been largely ignorant of vulnerability and resilience of dry land irrigation farming issues against climate change impact and unable to comment on matters of interest to the researcher which justify the selection of this method. Cohen et al. (2007) add that the method is also used in order to access 'knowledgeable people', *i.e.* those who have in-depth knowledge about particular issues, maybe by virtue of their professional role, power, access to networks, expertise or experience.

In this case, the dry land irrigation famers were the best sample satisfactory to the research study as they indicate most distinct factors of vulnerability and resilient to climate change impact compared to other people. The purposive sampling was done at two levels in the study area. The *first level* was selecting the research site (*i.e,* districts and villages) where three districts, each with two villages were purposively selected. The districts and villages selected included Lindi Rural District Council (Mkwaya and Mnazi Moja villages); Ruangwa District Council (Chimbile A and Chiheko villages); and Mtwara Rural District Council (Mbuo and Mapura villages). Most of these Districts selected had small scale irrigation farming schemes producing vegetables and horticultural products feeding the main markets in most urban towns of Mtwara and Lindi regions. The sites were also selected because they were among several villages which are affected by climate change impacts such as extreme floods and temperature because of their geographical location (coastal low land areas) as well as increased intensity of extreme climatic events such as frequent dry spell. Therefore, the selected sites are more vulnerable to impact of climate change than other areas in the region in the study area.

Apart from effects of climatic condition, other criteria that used were poor land use management (shifting cultivation), lack of resources entitlement (agricultural inputs) and lack of access to market for fresh produce. These factors also guided the selection of the villages with the aim of identifying other factors that are equivocal and expediting the vulnerability of dry land irrigation farming apart from climatic variability and how such factors relate to changes in the farming practiced by dry land irrigation farmers in the study area. The selection of the six villages (Mkwaya, Mnazi Moja, Chimbile A, Chiheko, Mbuo and Mapura) were also important so as to compare those villages in terms of levels of vulnerability (exposure and sensitivity - farming schemes and crops grown) and different coping and adaptive strategies employed by dry land irrigation farmers. Though the study area is located along the coastal low land area, the location of the villages at different altitudes (low altitudes - Mtwara rural and Lindi rural district; and medium elevated area - Ruangwa district) was also considered as a criterion for selection of the villages. The five institutions (*i.e* Lindi

Rural, Ruangwa and Mtwara Rural District Council, Ruvuma Water Basin Office and Southern Irrigation Zonal Office) were selected because of their mandates, jurisdictions and technical as well as administrative functions in the study area.

The *second level* of purposive sampling was selecting the respondents in the study area who were involved in the dry land irrigation farming as part of their livelihoods throughout their lives. This was executed by using the village household register (village book register) which provided easy access to important information on socio-economics profile and the commonly used categories of farmers (such as cashew nut, rice, cassava, vegetables and maize) in the village. With the assistance of Village Executive Officer, Village Chairperson and Village Economic and Development Committee in each village; respondents were selected based on criteria defined by the researcher *i.e* a dry land irrigation farmer. The main criteria's used for selecting respondents (dry land irrigation farmers) were based on farmer's characteristics such as dry season farming, size of the farm/plots (≤1ha), type of crops grown, farming methods and resources owned. For inclusion of diversity, other socio-demographic characteristics (age, gender, occupation, income) were also considered. Although the village book register formed the entry for getting household list, in the end verification of respondents (households) was needed to filter out many deficiencies such as names of deceased, respondents with multiple names/appearing more than once or respondents who are not currently residing in villages. Here, key informants and representative of hamlet in each village were also asked to verify the list of respondents (dry land irrigation famers) on the register. The underlying assumption for using these key informants and representative of hamlet was that they knew almost all households in the village plus their livelihoods activities more than other village authority. The variation among the farmer's characteristics (criteria) mention above were also observed during selection so as to have different composition in terms of size of the farm/plots, type of crops grown, farming methods and resources owned. Finally, the selection of expert's interviewees was made by heads of the respective institutions where the heads of institutions were consulted to identify the right individuals to be interviewed. Respondents for FGD's were also purposeful selected with the help of village leaders considering their roles, experience and knowledge on climate change and irrigation farming issues within their local areas.

Although purposive sampling can be a possible source of bias, it was justifiable for use in this study given the nature of respondents/households (dry land irrigation farmers) characteristics and distribution among farming communities across the villages and the heterogeneous nature of their livelihood strategies and socio-economic status. Flowerdew and Martin (2005) were vigilant on the key challenges (selection bias) when using non-probability sampling which may occur during the recruitment and retention of participants. However, the most effective way of avoiding such bias is by having a well-designed study so as to avoid under-coverage, volunteer bias and interviewer/researcher unconscious bias which may occur during field data collection (Visser et al. 2002; Babbie, 2010; Creswell, 2012). Welman et al. (2005); agree that though in purposive sampling, samples may not be representative and their comments may not be generalizable, this is not the primary concern in such sampling; rather the concern is to acquire in-depth information from those who are in a position to give it. According to Singleton and Strans (2005); adjustment can be made to ensure sufficient numbers of respondents are included for proper representation of the wider population, statistical analysis and policy implementation.

4.6.2 Sampling Frame

A sampling frame is a list or document that identifies most units within the target population. In the study area, sampling frame (*i.e.* village book or household register) was used to select individuals (dry land irrigation farmers) with some common defining characteristic (such as farming season, crops grown, size of the farm) that the researcher identified and used for the study. Within the village book or household register, samples (individual farmers) were select for a study. In this study (see figure 4.3), a household is defined as a person or group of people living together and sharing the same resources under the same house/hat (HBS, 2008; URT, 2012).

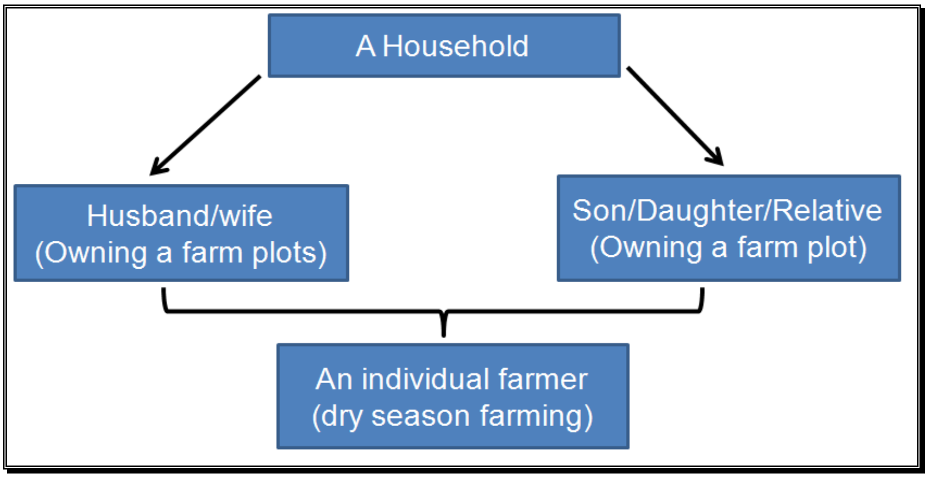

Figure 4.3: Households setting in the study area. Source: Mhagama, 2014.

For this research individual farmers were interviewed since the setting of the household is that respondents (individual farmers) living and sharing the same households; have or own a farm plot and use it to produce vegetables during the dry season. For the verification of the final selected list of respondents, key informants and representative of the hamlet in each village made sure that only one member of the family were selected from each household for the interview.

4.6.3 Sample Size

With the help of Zonal Irrigation Officer (Southern zone) and District Agricultural Officers, two sample villages were selected in each of the following Districts; Ruangwa, Lindi Rural and Mtwara Rural District making a total of 6 villages. Purposive sampling was used to select respondents for questionnaires interviews. A total of 187 respondents were selected using village book register with the help of Village Executive Officer, Village Chairperson and representative of the hamlet. The selection of farmer's characteristics were based on gender, age, education, occupation, dry season farming, size of the farm/plots (≤1ha), crops grown, farming methods, resources owned as well as experience of the farmer so as to represent the diversity of the local farmers' views on dry land irrigation farming schemes. The number of respondents in each scheme was determined using the criteria adopted by JICA/NIA (1991) where the irrigation area scheme commands was used as the criteria for sampling number of respondents. Based on irrigation command area criteria, JICA/NIA (1991): *i.e* 201 – 300 ha (50 respondents); 301 – 400 ha (60 respondents) and > 400 ha (70 respondents). Based on estimates made by zonal irrigation officer; most of the dry land irrigation area falls under the first category of irrigation command area making the number of respondents to be smaller. The distribution of respondents in each village was Mbuo 16; Mpapura 36; Mkwaya 29; Mkwaya 29; Mnazi Moja 30; Chimbile A 45 and Chiheko 31 making a total of 187 respondents interviewed (table 3.5).

Table 3.5: Number of respondents interviewed in each Village and District

S/N	Name of District	Name of Village	No. of Respondents	Total	Percentages (%)
1	Mtwara Rural	Mbuo	16	52	27.3
		Mpapura	36		
2	Lindi Rural	Mkwaya	29	59	32.1
		Mnazi Moja	30		
3	Ruangwa	Chimbile A	45	76	40.6
		Chiheko	31		
Total			**187**	**187**	**100**

Source: Mhagama, 2014.

Five District Agricultural Officials (one from each district) were selected for the expert's interviewees. The appointment of experts was made by heads of the respective institutions. For the focus group discussion, 12 respondents were selected with the help of village leaders considering their roles, experience and knowledge on climate change and irrigation farming issues within their areas of jurisdiction. The final sample size constituted a total number of 216 individuals distributed as follows: 187 for questionnaire; 24 for the FGD and 5 for the interviews. According to Visser et al. (2002); the main feature of qualitative sampling is the fact that the number of cases sampled is often small. This is because, as mentioned earlier, a phenomenon only need appear once to be of value (Babbie, 2010). Furthermore, because qualitative investigation aims for depth as well as breadth, the analysis of large numbers of in-depth interviews would simply be unmanageable because of a researcher's ability to effectively analyse large quantities of qualitative data (Ritchie and Lewis, 2003).

4.7 Primary Data Collection

Permission for field data collection was given by the District Commissioners Office, District Councils and Village Authority. The process of data collection was carried out in two field phases. The first phase took place between September and November, 2013, and was based on household questionnaire surveys; focus group discussion and participant observation and collection of secondary data. In the second phase which took place in July, 2014 and July, 2015 focused on semi-structured interviews with key informant's and expert's interviews and recap of all the missing data and information from the field. The strategy for data collection are summarised in the table 4.6 below.

Table 4.6: Data collection strategy

Technique	Selection	Participants	Main themes
Household questionnaire survey	Purposive selected	187 respondents (dry land irrigation farmers)	Household socioeconomic characteristics; farming strategies and constraints; Coping strategies
Field observation	Random and subjective	Few selected respondents and their farming practices and irrigation schemes in each village	Farming practices, land use, water availability, resources owned crops productivity (indicators).
Focus group discussion	Purposive selected	Dry land irrigation farmers with interest on selected based on knowledge and experience of vulnerability and resilience of dry land irrigation farming, gender, availability and willingness to participate	Perceptions, opinions, beliefs, and attitudes towards issues related to vulnerability and resilient of dry land irrigation farming schemes against climate change impact, choice and determinants of coping strategies.
Interviews	Knowledge and experience on the subject	Agricultural officers and irrigation experts.	Comprehensive and in-depth understanding of dry land irrigation farming practices, its exposure to climate change impacts, levels of mechanization, different copping and adapting strategies.

Source: Mhagama, 2014.

Apart from primary data, secondary data was also collected from various local and national archives and reports. The following sub-sections provide details of the process of data collection in the field.

4.7.1 Household Questionnaires

The household questionnaire were designed and administered to 187 respondents (individual dry land irrigation farmers) in the study area (figure 4.4). The questionnaires were divided into 4 sections: *i.e. First* sections on household characteristics such as socio-demographic profile, farm assets, household economics and farming systems. The *second* section included knowledge on dry land irrigation farming schemes and *third* section on farmer's knowledge on vulnerability of dry land irrigation farming schemes while the *fourth* section was on resilience of dry land irrigation farming schemes against climate change impacts.

Figure 4.4: Field questionnaire administration. Source: Mhagama, 2014.

Closed and open-ended questionnaires were used to collect information on farmers' experiences on local histories of dry land irrigation farming schemes and its management systems (*site selection, land preparation, cropping, water use and management, conservation*). Information of the farmers' perceptions on the climate change impacts were also collected *i.e.* if there are any changes in their farming practices overtime; and explanation of why those changes have occurred in terms of different farming schemes and types of crops and crop varieties as well as factors that motivate farmers' decisions to undertake such changes farming practices. Generally, each farmer selected into the sample was asked to respond to questions from the questionnaire and the enumerator filled in the responses as per participant's responses. Information on farmers' knowledge on vulnerability of dry farming to climate change, copping and adaption strategies so as to safeguard dry land irrigation farming schemes during periods of stress/shock such as drought, flooding and disease/pest outbreak were also collected and analysed. Other aspects of information collected from the farmers included their opinions on what strategies can be done as interventions so as to reduce the impact of climate change (vulnerability) to their farming schemes and enhancing adaptation (resilience) to climate change variability in future.

For the closed-ended questions, a list of possible climatic changes (variability in temperature and rainfall) and their impacts (floods and crop drought) relevant to smallholder irrigation farmers' context were made based on similar studies obtained from other relevant researches (Luers, 2005; Adger, 2006; Fussel, 2007; Deressa et al. 2008 and Gbetibouo and Ringler, 2009). Extreme events such as occurrence of flash floods, dry spells and strong winds and their frequency and durations were also included in the list. The researcher's experience on vulnerability of dry land irrigation farming schemes for smallholder irrigation farmers; in Tanzanian context were also included during questionnaire development. Then farmers were asked to select only possible changes suited to their local climate and the fact that they believe they had been experiencing according to their best level of knowledge and experience in the study area throughout their farming history. Apart from the provided list of possible changes, farmers were asked to name any other changes that are not in the list but they feel are important and have played a significant role in making the dry land irrigation farming schemes more vulnerable to climate change.

In case of open-ended questions; the study was of interested also to enquire on farmers' views regarding their prediction on the state of climate in future where farmers were asked to predict how climate would be in the immediate future, approximately the next five to ten years (whether the situation will be normal or worse than ever). Here, opinion of the farmers (farmer's knowledge) on what changes they undertake so as to enhance dry land irrigation farming schemes to adapt and cope (become resilient) to climate change impact were collected. Most of the farmers opinions were based on changes in the farming practices such as soil and water conservation; use of crop varieties or crops that are resistant to drought and diversifying household income. Information on what possible factors motivating them to make decision (s) to undertake those changes in the farming practices were also collected. In addition, for a complete detailed list of questions, see the questionnaire attachment (Appendix I).

4.7.2 Focus Group Discussion (FGD's)

In addition to the quantitative and qualitative household survey (local farmers), focus group discussions with dry land irrigation farmers and other stakeholders were carried out. Cohen et al. (2007) define a focus group as "a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research. With the help of village leaders and agricultural extension officers, 24 dry land irrigation farmers were randomly selected from households and participated in the group discussion (figure 4.5).

Figure 4.5: Focus group discussion. Source: Mhagama, 2014

Gender, age, experience and type crop (s) grown in the field were considered during selection. In each village participants (FDG) convened a meeting and were asked to discuss number of issues (such as exposure, impact and coping strategies of irrigation farming) related to vulnerability and resilient of dry land irrigation farming schemes against climate change impact based on the guideline provided by the researcher. The focus group discussion were structures through discussion only and documented in terms of minutes of meeting or briefings in response to the questions asked. Their perceptions, opinions, beliefs, and attitudes towards the aforementioned subject were collected and documented during discussion. The discussions were guided by the historical background of the villages and changes in the local climate that have been experienced over time (see appendix II). Other points included reason motivate them to make changes on farming practices and at what time as well as what are the expected future climate changes and impacts and what are the adaptation interventions.

4.7.3 Interviews

In addition to the focus group discussion, interviews with experts (KI) were carried out. Heads of institutions were responsible for selection of responds (particularly agricultural officer or irrigation officers) and after the selection; initial contact was made to determine if informants would be willing to participate in an interview. Once the expert had agreed, the researcher scheduled the interview at the place and time convenient to the interviewers. Discussions were arranged with interviewers on land use changes and how these changes affect dry land irrigation farming schemes as well as future water and food availability. Then, experts selected for participation in the study were interviewed, through a semi structured interview, to obtain details used to substantiate the data collected through questionnaire and FGD so as to validate farmers' information through a technical and experts' window. The interviews were designed to allow for comprehensive and in-depth understanding of information on dry land irrigation farming practices, its exposure to climate change impacts, levels of mechanization as well as different copping and adapting strategies used by irrigating communities during periods of stress/shock. The interviews generally lasted between 40 minutes and one hour depending on the details offered by experts. Interviews were held in the common areas in the offices or at locations where the respondents felt most comfortable. In addition, a few selected elders from the villages were also interviewed with a similar aim of cross checking the information obtained through the questionnaire in a historical perspective. Data and responses from experts interviews wer then triangulated against local farmers (dry land irrigation farmers) responses in order to validate information provided and observed during questionnaire interviews.

4.7.4 Field Observation

One of the inherent advantages in the participant observation approach is the ability of investigators to be able to discern ongoing behaviour as it occurs and are able to make appropriate notes about its salient features (Bailey, 2004). In this study, the researcher used variety of methods for observation, including observing farming practices including taking general notes and pictures (figure 4.6) on farming practices in the field as well as decision made by farmers and what reason prompted those changes.

Figure 4.6: Mulching and crop mixing as part of adaptation strategies to increased temperature. Source: Mhagama, 2014.

According to Creswell (2013) in many research cases where it has been used, participant observation was found useful in understanding the ways people live and their opinions as related to a particular situation. In few cases a researcher took part in village assembly meetings held during the duration of the field work, joining some farmers in gardening and watering the crops. In this case, the researcher was also able to watch, listen, learn and interpret actions and events as they occurred. Such opportunities allowed seeing in detail the intricate and dynamic of those activities, the voluntary decisions for undertaking such an activity and their implication. Apart from involving and engaging in participant's activities; *de* Vaus (2002) warns that boundaries have to be established on exactly what to observe whereas Esterberg (2002) suggest that the research should clearly decide on the amount of participation and observation for each event.

In the study area, observation during the fieldwork was used mainly to probe issues beyond those covered during the structured questionnaires and interviews. Babbie (2010) add that because case study observations take place over an extended period of time, researchers can develop more intimate and informal relationships with those they are observing, generally in more natural environments than those in which experiments and surveys are conducted. Other specific issues pertaining to dry land irrigation farming schemes such as site selection, land preparation, water use and management, cropping, conservation and copping strategies were collected by a means of field observation (field visits and taking pictures). *de* Vaus (2002) argue that the considerable time it takes for even a short observation, deters many researchers from using this method. According to Flowerdew and Martin (2005); the researcher also can risks his or her interpretation when taking notes, which is accepted by qualitative researchers, but meets resistance from post-positivists. In order to ensure that certain factors did not affect the process of participant's observations, the researcher considered the limitations of what to observe according to the list described above and how to participate in activities during field observation. Other scholars such as DeWalt and DeWalt (2002) and Flyvbjerg (2004); highlighted that the researcher should be aware of the compromises in access, objectivity, and community expectation that are being made at any particular place along the continuum. Generally, observations are designed to generate data on activities and behaviors, and are generally more focused on setting than other methods.

4.8 Secondary Data Collection

In the study area, the secondary data included collection of bio-physical data (temperature and rainfall variability). The long term monthly average temperature and rainfall records were collected from Naliendele Agricultural Research Stations (NARI and Mtwara Airport Authority), which are under the Tanzania Meteorological Agency (TMA), Southern Zone Office. The future climate projections from IPCC (IPCC, 2014) and various climatic models such as Non-Homogeneous hidden Markov Model - NHMM (Cioffi et al. 2014) and ENSO were used to predict future rain-fall patterns and temperature variability in Tanzania under a global warming scenario. The use of rainfall and temperature data in this study was intended to ascertain the perceptions of dry land irrigation farmers; key informants and local leaders and experts on the state of the local climate, which were expressed in the questionnaire, interviews and FGD.

Other secondary data included different information from various reports on climate change impacts, vulnerability and resilient of small scale irrigation farming schemes in Tanzania and the rest of the world. Documentary data in form of published and unpublished materials from government agencies (Ministry of Agriculture and Food Security), research institutes (Naliendele Agricultural Research Institutes), and other regional and international agencies or database were the main sources of data. Other multiple sources of data such socio-economic survey reports and statistics related to vulnerability and resilient of dry land irrigation farming schemes were also used

Deressa et al. (2008) and Isabel (2012) encourages that the use of secondary data is vital so as to gauge the perceptions of the farmers against actual climate data obtained from the relevant and mandated authority in Tanzania and see how these two sets of data tally in terms of results outputs and interpretation. While this was a relevant and approach, two challenges need to be stated at the outset. The temperature and rainfall data collected represent the use of Thiessen Polygons method (collection of weather data using boundaries define by the area that is closest to each point relative to all other points) rather than the exact point in each village studied. This was due to the fact that the TMA weather station in Mtwara was the only main station with both available temperature and rainfall data. The location of the all six villages along the coastal lowlands areas, indicates a strong representative of the study area because they are in almost similar elevation and share a number of characteristics such as the type of crops grown and climatic conditions as well as the average amount of rainfall they ought to receive, according to the interview data.

4.9 Data Verification and Validation

Cohen et al. (2007) describe data verification as a process of evaluating the completeness and accuracy of a specific data set against method or procedural used for data collection whereas validation is an act or process that extends the evaluation of data beyond method and procedural used (*i.e.* data verification) to determine the reliability and quality of a specific data set (*de* Vaus, 2002). *de* Vaus (2002); further argue that a reliable measurement is one where we obtain the same result on repeated occasions whereas validity refers to getting results that accurately reflect the concept being measured. The aim of this process is to ensure that the instrument used in data collection yield the intended and expected data that lead the researcher to precisely answer the research question (s) and allow reconstruction and evaluation of the study using the same procedure (Babbie, 2010). The process is vital for any research work so the standard and quality of the research data and results can be trusted and even be put into practical use by the consumers. The process of verification and validation of the data collected in this study were made throughout the research process. The researcher used different means to compare and corroborate information collected, such as expert review, pre-testing and triangulation methods.

The use of *expert reviews* involved four experts from Tanzania (namely Mr. Greyson Nyamoga – Sokoine University of Agriculture; Dr. Andrew Kabanza – Naliendele Agricultural Research Institutes; Dr. Juma Mwinjuma – Zonal Irrigation Office and Ruvuma Basin Office and Daudi Amas – Tanzania Meteorological Agency, Mtwara Zone). The argument behind is that the researcher subjected the questionnaire and guidelines to several experts in the field of vulnerability, resilience, climate change impact and irrigation for the aim of getting the instruments reviewed. According to Kothari (2009); the use of experts in reviewing the instruments and providing comments to the researcher on how they can be improved can be a better way of ensuring validity and reliability. In this study, the experts aforementioned reviewed the instruments and provided comments most of which were incorporated, shaping further the instruments before they were used in the field. The comments provided by reviewers were most related to structure of language used to portray some concepts so as to relate them to respondents' understanding level and the scope of the questions whether they really reflected all required issues intended to be measured for the study. Other comments were the avoidance of repeatability of some of the questions; lengthy of the questionnaire; and the practicality in terms of both data collection and data analysis.

The use of *pre-tested questionnaire* was another way to ensure validity and reliability of data collected. According to Babbie (2010); this is important so as to identify and rectify shortcomings of the instruments and get them addressed well before they are fully used for data collection in the field. Cohen et al. (2007) add that there are several advantages of pre-testing the instruments before they are used in the field such as providing the researcher with possibility of refining data collection instruments as well as predicting as to whether or not results are really going to be meaningful and reflecting the real context of the study. In this study, pre-testing of the questionnaire was done at Mbuo Village, Mtwara rural district and Mkwaya village, Lindi rural district between August and September, 2013. The process involved 8 dry land irrigation farmers selected randomly by the researcher in collaboration with village authority. The selected farmers were then briefed on the exercise of questionnaire pre-testing before they were requested to take part in the exercise. The process helped to identify incorrect and unclear words to the farmers (such as different terms used); appropriate and clarity of the instructions as well as any missing items in the list. The pre-testing of questionnaires helped to include part of frequency and duration of extreme climatic events (floods and dry spell) as well as the choice and determining factors for different coping strategies. Other modification of the questionnaires included rewording of few question items and pre-testing of results before the final version of the questionnaire were printed ready for data collection exercise in the field.

The last verification and validation methods were the use of *triangulation* methods which denotes a designed use of several different research methods, for offsetting biases in a study on a phenomenon and strengthening validity of the results (*de* Vaus, 2002; Cohen, et al. 2007; Babbie, 2010). Flowerdew and Martin (2005) describe triangulation as the process of using different bearings to give the correct position in mapping and surveying studies. In the same way researchers can use multiple methods or different sources of data to try and maximise their understanding of a research question. Cohen et al. (2007) fortify that triangulation is a powerful way of demonstrating reliability and validity, particularly in mixed method research. The concept is based on the assumption that an inherent bias or limitation in particular data sources, investigators and methods would be counteracted when used in conjunction with other data sources, investigators and methods (Cohen et al. 2007; Creswell, 2003). The process of triangulation is vital in reducing the possibility and chances of reaching false conclusions. According to Creswell (2003) cited in Deressa et al. (2008); interview and observation data, for instance, can be used to confirm the conclusions reached on the basis of questionnaire. It is a way of crosschecking results obtained in one method against those obtained in other methods in a similar study thereby making the study results strongly convincing and technically, strongly supported.

In this study, the researcher used information obtained from focus group discussion and expert's interviews to triangulate data obtained from household questionnaires. Information from respondents were also cross-checked for repetition and sometimes the researcher asked the same questions twice if not convinced of the first response and cross-checking data with key informants in the community as well as local experts from District Agricultural Departments, Zonal Irrigation Office and Ruvuma Basin Authority. Triangulation also involved comparing the information captured from respondents through direct field observation and the use of secondary data such as government reports and statistics as well as information synthesised from literature. In some cases observation included taking various photos showing farming practices, crops grown, surface water availability and different land use practices as indices of vulnerability and resilience of dry land irrigation farming schemes against climate change. Various sources of data and methods of data verification and validation (experts review, pre-testing and triangulation) were all compared and used so as to finally draw conclusions for this study.

4.10 Data Treatment, Processing and Analysis

4.10.1 Quantitative Data

The quantitative data obtained through collection of long term monthly average temperature and rainfall records from Tanzania Meteorological Station, Mtwara (TMA) and through household survey for the six villages studied. Temperature and rainfall data from TMA were entered in spreadsheets in MS-Excel (2010). The annually temperature variability and monthly average temperature were computed and analysed to indicate variability whereas annual rainfall averages and number of rain days per year were computed and analysed to indicate pattern and monthly fluctuation. The analysis helped to compare the claims from farmers concerns over the general temperature trend and rainfall pattern in the past 10 years (i.e. incidents of increased frequent floods and frequency of dry spell). The quantitative data from household questionnaire surveys from six villages were transcribed, translated into English and then coded for computer data entry. Each piece of information from all respondents was careful checked and compared before coded and entered so as to reduce redundancy and misinterpretation of the data. The final data was then entered into computer for data analysis using Statistical Program for Social Science (SPSS-version 20) for data analysis using descriptive techniques. Descriptive statistics from responses were run to generate frequencies and percentages. Cross-tabulation was made, particularly for the multiple response questions. This allowed comparison of different study parameters among the six villages studied.

4.10.2 Qualitative Data

Information and data collected qualitatively were careful transcribed and translated into English and then coded by assigning a numerical value to responses to facilitate data capture and processing in general. However, to avoid misinterpretation some parts of the text that were quoted for the purpose of reporting were accompanied by pictures taken from the field observation. Different data or information from the field such as notes from interviews responses were organised into digital format. Some questions were coded after data collection during a manual process of computer data entry. Due to expensiveness and time-consuming of data capture and coding activities, data quality and control was introduced so as to foresee the problem of any errors that can affect the final survey results. Quality assurance helped to anticipate problems and prevent them whereas control ensured the numbers of errors that occur are within acceptable limits.

Therefore, after data codification and computer data entry; data processing and analysis were undertaken by compiling information collected in the field using different data collection methods. The analysis of the qualitative data and the interpretation process used in study were closely aligned with the iterative process of qualitative data reduction used by Silverman (2011); and organisation, analysis and interpretation described by Creswell (2003). Other statistical method used includes the analysis of qualitative data used by Morgan et al. (2004). Descriptive, means comparison, correlation and test of functional relationships between variables were used during data analysis to present findings from the research inputs. Descriptive statistics (means, correlation, functional relationships) were used for interpretation of data from the research findings. The research finding was compared with various relevant research studies/reports so as to develop contrast among the obtained output and draw conclusion on vulnerability and resilience of dry land irrigation farming schemes against climate change in the study area (Ruvuma River Basin).

4.11 Limitation of the Study

General in any social survey studies there are apparently limitations that can be obtained using mixed research methods due to employment of various research techniques for data collection (Visser et al. 2002; Cohen et al. 2007; Kothari, 2009).

For example in observational techniques, it is difficult to learn about the underlying factors in the behaviour observed nor the attitudes, motives and explanations (Babbie, 2010). Several problems and their clarification have been mentioned in the previous sections related to different research approach and data collection techniques; however there are few limitations (challenges) encountered during field research process in relation to sample size and validity, time constraint and the perception of dry land irrigation farmers towards the researcher and the research output in general. Among the six villages studied, Mbuo village had a small number of dry land irrigation farmers which affected the number of sample size in that village. This was bolstered by the fact that since the field research is not meant to generalize for the whole Southern Eastern Tanzania dry land irrigation farming schemes, but to provide an in-depth understanding of vulnerability and resilience of the subject along the Ruvuma Basin. One of the main limitations was the selection of research participants for focus group discussion where the research efforts tend to attract respondents who had experience and are interested in the subject. Therefore, participants might have more positive attitude towards the subject than the average audience resulting in biased opinions. This had no impacts on the results, since most of the information collected during FGD session was cross-checked and verified by expert's interviews and collaborated by various local and national reports regarding the subject studied. Nonetheless, through transparently stating this weakness, the researcher tried to achieve credibility (Bazel, 2004; Yin, 2009).

In the villages studied, most of the individual farmers (study area) are renowned for being scattered and the fact that the farming practise is carried out during early morning and evening hours making it difficult to fix appointment with respondents or even to predict if they will appear regardless if a meeting time has been agreed between the researcher and the farmer. This was a limitation to the research as extra time and resources were allocated for this research thus affected the logistic and mobility of the researcher trying to meet up with other respondents for interviews. For example, in three cases separately, in Mbuo and Mkwaya Villages, 2 - 4 appointments had to be re-scheduled before an interview could take place. In this case a high flexibility, persistence and resilient were required in order to mingle and integrate with farmers so as to ensure that information being collected were accurate and reflected the local reality of the respondents without affecting their judgement or behaviours.

In few cases, the researcher observed questionnaire fatigue and some of respondents were not willing to give accurate and exact information. This was affected by their perception towards the researcher and the research output in general (being paid after interview session). This was offset in most cases, where farmers were told the purpose of the research, the confidentiality of the information provided plus their willingness to participate so as to exclude those with negative perception towards research.

4.12 Demographic Characteristics of Households Surveyed.

In the study area few people involve in the dry farming practices. The study findings (table 4.7) shows that Ruangwa Districts had the highest number of people (27.3%) involved in the dry farming practices followed by Lindi Rural (32.1) and Mtwara Rural District (40.6%).

Table 4.7: Number of respondents interviewed in each Village and District

S/N	Name of District	Name of Village	Freq	Total	Percentages (%)
1	Mtwara Rural	Mbuo	16	52	27.3
		Mpapura	36		
2	Lindi Rural	Mkwaya	29	59	32.1
		Mnazi Moja	30		
3	Ruangwa	Chimbile A	45	76	40.6
		Chiheko	31		
Total			**187**	**187**	**100**

Source: Mhagama, 2014

The survey data indicated the family size of the sampled households varies from 2 to 11 with a mean of 1.45 meaning majority of the respondents less family members which is slightly less than the average family size of 3.7 for Lindi and 3.8 for Mtwara. On the other hand, the study found out that there is high number of productive labour forces (18 to 35 ages) with in a family (table 4.8).

Table 4.8: Age of respondent

S/N	Name of Village	Age of the Respondent				Total
		18 – 25	26 – 35	36 – 45	46 – 55	
1	Mbuo	1	7	8	0	16
2	Mpapura	14	12	10	0	36
3	Mkwaya	9	14	9	0	29
4	Mnazi moja	6	14	6	4	30
5	Chimbile A	15	20	7	3	45
6	Chiheko	7	15	6	3	31
Percentages		27.8%	44.4%	22.5%	5.3%	187

Source: Mhagama, 2014.

Among the interviewed household heads 88 are female and 99 are male. There is high number of marriage and few cases of female household heads (Table 4.9). There is no significant variation in sex composition across the farmers in the villages. In many households, the study found out that people were living in one compound and working on different field or activities but pooling their income together and share the same dwelling and eat together.

Table 4.9: Sex and marital status of the respondents

S/N	Name of Village	Sex of the Respondent		Sum	Marital Status of the Respondent				Sum
		Female	Male		Single	Married	Divorce	Widows	
1	Mbuo	11	5	16	2	14	0	0	16
2	Mpapura	30	6	36	12	19	3	2	36
3	Mkwaya	21	8	29	6	20	3	0	29
4	Mnazi moja	16	14	30	4	19	6	1	30
5	Chimbile A	20	25	45	10	30	3	2	45
6	Chiheko	19	12	31	7	20	4	0	31
Percentages		62.6%	37.4%	187	21.9%	65.2%	10.2%	2.7%	187

Source: Mhagama, 2014.

Information on educational status was collected from individual agricultural households. The results show that the majority of the respondents interviewed had some basic primary education (63.1%) and followed by adult education (21.4%) and about 11.2% has no formal education while (4.1%) had secondary education. Though majority of respondent has primary education in each village studied, Chimbile A Village seemed to have large number of farmers with primary and adult education followed by Mpapura Village compared to other villages (figure 4.5).

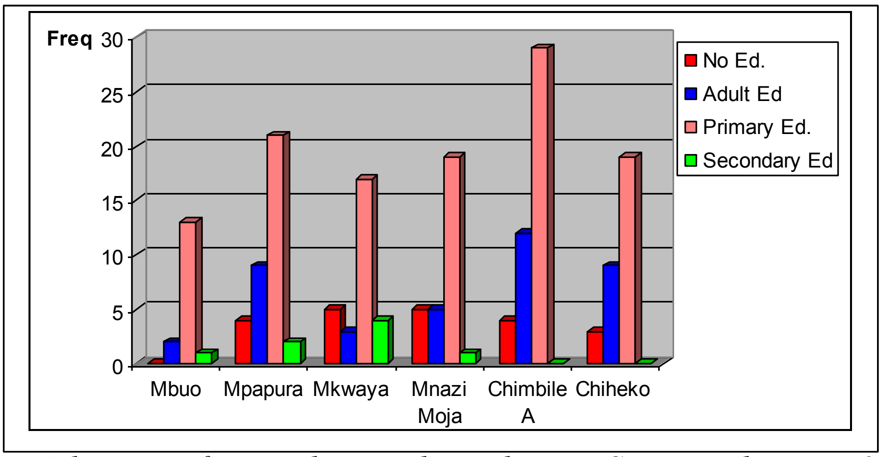

Figure 4.5: Education of respondents in the study area. Source: Mhagama, 2014.

Poverty and Human Development Report, 2005, shows that Mtwara region has higher adult literacy rate due to low secondary enrolment ratio (smaller number of public secondary school as well private school). In terms of occupation, majority of the respondents are subsistence farmers and mixed farming. Though majority of the farmers had primary education, analysis shows that there is a close relationship between level of education and occupation status in the study area (figure 4.6). Mixed farming (subsistence farming and livestock keeping) seems irrelevant in the study area, however smaller numbers of livestock's (goat, sheep and cattle) and poultry have been observed in the field and around household compound respectively.

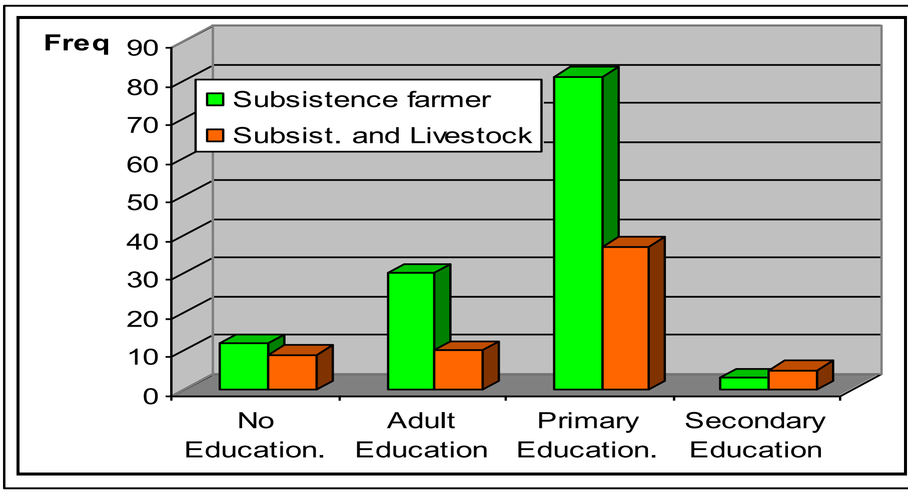

Figure 4.6: Occupation and level of education of respondent in the study area. Source: Mhagama, 2014.

CHAPTER 5: THE STATE OF LOCAL CLIMATE AND CLIMATE CHANGE IMPACT IN THE STUDY AREA

5.0 Introduction

This chapter provides overview information on the local state of the climate and climate change impacts in the Ruvuma River and Southern Coast Basin. The chapter describes key important climate variables that affect dry land irrigation and thus making it vulnerable to climate change impacts. The chapter describes in-depth the local state of climate, temperature and rainfall characteristics in the study area. The temperature and rainfall variability as well as intensity and duration are well elaborated here. The chapter describes further how these variables affect dry land irrigation farming schemes and thus making it vulnerable to climate change impacts.

Finaly, in this chapter, water resources availability and characteristics in the study area are described as well as water resource demand and how these two terms affects dry land irrigation farming schemes in the study area. Narratives from key interviews cement and fortify the information collected from the field. The urgent concern on land-use and land use changes in the study area was also described here as this affects climate change impact by reducing vegetation cover and increased soil erosion due to land degradation and thus affects dry land irrigation farming indirectly by reducing water retention capacity and decrease volumes of water in various reservoirs. Although, most of the information comes from Tanzania Meteorological Weather Station in Mtwara as well as reports from Ministry of Water and Regional Profile reports; field observation as well as data from interviews conformed to the data and information adhered below.

5.1 State of Local Climate in the Study Area.

The Tanzania's geographical position, physical geological features and the like create various climatic patterns and conditions: tropical to temperate and alpine deserts (Shemsanga et al. 2010; URT, 2013b). According to Shemsanga et al. 2010; because of its geographic position and geological features, the country has interesting climate patterns. These climatic patterns are influenced by several factors including the Inter-Tropical Convergence Zone (ITCZ), the El Niño Southern Oscillation (ENSO), La

Nina, altitude and distance from the ocean (Kijazi and Reason, 2005). Generally, across the country, temperature and precipitation vary between (20^0C to 32^0C and 600mm to 1800mm) respectively (URT, 2013b). The mean duration of the dry season is between 5 to 6 months. In Tanzania altitude is an important factor in rainfall patterns; higher elevations usually receive more precipitation than lower ones (Yanda and Mubaya, 2011). However, coastal areas have relative different experience due to their proximity to the influence of Indian Ocean as they receive frequent showers. Paavola, 2003; explain that the variations in rainfall in the country are strongly related to the sea surface temperature variations (SST) in the Indian and the Atlantic Oceans which may sometimes alter standard oscillation outcomes. Moreover, the climate of Tanzania is also greatly influenced by *El Niño* and *La Nina* both of which have serious climatic problems such as floods and drought (Kijazi and Reason, 2005).

Generally, the climate in the study area features tropical climate; a hot and humid rainy season which starts from November/December – April/May and a cooler less humid dry season June – October. The average temperature is 24.3^0 C during the month of June/July (coolest period) and 27.5^0 C in December (hottest month). Most of the rainfall and temperature data were collected from Naliendele Agricultural Research Station and TMA, Mtwara sub office located at Mtwara Aiport. The mean maximum temperature is 30.5^0 C and mean minimum temperature is 21.7^0 C (NARI Research Station). Relative humidity varies between 87% in March and 79% in October. The mean annual rainfall ranges from 800 mm in inland and central areas to 1,200 mm in the hills and plateaus near the Coast. The rainfall pattern is unimodal but often has seasonal interruptions. This is due to common occurrence of short period of frequency dry spells during the end of January and early February. The rain days varies from 40-90 per annum (Kijazi and Reason, 2005). The area is influenced by dominant North – East winds during the wet season (November to May) and South-East Winds during humid long dry season from June to October while the north-east monsoon wind blows from December to March bringing the hot weather, whilst the southeast monsoon winds blow from March to September bringing intermittent rains (Shemsanga et al. 2010). The land proximity to coastal low lying area experience maritime effects of Indian Ocean where the winds are moderate to strong with varying temperatures and sometimes with few showers (Kijazi and Reason, 2005).

5.1.1 Temperature Characteristics in the Study Area.

Generally, agricultural crop performance in majority of Sub-Saharan countries is affected by intensity of solar radiation, daily temperature range and their interaction (IPCC, 2007; Deressa, 2008). As the temperature mostly regulate growth and flowering mechanism in plants; any increase in temperature can results in reducing the total deviation of the crops by inducing early flowering and shortening the grain fill period. As the crop maturity duration gets shorter or become interrupted by temperature variables; the final yield per unit area becomes lower than the normal. For example, reduced crop yield can be caused by increase in higher temperatures; which cause a greater stress due to increasing evapotranspiration as well as evaporation from the soil. Any rise in temperature on the earth, will make agriculture production more vulnerable in low and mid latitudes as a result of decreasing agricultural production. However, in higher latitudes where crop duration is limited by low temperature, the crop duration could increase resulting in improved productivity. Thus, as the dry land irrigation farming (agricultural production) lies along the coastal low land areas in low latitudes; any slight changes in temperature variables can cause the dry land irrigation farming schemes to be exposed and susceptible to these changes and hence more vulnerable. The description of temperature characteristics described hereunder fortifies the aforementioned changes and their effects on dry land irrigation farming schemes in the study area.

Generally, the average temperature in the study area is 24.3^0 C during the month of June/July (coolest period) and 27.5^0 C in December (hottest month). The mean maximum temperature is 27.8^0 C and the mean minimum temperature is 21.7^0 C (NARI Research Station). The driest month is August with precipitation less than 10 mm. The lowest average temperatures in the year occur in July, when temperature is around 20.5 °C. The minimum variation in temperatures throughout the year is 3.2 °C. Throughout the month of October daytime temperatures will generally reach highs of around 31.9°C. At night the average minimum temperature drops down to around 20.7°C. In recent times the highest recorded temperature in December has been 23.8°C with the average recorded temperature of 16°C (figure 5.1). In few cases, temperature readings go as high as 37.8°C.

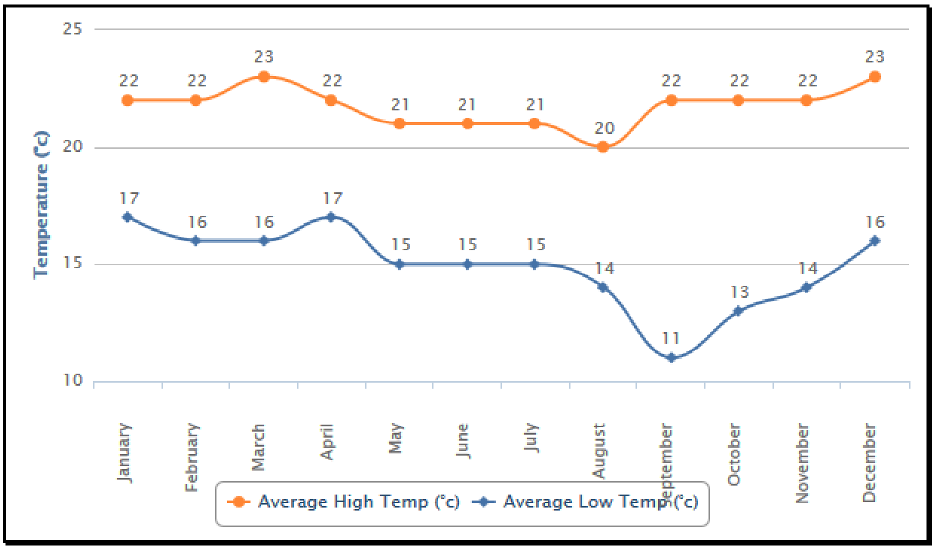

Figure 5.1: Average high/low temperature data for Mtwara. Source: TMA, 2015

Data from Climate Portal shows that the average annual temperature in the country has increased by 1.0^{0}C since 1960 (See figure 5.2). OECD, 2003 indicates that the patterns of seasonal temperature increase are consistent specifically, greater warming is projected for the cooler months (July – September) compared to the warmer months (December-February). The IPCC, 2014 indicate that mean annual temperatures in the country is projected to rise by 2.2 C by 2100, with increases over June, July and August, and lower values (1.9°C) for December, January, February. The Initial National Communication of Tanzania (2003) projects a temperature increase between 3 – 5°C under doubling of carbon dioxide, which is benchmarked to the year 2075. The increase in night temperatures has been much more pronounced than daytime temperatures.

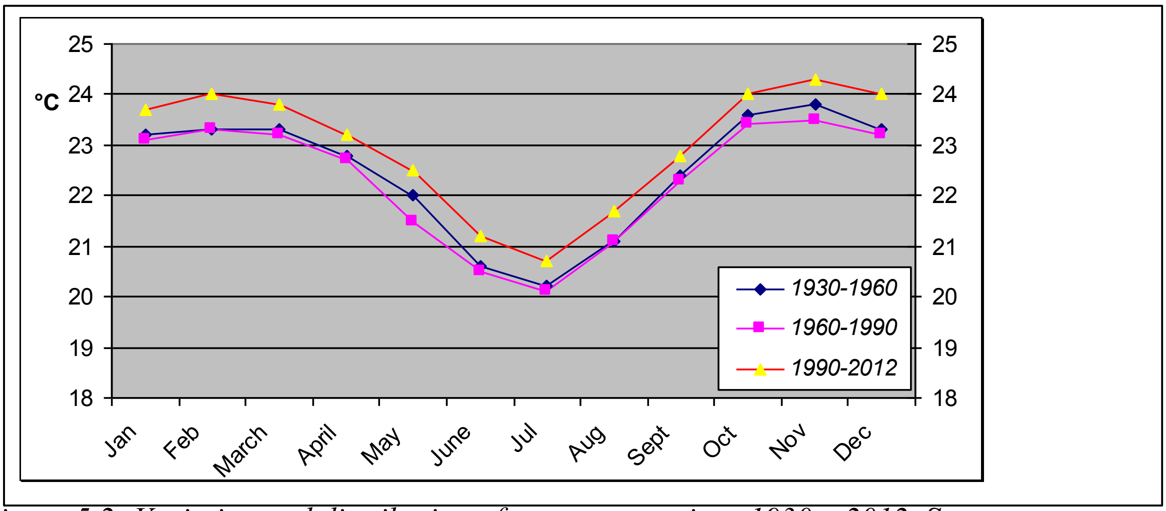

Figure 5.2: Variation and distribution of temperature since 1930 – 2012. Source: Climate Portal Data, 2015.

The spatial distribution and variation of temperature during the dry season is higher affecting the dry land irrigation farming extensively making it more vulnerable due to reduction water (surface water sources) and soil moisture (excessive evaporation) as well as crop wilting. In some cases it affects the planting season as farmers has to change the cropping pattern (early planting/mulching/planting along the water sources) and variety of crops (high resistance crops) to withstand dry condition though not necessarily high profitable crops. The National Climate Change Strategy of 2012 outlines findings from the Tanzania Meteorological Agency that some of the previous highly productive areas of Tanzania such as the Southern and Coastal low land area will continue to be affected by declining rainfall, frequent droughts and significant increase in spatial and temporal variability of rainfall.

In general, the results on the state of the local climate presented in this section shows that the long-term temperature variation is increasing with increasing instesity during the month of July – November which are the most prefered irrigation farming season. Though the data were taken only in Mtwara Meteorological Weather Station, but other country data indicates that temperature trends is on the rise, (TMA, 2015). Similar findings were documented in other studies conducted in the country and across the African continent (Paavola, 2004; URT, 2007; Deressa et al. 2008; Gbetibouo and Ringler, 2009; Shemsanga *et al,* 2010; Kangalawe and Lyimo, 2013; IPCC, 2014; Midega et al. 2015; Kihupi et al. 2015). The most important outcome of these data is that temperature readings from TMA and information from various literature sources confirmed the increasing temperature as well as their effects in agricultural production. The continuous increase in temperature and its high intensity during dry season makes dry land irrigation farming more vulnerable and this affects irrigation farming practices in the study area. Another climate variable that affects irrigation farming is rainfall characteristics in the study area.

5.1.2 Rainfall Characteristics in the Study Area.

Any reduction in water availability below a threshold; reduces productivity of almost all crops particularly water dependent crops (Deressa et al. 2008). In order to complete life cycle efficiently and effectively; crops need sufficient amount of water (rainfall) on timely basis. Therefore; a decrease in rainfalls amount can cause reduced water availability in any reservoirs which in turn cause severe damage on crops due to disturbance in critical water demand of crops needed during farming season. Even any slight amount of rainfall pouring down during dry season before harvesting period can spoil standing crops either physical damage, making seeds to germinate, and/or proliferating crop diseases and pests. Although, heavy storms may also sometimes cause crop losses by destroying crops and cause soil erosion; majority of water related issues in the study area is frequent dry spell and reduced water availability in various water sources (rivers and reservoirs) due to prolonged dry condition during the dry season where dry irrigation farming occurs. Therefore, the frequent occurrence of unpredictable dry spells and short period of rainfalls has caused a major concern for many poor farmers in the study area. Most of rainfall data obtained in the study area were provided by Meteorological Agency based in Mtwara.

According to TMA (2015), the rainfall in the study area follows a unimodal type of rainfall (starting from November/December – April/May). The hot and humid rainy season starts from November/December – April/May and a cooler less humid dry season June – October. Generally, the Tanzania’s mean annual rainfall ranges from 800 mm in inland and central areas to 1,200 mm in the hills and plateaus near the Coast. In the study area, the greatest amount of precipitation occurs in January, with an average of 189 mm while the lowest recoded rainfall is July with less than 10mm of rainfall. As the number of rain days varies from 40-90 per annum so do the precipitation varies between the driest month and the wettest month (see figure 5.3).

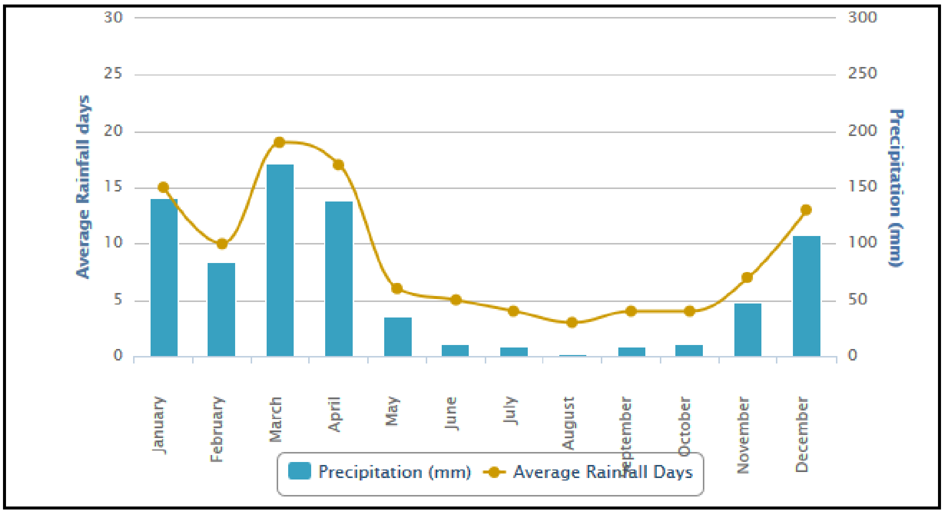

Figure 5.3: Average rainfall (mm) data for Mtwara, 2000 – 2012. Source: TMA, 2015

Although, the rainfall in the study area follows a unimodal pattern, seasonal interruptions have been often observed. This is due to common occurrence of frequency dry spells during the end of January and early February. The seasonal rains follows normal to below normal however, pockets of normal to above normal rains have been observed in eastern parts of Lindi and Mtwara regions (TMA, 2015). According to TMA/Climate Portal, decreases in observed rainfall have been significant with observations showing annual rainfall have been decreasing by 2.8mm per month per decade since 1960. The greatest annual decrease has occurred in the central and southern-most parts of Tanzania (See figure 5.4).

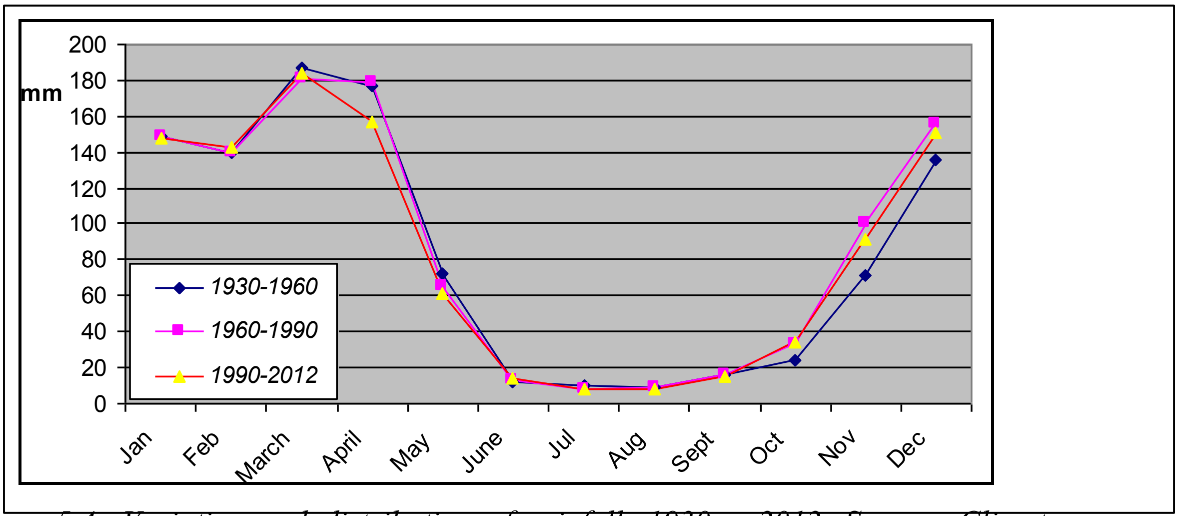

Figure 5.4: Variation and distribution of rainfall, 1930 – 2012. Source: Climate Portal Data, 2015.

Other studies indicate similar results and trends on rainfall and temperature variability in Tanzania and particular southern coastal area (Kijazi and Reason, 2005; Rowhani et al. 2010). For example, Cioffi et al. (2014) used a Non-Homogeneous hidden Markov Model (NHMM) to predict future rain-fall patterns in Tanzania under a global warming scenario, using predictors from the CMCC-CMS simulations from 1950-2100. The future downscaled simulation model (NHMM), indicate that, Tanzania may be subjected to a reduction of total annual rainfall with reduction concentrating in the wet seasons (OND), mainly as a consequence of decreasing of seasonal number of wet days. These changes are contributed by seasonal anomalies brought about by spatial variation in temperature and rainfalls over the Indian Ocean and Easterly Winds. Generally, the future changes and reduction in rainfall (pattern, quantity/availability and rain days) have consequences for agricultural production particularly dry land irrigation farming schemes due to less water available during dry season as a result of decreased rainfall.

These climatic patterns around the study area are influenced by several factors including the Inter-Tropical Convergence Zone (ITCZ), the *El Niño* Southern Oscillation (ENSO), *La Nina*, altitude and distance from the ocean (Shemsanga et al. 2010). In both villages studied the spatial rainfall anomalies and temporal variability within the wet season itself can be prominent and lead to significant deficiencies. In general the circulation models described above (modelling simulation of precipitation) are not satisfactory. Therefore based on the information analysed from Cioffi et al. (2014) and Shemsanga et al. (2010); it's clear that any reduction in precipitation will not only influence rainfed crops but also cause shortage of water for irrigation particularly along the coastal low land area due to low amount of rainfall received during wet seasons (OND). In this respect coupled with land degradation and increased human activities (water abstraction/diversion); the surface run-offs and water collection in various water bodies could differ and vary significantly along the Ruvuma Basin. Field observation in the study areas shows that rainfall deficiencies has been a limiting factor in dry land farming (water availability) and result in loss of crop and reduction in yield. In some cases too much rainfall can delay the planting season during dry season as most of the valleys are flooded. According to Mhita, 1984 in some areas of Tanzania, agriculture is limited by the length of the rain season while in others it is amount limited.

The temperature and rainfalls are essential climate variables that affect crop production particularly moisture (water) availability during the dry season. Any decrease in amount of rainfall during wet season affects water availability for irrigation farmers during dry season while any increase in temperature increases water evaporation which in turn affects water and moisture availability as well. The decrease in rainfalls and increase in temperature adversely affects crop production for dry land irrigation farmers during the dry season as both variables affects water and moisture availability for the crops as well as affects crop performance during the entire dry season farming. The increasing temperature readings and decreasing rainfall data depicted by Tanzania Meteorological Station (see figure 5.2 and 5.4 above) have implications for low water availability during the dry season which affects the length of the growing season and consequently crop yield. These changes also affects many traditional seasonal crops varieties that are not able to complete their fully growing cycle as they take longer duration and high water uptake.

5.1.3 Water Resources Availability and Characteristics in the Study Area.

The study area is close to the Indian ocean which is strongly influenced by maritime weather particularly high temperature, warm moisture and strong wind. These factors affect irrigation farming with regards to moisture loss due to excessive evaporation and extreme temperature coupled with strong winds. The Indian ocean also has strong influence on rainfall availability during rainy season where the area receive above normal pockets (TMA, 2015). Although, heavy rainfalls in the study area leads to soil erosion as well as floods; it also creates pools of water in various wetlands and water bodies such as ponds and rivers which are beneficial to farmers during dry season farming. Apart from influence of Indian ocean, the study area is within the Ruvuma River Basin which is a shared river basin between three country namely Tanzania, Malawi and Mozambique. On the Tanzanian side; Ruvuma River Basin (mostly reffered as Ruvuma River and Southern Coast Basin) is one of the major nine drainage water basin in Tanzania. The basin comprised of the Ruvuma river and 22 other rivers between the Ruvuma and the Rufiji rivers, which drain into the Indian Ocean directly. The Ruvuma River has a length of 800km and the Ruvuma basin has an estimated area of 152,200km^2 (URT, 2006). The annual precipitation averages 1,160mm and varies from 500mm to 2,000mm in the highlands (URT, 2005). According to Ruvuma Basin Authority; the mean annual run-offs in Ruvuma Basin is estimated around 15,000mm$^{3/yr}$ with a river annual flow approximating at about 28km^3, of which the contribution of Tanzania is estimated at 10km^3.

There are different water resources existing in the study area including rivers, wetlands, natural and artificial reservoirs, groundwater aquifers, and many other water bodies. Major wetlands in the study area include Chidya, Kitere, Milola while natural springs are found in Ndanda, Mbwinji, and Mnazimmoja. In this basin, main independent river systems that drain water into the Indian Ocean (figure 5.6) includes; River Ruvuma, River Matandu, River Mavuji, River Mbwemkuru, River Lukuledi, Rivers Mambi and Mbuo (URT, 2003b).

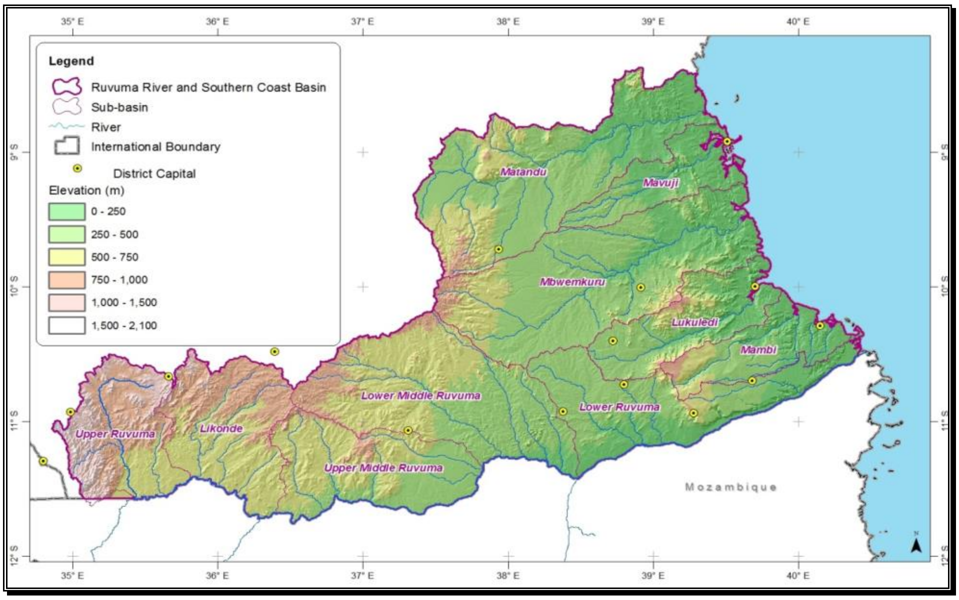

Figure 5.6: Main independent rivers in Ruvuma River and Southern Coast Basin. Source: MoW, 2015.

The study area is found along the coastal low land area with several swamps, ponds and flood plains which floods during heavy rainfalls. This is due to the nature of landscapes and topographical features present in the study area (see figure 5.6 above). Mtwara and Lindi regions have an extensive land cover (84,700km^2); however, the area covered by water represents less than 1% of the total area, most of it being along Ruvuma river and southern coastal waters (URT, 2003b). Majority of the dry land irrigation farmers depends on surface water for irrigating crops during dry season; thus water and moisture availability is very important throughout dry season farming. Though there are several water sources as described above; water abstraction, poor land use, deforestation and land degradation coupled with climate change impacts cause serious consequences for basin's available water resources particularly surface water. Rainfall as low as 200mm have been recorded at Mtwara and Lindi (TMA, 2015) which have implications on water availability in dry season.

The SPATSIM (Spatial and Time Series Information Modelling) for water resources assessment (1981 – 2010) shows that the mean annual runoff decreases from about 300-350 mm/year in the western part of the Ruvuma Basin in Tanzania to values as low as 30-40 mm/year for some of the Southern Coast Basins (MoW, 2009). The SPATSIM Modelling results suggest that apart from the future climate change projections in Tanzania; climate in the study area is getting wetter during the wet seasons (intensification of seasonal rainfall) and drier during dry season (increased warmer temperatures across all seasons). The result from SPATSIM Model (MoW, 2009) combined with IPCC (2014) projections and Markov Model –NHMM (Cioffi et al. 2014) translate into an increase in Potential Evapotranspiration which is expected to increase in the range of 2% to 5% in the 2020's and 2030's. Severe rainfall variability and recurrent dry spells (describe in section 5.1.1 and 5.1.2 above) each year in the study area; triggers a decrease in water flows in rivers, hence shrinkage of water (volumes) in water receiving bodies (figure 5.7) as well as changes in perennial rivers to season rivers and increased drying of water in wetlands and ponds which have consequences for dry season farming due to continuous decreased moisture availability for crops.

Figure 5.7: Mkwaya River (wet season and dry season). Source: Mhagama, 2014.

The flow regimes of the rivers in the basin follow closely the rainfall pattern and temperature variability. Many river channels are dry during the dry season farming hence making dry land irrigation farming more difficulty as dry land irrigation farmers cultivate crops in narrow strips near river channels or along river flows. This affects dry land irrigation farming schemes particularly at the end of farming season as farmers reduces crop field's size by cultivating along the river banks or towards the river valleys sourcing water availability. This in turn affects crop performance and production resulting in low yield thus makes farming more vulnerable and less adapting to the existing situation. Apart from climate variability and land use changes; there other different characteristics of water (such as pH, mineral concentration) also affects water quality and significantly impacting dry land irrigation farming schemes by making water resources unsuitable for irrigation purposes. For example Sechu, (1986); recorded higher content of organic matter and variation in pH values (6.5 to 8.4) along the different water sources (e.g Kitere and Chidya wetlands) in the study areas which in turn affects water quality required by different crops (water uptakes). As water becomes slightly acidic during dry season; some crops are affected due to pH requirement as well as mineral uptakes by plants.

On top of variability in pH and mineral concentration in water sources in the study area; high organic matter content particularly during rainy season (as a result of soil erosion in the uplands) causes increased water siltation and reducing the capacity of different water reservoirs to store enough volumes. Although different water resources in the study areas are overwhelmed by an unprecedented combination of climate change impacts, and poor land-use changes, acidity and salinity as well as siltation and over-utilization of water resources; these changes and impacts affects dry land irrigation farmers differently depending on their socio-economic status. Generally; elderly people, women and people with disabilities are the most affected compared to the rest of the groups in the society due to their vulnerability (exposure and lack of social safety nets such as access to information, entitlements).

The study area is characterised by four main hydrogeological zones; coastal, plateau, basement and karoo. The groundwater availability and quality across the Ruvuma River and Southern Coast Basin is highly dependent upon the geology types. The Groundwater Potential in the study area is high in the upper and lower Ruvuma River while medium and low across Southern Coast Basin. Although the mean annual ground water recharge in the study area is higher as well as sustainable ground water availability in the catchment area; potential ground water extraction for irrigation purposes is very low thus making the dry land irrigation farming dependent only on surface water for irrigating crops. According to MoW (2009); a major issue of concern regarding groundwater quality in the study area is the potential for saline water intrusion along the coast at Mtwara and Lindi region. In the future; this scenario will makes ground water unsuitable for irrigation farming and if used may contaminate the agricultural land (salinity) hence rendering irrigation farming more vulnerable.

5.1.4 Water Demand in the Study Area

According to National Population and Household Census Report (2012); the population in study area is unevenly distributed and most of the population in the regions (Mtwara and Lindi) live in rural areas with approximately 15% living in urban areas. The large segment of population living in the rural areas depends on agricultural production (rainfed agriculture). They also supplement food security and earn income through irrigation farming during dry season. The main economic activities demanding high amount of water in the study area are agricultural production (wet season), irrigation farming (dry season) and domestic water consumption as well as ecological water requirement. The low water demand in the study area due to fewer competing end users in water resources indicates less focus on water resources development and management in most rural areas. However, with increasing population growth and available fodders for livestock's, soon the quest for integrated water resources management will be the main focus. Water demand in the study area has been determined by various sectors such as rural water sanitation and supply, rainfed agriculture, irrigation, forest, wildlife and other non-consumptive uses such as navigation.

According to Mow (2009); environmental flow demand is by far the largest demand currently standing at 4,800 Mm^3 per annum in the Ruvuma River and Southern Coast Basin Waters – RSCB (96% of total demand); however other sectors utilizing water includes rural and urban water supply and irrigation. Although irrigation demand at 141.6 Mm^3 per annum is very low in the study area (3% of total demand) but it is expected to increase to 254.3 Mm^3, 568.2 Mm^3 and 1,056.1 Mm^3 in the years 2015, 2025 and 2035 respectively (URT, 2003b; MoW, 2009). By 2035 it will account for 17.6% of total demand (MoW, 2009). This demand puts pressure on the already existing water scarcity problem in the study area. With climate change impacts projections and increased human activities, urbanization and population growth; these figures underlie the need for sound water resource management to avoid conflict with environment flow requirements during drought periods as well as ensuring the sustainability of dry land irrigation farming schemes. This can be done by increasing the efficiency of water use in irrigation farming and improving water harvesting systems for dry land irrigation farmers. The prevailing system of uncoordinated water resources management in the basin cannot sustain the ever-increasing water needs for irrigation farming and other various expanding sectors along the Mtwara Corridor Development Project as well as industrial development and urbanization in Mtwara and Lindi Urban.

5.1.5 Vegetation and Land Use – Changes in the Study Area

The study area is characterised by hills in the western part and undulating landscapes and valleys in the eastern and the South Coast Basins. The dominant features in the South-Eastern part of the Ruvuma River and Southern Coast Basin are the Makonde and Rondo Plateaux which provide spring flows to some of the nearby rivers. The Lukuledi Valley runs between these two plateaux and joins the coast between Mtwara and Lindi. The Basin is dominated by the Eastern Miombo Woodlands eco-region whereas the coastal zone is characterised by coastal vegetation types such as mangrove swamps at the estuary of the Ruvuma River and coastal forests along the coast (MoW, 2009). The forests in the study areas provide vital water supplies (especially Mkunya River and Makonde Plateau) and protection from floods and landslides particularly low land coastal areas in Mtwara and Lindi (e.g. Mpapura and Mahunga valleys in Mtwara and Mkwaya and Milola valleys in Lindi).

The Ruvuma River and Southern Coast Basin comprises a biosphere reserve (Selous Game Reserve), Estuaries (Ruvuma) and a significant livestock activities as well as very fertile land for agricultural production and irrigation farming. The geology around the basin is based primarily on sedimentary deposits from the Jurassic and Lower Cretaceous (URT, 2006; MoW, 2009). The coastal sedimentary formation produces deep, well drained, sandy soils of low fertility and low moisture holding capacity such as soils of eastern basin and some few low lying areas which give rise to heavy muddy black clay soils (western basin) while other high elevated hills gives a mixture of poorly drained lime/gravel/soil to red, well drained and heavy textured soils (coastal basin). The nature of landscapes in the basin makes land use change highly sensitive to erosion and degradation. Land-use change in the study area is one of the main drivers of environmental change as it influences the basic resources of land, including increase rate of deforestation and loss of soil fertility and vegetation.

Deforestation resulting from poor land-use and land-use changes leads to reduction in vegetation cover which would have act as carbon abatement (potentials for carbon sequestration) and thereby mitigating the impacts of climate change. Similar findings were reported by national reports on Climate Change Impacts and Adaptation Programme (NAPA, 2007) which indicated the impact of poor land use and land use changes in Tanzania and its effects to the increasing share of CO_2 in the atmosphere which is a major threat to climate change. Kumar and Nair (2011) concludes that sustainable land use systems has increasingly receiving attention worldwide due to its great role in stabilizing the CO_2 levels and increasing the carbon (C) sink potentials. According to IPCC (2014); the discussions on climate change are also heavily oriented towards an agenda on mitigating the rising atmospheric CO_2 levels through C sequestration in terrestrial vegetation systems. Furthermore, vegetation cover enhances evapotranspiration which creates micro-climate and thereby influencing the state of local climate on a particular area.

The land use along the basin is changing very fast due to increased human activities, urbanization and industrial development. While some areas in the basin (Western part) are undergoing expansion of cultivation and grazing (in the southern coast basin); other areas in the basin undergo agricultural intensification. For example field observation in the selected villages along the study area (Mbuo, Mpapura, Mkwaya, Mnazi Moja, Chiheko and Chimbile Villages); shows that same portion of land have been used twice per year (*i.e* rice farming during wet season and irrigation farming-vegetables during dry season). Majority of the farmers in the study area practice poor land management such as shifting cultivation and deforestation (charcoal and timber production) which degrade vast amounts of land, reduce vegetation cover and ability of soil to provide enough nutrients for food production.

In general, poor land use management in the study area and land use changes makes the soil loose and prone to soil erosion which fills water bodies (ponds, rivers, flood plains and reservoirs). The eroded soil/organic matter in turn fills the wetlands/ponds and thereby reducing volumes of water in these waterbodies along the basin. As a result less and less water is available during dry season making a major threat to the dry land irrigation farming for farmers who depending on these water reservoirs in the study area for irrigating their crops. Agricultural intensification coupled with poor land use management and competition from other water users (livestock feeding) as well as climate change impacts present a large future problem for the dry land irrigation farming schemes which depends entirely on large quantity of water during the dry season particularly for high water demanding crops such as vegetables and fruits (green vegetables, tomatoes).

5.2 Information from Interviews and FGD's Discussion.

During the field work data collection; interviewees were asked to explain the state of local climate in the district and particularly in their villages. Information from some of the key interviewees in the study area revealed complex and diverse changes in the local state of climate in the study area. These changes which affect agricultural production and particularly dry land irrigation farming schemes are associated with livelihood activities, land use changes and climate change impacts over time. Typical examples mentioned included increased temperature; severe rainfall variability coupled with unpredictable rainfall pattern as well as strong winds and reduced water availability in various water sources during the dry season. Participants from Chimbile A and Chiheko villages confirmed that there has been an increase in temperature recently in such a way that during dry season farming, they have to water their crops twice per day and cover some of the crops (apply mulching) to reduce water uptakes. During Focus Group Discussions (FGD's); one respondent expressed great concern over changes in the climate particularly increased temperature during the dry season. He mentioned that:-

"This practise was not common in the past, about 20 years ago..... we were not used to cover our crops with grasses to reduce impacts of water loss through high evaporation but nowadays we must do....Otherwise you get nothing.". (KI,13; Member of village water committee, Chimbile A Village).

Similar cases were mentioned during interviews with village leader, Chiheko village where he mentioned the use of mulching to cover their crops in order to reduce evapotranspiration. The concern was not only on increasing temperature but also the impact it has on certain crops even those that can withstand harsh condition such as dry condition and high temperature. He further mentioned that:-

"We used to plant Okra's and they were flourishing without any difficulties and required less water, however nowadays without mulching and watering twice per day; Okra's do not flourish and produce well as they used to…This is contributed by increase in high temperature around August - November", (Village leader, Chiheko).

In Mpapura and Mkwaya Village; interviewees mentioned that rainfall has changed so much for the past 25 years in such a way that nowadays the dry season farming start as early as June and sometimes mid-May each year instead of early July. In some cases for example, other interviewees and participants in the FDG's showed high state of concerns over temperature variations where they stated that the temperature has been increasing and indicators shows that it will continue to rise. Argument from Ward Executive Officer fortifies the discussion. He said that:-

*"There has been changes in the temperature for a very long time now (...increased temperature both during rain and dry season) whereby during my childhoods, the month of July – August was not very hot as it is nowadays. We have to plant crops that withstand high temperature and resist dry condition, though some of these crops sometimes are not preferred by customers (*Ward Executive Officer, Mpapura).

In few cases, dry land irrigation farmers have indicated an increase in rainfalls, associating wet season with heavy rainfalls and frequent floods while majority of the interviewee's response's associate these changes with *El Niño* Southern Oscillation (ENSO) which occur after 10 years circle. National reports on Climate Change Impacts and Adaptation Programme (NAPA, 2007) indicated that along the Southern Coastal areas, some of the years, the amounts recorded were optimum while in some places the distribution within that year concentrated within few weeks to one month creating a heavy downpour within a shorter period. This however, creates a problem since apart from affecting farming activities; it destroys crops and damage properties and infrastructures. Several hectares of rice and maize farms were swept away in Mkwaya, Mpapura and Chimbile villages while some bridges connecting remote areas of the village and town were damaged beyond repair.

The concentration of rainfall had mixed effects on wet season farming as well as irrigation farming during dry season. For example, the concentration of heavy rainfall in one week/month may leave other months without rainfall and thereby creating shortage of water due to early commencement of dry season and thereby affecting dry land irrigation farmers and their farming activities due to less water available. This was similar to the various studies conducted about effect of climate variability (rainfall pattern) on agricultural production in other parts of the country and Africa in general (Deressa et al. 2008; Gbetibouo and Ringler, 2009; Shemsanga et al. 2010). Cioffi et al. (2014) had similar findings when predicted future rain-fall patterns in Tanzania under a global warming scenario from 1950-2100. The findings shows a reduction of total annual rainfall with reduction concentrating in the wet seasons (OND), which means less water available for dry season farming. During discussion with key informants, similar concern also becomes apparent on consequence of decreasing rainfall and number of rain days. In the following quote, one of the respondents (*Village Leader, Mpapura*) explained further that:-

"During my youth, we had enough water during dry season to raise vegetables and fruits crops and expect them to mature without experiencing any shortage of water. This is because the rainfall was predictable, it rained regularly and the amount was enough…. In those days normally rainfall lasted longer enough to fill our ponds and dams with enough water that would last thought out the dry season farming".

Authorities from Ruvuma Water Basin Board (RSCB) describe the state of local climate as changing and becoming drier and drier each day. They explained that water levels along the Ruvuma River Basin are decreasing below thresholds which affects dry season farming schemes along the basin. According to their opinions, the conditions has been triggered by climate change impacts-decreasing in rainfall amount and number of rain-days as well as unpredictable rainfalls coupled with frequent dry spells. The Water Basin Manager (RSCB) mentioned that:-

"In the past, water levels in many reservoirs were normal and rivers, streams or ponds along the basin used to floods in each rain season due to regular and predictable rainfalls in terms of amount and number of raindays per year….. In few cases, we had some fluctuations in terms of amount but not very much and rarely dry season farmers would experience water shortage for their agricultural activities.

The changes in the rainfalls in the study area have been noted throughout the season with regards to distribution, amount and pattern. During discussion with water basin manager, he describe further that currently rainfall is unpredictable in terms of amount and onset which affects water availability during dry season. One of the trainees (an intern) at the Ruvuma Basin Office narrated that although climate is changing, local community are the one influencing the changes much more compared to natural processes. She added that poor farming methods (such as shifting cultivation, slash and burn) and demand for energy (charcoal production) leave the land bare of vegetation and prone to soil erosion (*sand, mud and debris*) which fills dams and ponds and thereby reducing the size of these reservoirs to hold more volumes compared to their capacity.

The state of state of local climate in the study area has changed over time compared to the past 20 years and these changes that have been identified by interviewees having negative impacts particularly on dry land irrigation farming schemes. These changes makes dry season farmers vulnerable to climate change impacts due to shortage of water, affecting cropping pattern, crop performances and productivity as well as time and cost incurred to tend the crops. According to the interviewees these changes has been characterized by changes in the rainfall pattern and temperature fluxes. Information from Tanzania Meteorological Agency (TMA), Mtwara Zone conforms and fortifies the data collected from interviewees and focus group discussions. According to Meteorogist (TMA, Mtwara Zone); he described that:-

"The climate in Southern and Coastal Zone has changed since 1980's (about 36 years) in terms of rainfalls variability (amount, distribution, pattern and number of rain days) as well as temperature variations (increase in intensity of sunlight, frequent period of dry spells). The increase in temperatures (e.g. in 2012-2013 there has been higher readings recorded ever) occurs during dry season and particularly onset of heavy rainfalls in the month of November and December…These changes have been brought about by changes in climate-global warming and natural processes such as tropical cyclones and El Niño Southern Oscillation (ENSO) creating low pressure belt which brings heavy rainfall along the coast of East Africa but also an increase in human activities particularly removal of vegetation's and land degradation have contributed to the magnitudes of the impacts (increasing temperature due to higher surface albedo) affecting farmers particularly dry land irrigation farmers who have less adaptation mechanisms".

In the data analysis; although majority of the farmers admitted that rainfalls (*pattern, amount, intensity and frequency*) during the rainy season have increased; data from TMA shows that rainfall changes have been erratic and unpredictable causing changes in farming season. In case of rainfalls, the increase indicated by farmers has been attributed by short frequent heavy downpour of rainfall which rain for a very short period of time where majority of the farmer's perception has been influenced by these extreme events concentrated in one week to one month as well as ENSO (*El Nino*). This is also in line with 2013 and 2015 early warning reports from TMA on occurrence heavy rainfall characterized by strong winds and heavy floods. With regards to temperature variations, other farmers have associated changes in state of local climate as attributed by the temperature flux (*amount of sunshine and heat intensity*) that has been increasing over the past 20 years where water level drops quickly before the end of dry season. Farmer's perceptions on temperatures and rainfalls variability in the study area over the past 20 years; are in line with the information collected from TMA, Mtwara and national and regional reports on climate change impacts in Tanzania.

Despite the manifestation of the effects of different stressors on dry land irrigation farming schemes, the farming activities during the dry season have continued to be pursued with some adaptation mechanisms such as early planting season, changing cropping pattern and planting varieties of crops that requires less water and withstand dry conditions. In three cases, discussions with FGD's participants from Mkwaya, Chimbile and Chiheko villages who depends on rivers and underground reservoirs (as their main source of water), mentioned that they are not in danger as they have never experience high shortage of water. The main argument raised by these farmers were that rivers Mkwaya and Mnazi Moja are perennial (never dries out completely, only decrease in amount towards the end of dry season) and underground reservoirs in Chimbile and Chiheko Village always have enough storage to cater the whole dry season farming. One participant during discussion at Chimbile village mentioned that the only thing they have to worry is increasing temperature; which forces them to change the cropping pattern and type of crops so as to encounter the effects of increased temperature and reduce evapotranspiration. Generally, qualitative data conformed to the data collected through questionnaire in most of what farmers perceived about the state of local climate and this implies that the state of local climate has changed over time and will continue to change. The general trend of temperatures readings from TMA in the study area indicates an increasing trend while for rainfalls, data indicates there has been decreasing trends with increasing number of frequent dry spells and reduced number of rain days. Data from TMA also conform to the perceptions of dry land irrigation farmers, experts and village leaders whereby interviewers indicated that there is a decreasing rainfall and increased temperature incidents during past 25 years.

5.3 Summary.

This chapter has highlighted the state of local climate in the study area. The main focus was on two key climatic variables (temperature variation and precipitation pattern) and how these variables have adverse effects on dry land irrigation farming schemes. Other variables such as wind movement and moisture were also presented and its effects on irrigation farming described in details. With the help of meteorological data from Tanzania Meteorological Agency, Mtwara Sub-Office and climate portal data; the chapter presented the frequency, duration and intensity of the two climatic variables. Temperature and rainfall data from Climate Portal since 1930 were presented. Different temperature and rainfall characteristics and their changes resulting from seasonal anomalies were presented and how these changes are influenced by spatial variation in temperature and rainfalls over the Indian Ocean and Easterly Winds in the study area. The identified changes in state of local climate in the study area includes increasing temperature as well as decreasing rainfalls in terms of amount, distribution and number of rain days per year were noted in the data analysis. Responses from the farmer's perception on changes in rainfalls pattern and temperature variability also conformed to the analysed data from Tanzania Meteorological Agency, Mtwara Zone.

The chapter shows how the changes in climatic variability affects crop production particularly moisture (water) availability, crop wilting, weed infestation and pest outbreak during the dry season and how this in turn affects crop productivity and crop yield and thereby compromising dry land irrigation farming schemes practices in the study area. The chapter pointed out other factors influencing the state of local climate in the study area such as its close proximity to the Indian ocean and availability of water resources from Ruvuma River and Southern Coast Basin as well vegetation and land use changes and their influence on local climate. It describes how the increase in extreme temperature affects moisture availability in various water sources through excessive evaporation. Most of the information described here includes documentary reviews and primary data as well as field observations and qualitative data.

Qualitative data from some of the key interviews in the study area revealed complex and diverse changes in the state of local climate in the study area. Interviewees and participants from FGD's had the views that in additional to temperature variation; there is unpredictable rainfall in the study area and the distribution within seasons is not always uniform and it's accompanied by frequent dry spells while extreme temperatures have been common in the area. Furthermore, key interviews pointed out that these changes affecting crop productivity are due to increased temperature (crop wilting) and water availability (reduced rainfall amount) which in turn affects their irrigation farming practices. Decrease in rainfall in the study area in terms of amount and number of rain days; means that there is decrease in water availability for dry season farming making irrigation more vulnerable. Frequent dry spells coupled with extreme temperature and strong winds indicates further how vulnerable dry land irrigation farming schemes is to climate change impacts.

The perception of irrigation farmers, key interviews, participants from FGD's and experts all converge to the same conclusion. They have perceived that the state of local climate has been changing for the past 25 – 30 years. While key interviews were comparing the state of local climate in the past, experts (zonal irrigation officer and water basin officer) compared the level of water availability in Ruvuma River during the dry season in the past 10 years and described that it has changed so much (keeps on decreasing every year). Generally, qualitative data conformed to the data collected through questionnaire in most of what farmers perceived about the state of local climate and this implies that the state of local climate in the study area has changed over time and will continue to change if no effective mitigation measures are in place to encounter the effects of climate change. The general trend of temperatures readings from Tanzania Meteorological Agency (TMA) in the study area indicates an increasing trend while for rainfalls, data indicates there has been decreasing trends with increasing number of frequent dry spells and reduced number of rain days.

CHAPTER 6: OVERVIEW OF DRY LAND IRRIGATION FARMING SCHEMES IN THE STUDY AREA.

6.0 Introduction

This chapter provides a general overview of the dry land irrigation farming schemes in the study area. The chapter describes different farming season, land tenures and different land rights along the Ruvuma River and Southern Coast Basins. The chapter describes how different land rights and land tenure affects dry land irrigation farming schemes with regards to gender and land ownerships. The chapter also describes in-depth the type of dry land irrigation farming schemes practised and types of crops in the study area. The chapter further relate the type of dry land irrigation farming scheme practised and the type of farming systems used to raise crops and the labour employed.

The size of the farm and duration of farming during the dry season were finally described in this chapter. The chapter shows how the size of the farm in the study area which is determined by the existing land tenure systems dry land irrigation farming schemes in the study area. Although, most of the information comes from dry land irrigation farmers; field observations and various agricultural reports conformed to the data and information adhered below.

6.1 Dry Land Irrigation Farming Season

In the study area though few farmers practice mixed farming (subsistence farming and livestock keeping); research finding shows that farmers do engage in farming activities as a major means of livelihood. During the dry season; farmers in the six villages studied do practice irrigation farming nearer water sources such as river, ponds and where there is available moisture in the soil such as wetlands. About 63.6% of respondents in the study area engage in farming during the dry season while 29.4% cultivate crops both during dry and wet season (figure 6.1). During interview few respondents 7.0% said that they cultivating crops during wet season only since they do not have access to land (do not own land or have no money to buy or rent a farm) so they only borrow from other farmers who do not use the land during dry season or to those who have excess land. Although access to land along or near water sources in the study area is limited, field observation showed that several hectares of land were idle or uncultivated for several years indicating either the land is fallow period or unused land.

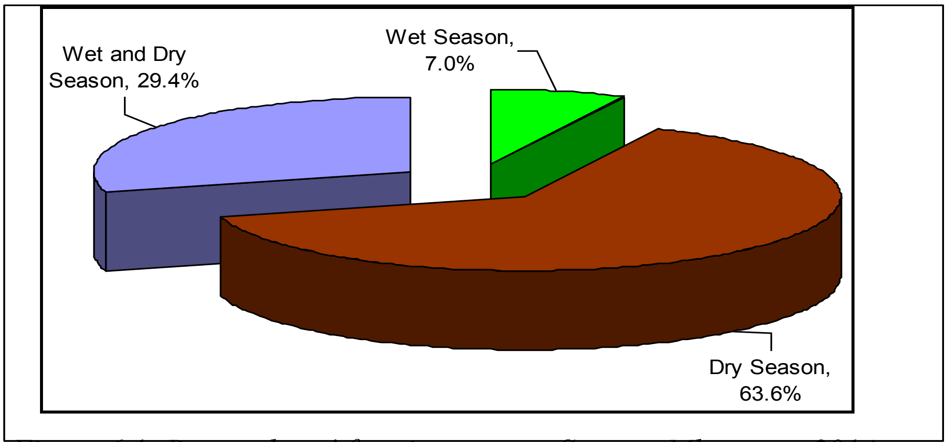

Figure 6.1: Respondents' farming season. Source: Mhagama, 2014.

The research findings show that in the six villages studied, there is variation in terms of farming season with regards to vegetables production. Farmers at Mnazi Moja and Chiheko villages seemed to engage whole in both dry and wet season without a clear gap between seasons compared to other villages (figure 6.2). Field observation shows that the availability of water (Mnazi moja river and Lukuledi river) in these villages makes it suitable to cultivate throughout both wet and dry seasons.

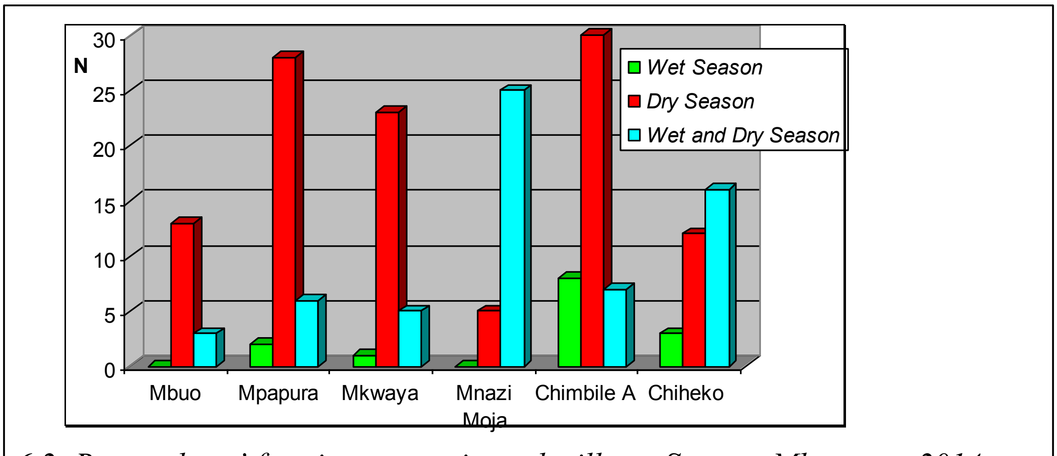

Figure 6.2: Respondents' farming season in each village. Source: Mhagama, 2014.

The available land at Mnazi moja Valley is flooded during rainy season and conducive for rice farming while during dry season there is enough water (flooded rice paddy) making it suitable for rice or vegetables cultivation. Along the water sources in the study area; other vegetables and horticultural produce are cultivated at the edge of the valley depending on available moisture or possibility of irrigating the field/crops. Other villages with farmers practicing both wet and dry season farming are Chiheko Village followed by Chimbile A Village. These villages (Chiheko and Chimbile A) have flat valleys with suitable soil for cultivation of other crops during rainy season (rice, cow/pigeon pea and maize) and vegetables (onions, eggplant, bell/sweet paper, okra) during dry season. However, in these villages, most of the farmers farming during the dry season in these villages do not own the land; they only rent it from land owners at agreeable terms/price (sharing the small percentage of profits per one harvest or a reasonable amount). A statement made by respondent in Chiheko villages (KI,16), conform the argument. He said that:

"I pay up to TShs. 100,000/= (equivalent to 42.9€) per season per a plot of land (0.4ha) and sometimes I share the profit from harvest I made during the dry season farming"….it is a common practise and everyone in the village is happy about it.

Field observation noted that one plot of land can be utilised once to twice (one or two harvest season) per dry farming season depending on productivity of land (crop performance and profits made) and available moisture or water. This has been also contributed by limited access to land but as well as profit made from previous harvest especially for farmers who had started planting crops early onset of the dry season.

In all the six villages studied; most of the dry land irrigation farmers interviewed practice farming along or adjacent to the water sources such as River Mnazi Moja and River Mkwaya – Lindi Rural District, River Mpapura – Mtwara Rural District. The dry land irrigation farming pattern is the same across the six villages studied where farmers cultivate small plots of land utilizing the available land and moisture effectively. In most villages studied water scarcity is the limiting factor in dry season farming making irrigation farming difficult and in many cases impossible for the farmers to produce vegetables crops especially twice per dry season farming. In cases where river runs dry, others use water from the ponds – *Ndiva* (*e.g.* Mbuo village) and other natural wetlands. During field visits in Chimbile and Chiheko Villages, Ruangwa District, some farmers use available soil moisture to cultivate crops especially early farming while others use underground water reservoirs (shallow water table) through dug out ponds (*vinyungu*) as shown in figure 6.3 below. Here farmers dig a hole (*vinyungu*) and water eventually emerges from below the surface like spring.

Figure 6.3: Irrigating crops using traditional vinyungu (underground water reservoir). Source: Mhagama, 2014.

Irrigating crops (vegetables) using traditional *vinyungu* has been used by other dry land irrigation farmers in Iringa and Morogoro regions (Majule, 2003; Kaswamila and Masuruli, 2004). Depending on water availability, nature of the landscape and available resources, most of the farmers in the study area use a mixture of two or three methods to irrigate their crops in the field. Most of the villages studied, majority of the farmers use buckets, watering cans, manual pumps and irrigation canals to irrigate their crops/vegetables. In Mnazi moja village most farmers use flash irrigation. In few cases during field observation in Mpapura and Mbuo Villages, farmers were spotted pumping water using manual pump and flash the whole field. Some studies shows that the price of land (renting price) adjacent to the water sources such as river or ponds increases during dry season compared to wet season (Mkavidanda and Kaswamila, 2001; Kaswamila and Masuruli, 2004; Majule and Mwalyosi, 2007). The field observation shows that the average areas planted vegetables crops per household during the dry seasons was not large than 0.4ha compared to wet season which is 1 – 2 ha. According to the Mtwara Regional Economic Profile, the village with the largest area planted per household (two season's average) are Nanyumbu district 0.5 ha, followed by Masasi and Mtwara rural districts (0.4ha). The research findings revealed that there are different types of land tenure in the six villages studied as described below.

6.2 Land Tenure and its Impacts in the Study Area

6.2.1 Land Tenure in the Study Area

In the six villages studied, there are four major land tenure systems that exist. The cultural setting in the study area shows that men are given high priority when it comes to inheritance compared to women. According to Carpono (2010) and Behrman et al. (2013) argues although formal laws provide equal rights for men and women with regard to access to land and secure tenure (through mechanisms such as registration of joint rights and marital property laws), in many parts of Tanzania customary law and traditional practice prevent these provisions from being applied. Hence women's access to property rights and the other services that accompany such rights remains constrained and specifically rights to access, control and transfer land are weaker compared to those of men. This in turn affects farmer's particularly women from accessing and owning land for agricultural production purposes. In the study area, men seems to have more access to land compared to women where large proportion of male respondent have inherited the land from their parents (29.4%) compared to female respondents (20.9%). Findings show that women have more access to land through renting (27.3%) and buying (11.8%) from other farmers (table 6.1).

Table 6.1: Type of land tenure systems practised in the study area

Gender	Type of Land Tenure Systems Practised							
	Inheritence		Village Authority		Buying		Renting	
	N	%	N	%	N	%	N	%
Male	55	29.4%	1	0.6%	4	2.4%	10	5.3%
Female	39	20.9%	5	2.3%	22	11.8%	51	27.3%

Source: Mhagama, 2014

Discussion with FGD's shows that in Chimbile and Chiheko Village its possible to get land from the village authority due to available general land (woodland or shrub land) in the village. In Mkwaya village, a participants (KI, 06) mentioned that:- *"the village authority do not have land. This is due to the fact that historically, vast amount of land was formerly owned by Sisal Company during 1960's. The sisal company was Mingoyo Sisal Company in Mkwaya village and Tanzania Agricultural Sisal Company – TASCO in Mpapura village".*

According to Mkwaya village leader; *"the sisal company closed down in the 1980's and stopped producing sisal fibres. The existing sisal land was then converted into agricultural farms and taken by local community particularly farm workers and thereby passed it to the next generation"* (Village Leader, Mkwaya village).

Though men have more access to land in the study area, women seem to be more participating in on-farm activities such as dry land irrigation farming and rainfed agriculture. The aforementioned land tenure systems existing in the study area include:-

i. ***Inheritance system:*** Majority of the respondents inherited their land from parents or family and is passed from one generation to another by the head of the family in which according to Makonde and Yao customs is the owner of the land is normally the husband. According to their norm and customs, women have no right to control over land. They can only access and use family land or their husband's land if married.
ii. ***Village Government:*** This is the land that belongs to the village government and is given to individuals in the village who are in need under local authority procedures. Under this system both men and women have equal rights to acquire and use the land. In the study area, very few people were given land by village authority due to availability of land along the coastal area.
iii. ***Buying from other farmers:*** This is the land which is acquired through buying mainly from other farm owners. Under this system, farmers have the chance to choose the potential land that is fertile and near the water sources.
iv. ***Renting from farm owners:*** There are few cases where dry land farmers acquire land temporarily by renting from farm owners. Although rented land is utilized very effectively, only annual crops are allowed for cultivation; mostly green vegetables cultivated during dry season. In this system, the right of occupancy can be revoked at any time if the occupant violet the guidelines and rules. During the interview, the respondents revealed that there are no signed contract only verbal communications are used.

6.2.2 Impacts of Land Tenure on Dry land Irrigation Farming Schemes

The existing land tenure systems in the study area affect dry land irrigation farming schemes in different ways. Data from the field interviews shows that the different types of land tenure systems that exist in the six villages affect the irrigation farming schemes in three aspects. *First*, land tenure systems in the study area dictate the size of the farm a farmer has to cultivate and produce crops making dry farming scheme unproductive and difficult to expand/grow (figure 6.4). Apart from water availability being a limiting factor in dry land irrigation farming; analysis and field observation shows that those who do not own land cannot afford to cultivate large portion of land due to high price of purchasing the land or renting a farm/plot. Inheritance (inheriting land from parents/given piece of land by a spouse) seemed to play a big role where most of the respondents interviewed revealed that they have inherited the land from their parents. Gender play a big role in inheriting land where response from the farmers shows that men have more access to land compared to women through inheritance. This has been also influenced by traditional and culture of Makonde community around the coastal area where resources belongs to a man.

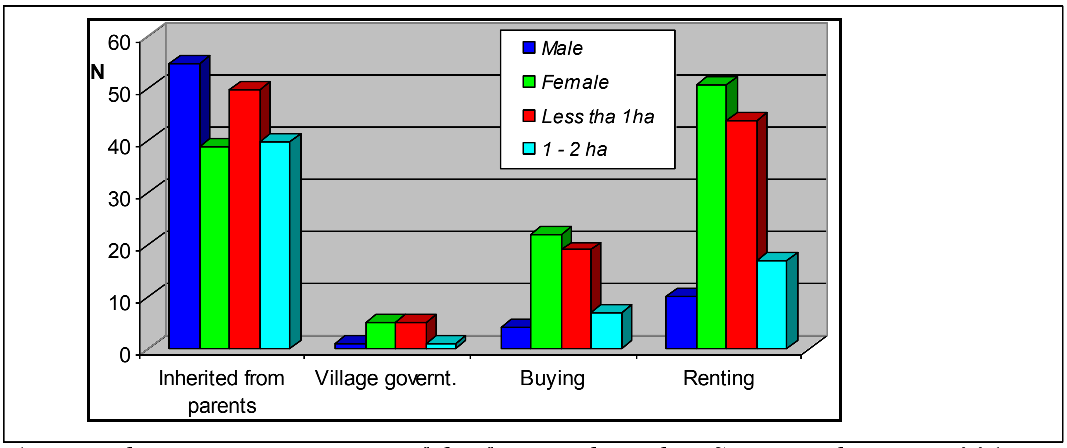

Figure 6.4: Land tenure systems, size of the farm and gender. Source:Mhagama, 2014

Secondly, land tenure control and determine the farming season in the study area making the dry farming more vulnerable as the land owners can affects or interfere the planting and harvesting time. For example late release of the land by land owners to the farmer for dry farming season can affects crop performance and harvesting season as well. The same may happen when the owner reclaiming the land back early before the end of dry season farming. This is because land is provided based on casual relationship or verbal agreement between land owner and the farmer. In the six villages studied large numbers of respondents interviewed (32.1%) who practice farming during dry season, own the land followed by those who have rented (19.7%) the farm plots and few farmers do buy the land from land owners (figure 6.5). The land tenure and land rights also dictate the ownership pattern as well as the duration of farming during the dry season farming thereby making dry land irrigation more vulnerable as farmers who had the ability to cultivate vegetables such as onions twice per season may fail to do so due to the existing land tenure.

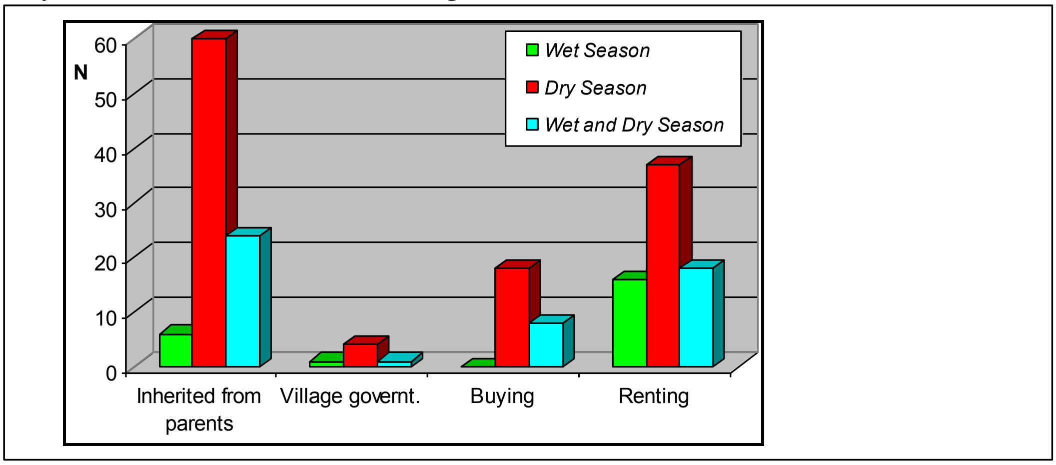

Figure 6.5: Land tenure systems and farming season. Source: Mhagama, 2014.

Land ownership affects dry land irrigation farming schemes as the land owners can decide which part of the land he or she has to release for renting. Most of the farmers who have rented the land find it difficult to farm during the end of the dry season as some of the rented lands are allocated far from the water sources. In few cases the rented land is marginal land (degraded land with less fertile soil) and sometimes land owners may need the land before the end of the dry season. Another interviewee (KI,14), a vegetable farmer at Chimbile A village narrates that:-

"Sometimes farm owners can also dictate when to release the land hence interfering with farming season (onset and at the end of dry season) ....they sometimes give us land that is unfertile and very far away from the water sources".

In general, buying the land from land owners is very expensive while getting land from village government is difficult because of bureaucracy and procedures. Most of the lands in the villages belong to farm owners (local residence) through customary and traditional laws. In some cases (Mpapura, Mkwaya and Mnazi Moja Villages); the land farms (plots) located nearer the water sources (river) are relatively expensive when compared to upland farms because they can be used to produce various crops throughout the year. The land tenure has no relationship with access to water for irrigation although it influences the price of land for people who have no access to land (renting or buying). In all six villages visited water is provided free of charge for irrigation and farmers can access water throughout the day.

Thirdly, there is no contractual agreement during land acquisition for irrigation farming hence making it difficult for farmers in case of any emergence or disagreement. Narration from the field indicates that buying the land from land owners is very expensive and renting the land has complicated processes and brings a lot of confusions since there are no clear terms in contractual agreements. Land is acquired via negotiation and different negotiating terms are applicable. The common observed terms are payment in cash or sharing profit from harvest. Normally land is given to a family friend or someone known by the villagers. Moreover, when the land owner needs the land before the end of the dry season for land preparation the renter has to return/release the land sometimes with no refunds. This complicates the dry land irrigation farming schemes when a farmer rent the farm and expects to complete two or three harvesting season. This was noted in Chimbile A village where there are two or three harvest season for onions per one dry farming season and where the farm owner needed the land before the completion of dry farming season. Therefore the contractual agreement on the land tenure again can affect the already constrained farming system compared to farmers who inherited land from their parents and can use the land during the dry and wet season without any difficulties.

6.3 Types of Dry Land Irrigation Farming Schemes Practiced

In the study area four types of dry land irrigation farming schemes were identified. They include ponds *(ndiva/lambo),* dug-out ponds *(vinyungu),* canals *(mifereji)* and others (*using manual pump/soil moisture*) which are only used during the dry season farming. Ponds/wetlands are common around wetlands or collected flood water and dug-out ponds are common in low water table areas while canals around river course. Manual pump is common on both ponds/wetlands and rivers while soil moisture is common around weltands and bottom flooded valleys. During field observations, in most cases farmers were seen using two or more types of irrigation farming so as to maximise outputs. The following part describes the four identified types of dry land irrigation farming schemes in the study area include:-

i. ***Ponds (Ndiva/lambo):*** This is the type of dry land irrigation farming schemes where farmers use natural ponds or construct large artificial pond (see figure 6.6) and harvest rain water or water from the rivers and use it to irrigate crops. The large artificial pond is constructed for the purpose of storing water to be used during the dry season. The size of the ndiva/lambo differs from place to place depending on financial resources and availability of water. They are commonly affected by excessive evaporation.

Figure 6.6: Traditional ndiva/lambo at Mbuo village. Source: Mhagama, 2014

Some of these ponds have been constructed by farmers, but according to the narratives from village authority most of these ponds have been constructed by various projects supported by donors and government. Sometimes natural ponds do exist in few places depending on the landscape. Irrigation using water from the *pond/ndiva* is very labour intensive and affects irrigation farming due to labour and time involved in irrigating crops in the field. Apart from that, temperature variability affects water availability in the pond due to increased evaporation and thereby complicating irrigation farming practices.

ii. ***Dug-out ponds (Vinyungu):*** These are small dug-out ponds that are constructed during dry season across the river bed (see figure 6.7) in order to tap water from underground stream or from the small water springs that emerge from the river bed. In this case, farmers use the water from the dug-out ponds to irrigate crops. Depending on the nature of water table and pressure; the deeper the dug-out ponds the more water is pumped out.

Figure 6.7: Dugout pond or traditional vinyungu at Chimbile A village. Source: Mhagama, 2014.

However in most cases, farmers take advantage of the fact that the surrounding land contain enough moisture to support crop production for a certain period of time usually one month immediately onset of dry season. The size and orientation of the *kinyungu* plot depends on the quantity of water at the site. As the water level decreases at the end of dry season so does the depth of the *kinyungu* increases. Dug-out ponds are affected by falling water table every year. They are normally constructed parallel to the land slope where the moisture content is high. Though in many dug-out ponds *(vinyungu)*, water is available throughout the dry season farming but in few cases, depending on nature of water table (particularly low water table), these dug-out ponds run dry especially at the end of dry season farming due to fall of water table and thereby affects dry land irrigation farming.

iii. Mifereji/Canals: Here dry land farmers use channels/canals constructed using crude resources (earth canals lined with clay soil/thatches) and harvest water from the river and direct it to their farms or rice pads by flooding the field (see figure 6.8). These canals are affected by flood water and needs maintenance immediately onset of the dry season so as to maximise water output. Though, water is available throughout the dry season farming, they are affected by infiltration and excessive evaporation. In most cases farmers do prefer cultivating along the river course so as to abstract water, however with increasing competition for water users; the sustainability of irrigation farming depending on canal irrigation is questionable.

Figure 6.8: Mfereji – canals lined with earth materials and flash irrigation. Source: Mhagama, 2014.

iv. **Others *(Using Manual Pump or Available Soil Moisture):*** In this case farmers exploit the available moisture around the valley or pond where flood water has been collected during the rainy season. They cultivate crops (green vegetables) on these flooded valleys and depend entirely on soil moisture from planting until harvesting (figure 6.9). In few cases little water (moisture) is added during planting and plant roots search for water beneath. Generally, farmers cultivate crops that can withstand harsh conditions such as okra, cow peas, sweet potatoes and fruits like banana and pawpaw.

Figure 6.9: Farming around the valleys using soil moisture/flooded valleys. Source: Mhagama, 2014.

The four different types of dry land irrigation farming schemes identified in the study area differ from village to village depending on the availability of water, landscape, resources and land tenure systems that are applied to the different farming season mentioned above. For example in Mpapura village majority of the farmers (13.4%) use natural pond (*ndiva/lambo)* as source of water to irrigate their crops while in Mnazi Moja village majority of the farmers (11.2%) use water from canals/stream (*mifereji)* and manual pump (figure 6.10). In Chimbile A village, farmers (18.2%) use underground water through small dugout ponds (*vinyungu*) to irrigate their crops as well as soil moisture around bottom valleys.

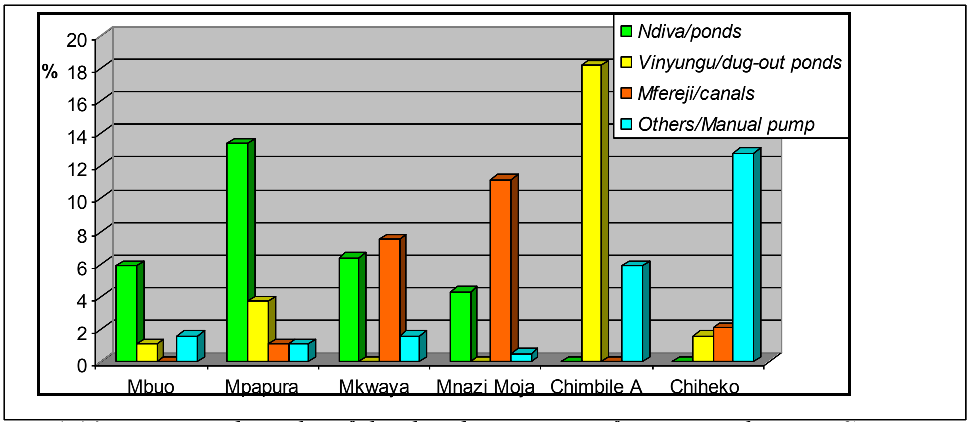

Figure 6.10: Type and mode of dry land irrigation farming schemes. Source: Mhagama, 2014.

Soil moisture is common around low lying areas surrounded by marsh lands and swamps and is used only onset of dry season instantaneously. During discussion with FGD's; participants in Chimbile A described that soil moisture is normally used for one plating season and only crops that withstand dry condition can be planted. Majority of the participants interviewed in both villages prefer natural ponds-*ndiva/lambo* (Mpapura and Mkwaya) and dugout ponds-*traditional vinyungu* (Chimbile A and Chiheko) to irrigate their crops while participants in Mnazi Moja and Mbuo prefer using *manual pump* or *using soil moisture* and canals-*mfereji* for irrigate their crops during dry season farming. Although each village prefer using one particular type of irrigation farming schemes (depending on the water source available); mixture of other methods are employed as well to irrigate crops in case one particular farming type fail to supply enough moisture to the crops in the field.

In few cases, dry land irrigation farmers were spotted using manual pump and other equipments such as buckets and watering can to harvest water from the river and ponds and irrigate their crop. This type of farming is labour intensive and requires financial resources in purchasing and maintaining the pump, hence very few farmers use manual pump to irrigate their crops. In some cases farmers prefer using a mixture of manual pump or watering can or two methods mentioned above to supplement soil moisture for their crops especially when water level drops in various water sources (water reservoirs). In some cases some farmers abandon the farm, reduce the size of the farm or change the crops (planting crops that use less water and requires short time to mature) due to water shortage. However, when water availability is not an issue farmers utilize this opportunity to expand their farms and produce more crops.

Water availability coupled with demand of a particular crop in the markets dictates the type of crop a farmer has to produce throughout the season. For example a farmer may choose to change type of crops (change from green vegetables to okra or egg plants) after the first harvest depending on water availability by choosing crop that require less water at the end of dry season when moisture and water level drops. High demand and better price may also motivate the farmers to choose the type of crop to cultivate in a particular season.

6.4 Types of Crops Grown During Dry Season Farming

Green vegetables such as green amaranthus, spinachi, collard green, green pepper and okra accounts for over 80% of the cropped area under irrigation in Mtwara and region. The cultivated vegetables are consumed in many parts of Mtwara and Lindi town as well as other villages in the two regions. Other local vegetables produced in the study area includes African nightshades (*Solanum villosum*), jute mallow (*Corchorus olitorius*) cowpea leaves (*Vigna unguiculata*), pumpkins and sweet potatoes leaves. When farmers in the study area were asked to indicate which common crop they prefer to plant around their farm results in table 6.2 below shows that majority of the farmers cultivate onions (16.1%) followed by green vegetables (11.3%) and tomatoes (10.2%).

Table 6.2: Types of crops grown during dry season farming.

S/N	**Village**	**Types of crops grown**							
		Green vegs		***Tomatoes***		***Onions***		***Others***	
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
1	Mbuo	11	5.9	2	1.1	0	0	3	1.6
2	Mpapura	21	11.3	8	4.3	4	2.2	5	2.7
3	Mkwaya	11	5.9	9	4.8	1	0.5	8	4.3
4	Mnazi moja	7	2.8	11	5.9	0	0	12	6.5
5	Chimbile A	4	2.2	7	3.8	30	16.1	4	2.2
6	Chiheko	3	1.6	19	10.2	4	2.2	2	1.1

Source: Mhagama, 2014

In additional to the above mentioned vegetables, farmers also cultivate other crops such as okra (6.5%), eggplant (4.3%) as well as bell paper (2.7%). Field observation indicated that vegetables grown appeared to be distributed differently in each of the villages studied where green vegetables were common in Mbuo, Mpapura and Mkwaya villages while onions, cabbages and green peppers were common in

Chimbile A and Chiheko villages. Other crops such as okra, eggplants, sugarcane, maize and rice were also common in Mnazi moja village.

Despite the availability of improved crop varieties and horticultural practices, the average vegetables produced and crop yield in the study area has stagnated and remain very low. National agricultural reports shows that in Mtwara region the most cultivated fruit and vegetable crops are tomatoes with a production of 6.4t/ha followed by eggplant 3.4t/ha and okra 0.6t/ha while in Lindi region the tomato and onion were the two most dominant vegetable crops with tomatoes 8.9t/ha and onion 2.5t/ha produced in year 2014/2015 (URT-Vh, 2012; URT-Vi, 2012). The production of the other fruit and vegetables crops such as watermelon, cucumber, pawpaw, cabbage, carrots, green peppers and African eggplants are on the rise in the study area. Mnazi moja village is famous for maize, sugarcane, rice and banana cultivation.

Interesting scenario was observed during field visits; where other crops such as cucumber, watermelon maize, and cabbage which are high valued crops were only being planted as trials or around field boundaries. Some of the reason such as high water requirements for a particular crop and crop duration to maturity, mentioned by interviewees fortified the reason for such low practices. One of the participants from Mkwaya village FGD's (KI, 07) mentioned that:-

"I normally plant various green vegetables and I agree that some crops command high price at the market, but planting maize, banana, sugarcane or watermelon is a waste of time and resources....as these crops consume lots water and the duration for crops from planting to maturity is longer which is very risky business…I only plant few around the boundary for consumption, however, I also sell them if I get customers who can pay for good price".

Most of the crops are sold on site to the middle men who are collecting vegetables to sell at the main markets in Lindi and Mtwara town while few vegetables are sold to the local market or consumed as foods. During field visits; most of the farmers were seen selling the crops on site, indicating the main purpose of vegetables production under irrigation farming is income based (cash oriented) however discussion with interviewees indicated that in most cases the same vegetables are consumed around household as part of the meal or food recipes. Though the results from farmer's responses shows that most of the vegetables produced (such as cabbages, tomatoes, spinach, okra and onions) are sold to the markets; still the dry land irrigation farming schemes in the study area are practised as subsistence only. The main explanation for this might be due to the fact the vegetables produced are sold only for survival (buying households needs for the families) and farming is mainly for sustenance or supplementing household income and food security during dry season.

Most of the farmers in Chimbile A, Mpapura and Chiheko villages has large farm land/plots compared to farmers at Mnazi moja, Mbuo, and Mkwaya villages. This is contributed by the fact that Chimbile A, Mpapura and Chiheko have extensive flat land compared to the rest of the villages in the study area. Additionally, these villages have been involved in irrigation farming business for a very long time producing different types of vegetables and fruits. Field observation showed that these villages have extensive flat flooded valleys that are suitable for both rain season (rice pads) and dry season (vegetables) farming which explain why these villages have larger farms size land compared to other villages.

6.5 Size of the Farm, Duration of Farming and Cropping Pattern

Climate change impacts does not only affects crop productivity but it also alter land-use patterns, both in terms of the total area cultivated (size of the farm) and geographic distribution of crops. For example, a decrease in water availability as a result of high temperature (evaporation) or low rainfalls affects the total area under cultivation as well as change of cropping pattern and crop varieties. At the same time the existing size of the farm and cropping pattern affects the dry land irrigation farming schemes. As described above (section 6.1.1 and 6.1.2); findings shows that the land tenure systems determine the size of the farm (plot/field) a farmer has to cultivate which in return affects dry land irrigation farming schemes due to the fact that it affects cropping pattern and crop yield per single harvest. The findings indicate that there is close relationship between type of land tenure and size of the farm. In general, data analysis shows that there was high number of respondents (50.1%) who inherited land from their parents followed by 32.8% who rented the farms from farm owners (table 6.3). Further analysis indicates that farmers (23.5%) in the study area with large farm size (1-2ha) have inherited the land from their parents followed by farmers (9.1%) who rented the land from land owners. In general, land ownership seemed to be from inheritance which again affects farmers who do not have access to land but would like to practise dry land irrigation farming schemes.

Table 6.3: Land tenure systems and size of the farm

S/N	Type of land tenure systems	Size of the farm				Total Percentages
		< 1 ha		1 – 2 ha		
		N	%	N	%	
1	Inherited from parents	50	26.74	44	23.5	50.1%
2	Village government	5	2.7	1	0.5	3.2%
3	Buying	19	10.2	7	3.7	13.9%
4	Renting	44	23.5	17	9.1	32.8%

Source: Mhagama, 2014

Although, the land tenure systems dictate the size of the farm a farmer has to cultivate and produce crops; there were little significance in terms of duration of farming and the type of land tenure. Discussion with interviewees revealed that dry land irrigation farming schemes is a recent practices and majority have been doing it to capture the new market or demand for vegetables particularly tomatoes, onions, red paper and other green vegetables that previously were imported from outside the region such as Dar es Salaam and Iringa. The demand for vegetables is high in the near towns of Lindi and Mtwara due to on-going oil and gas exploration and construction of factories. This might have contributed to the farmers to engage more in farming compared to previous years. There were good relationship between farming season and duration of farming as large number of respondents practice dry land irrigation farming schemes during dry season compared to wet and dry season and wet season only (see figure 6.11). The result however, shows that dry land irrigation farming is a new practice that has been practised not less than a year.

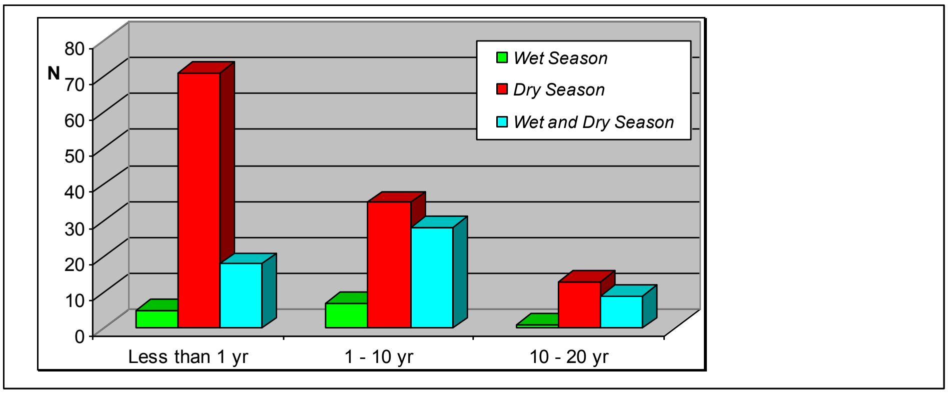

Figure 6.11: Duration of farming and farming season in the study area. Source: Mhagama, 2014.

Those who do not own land cannot afford to cultivate large portion of land can only cultivate crops in one season only such as dry season. Buying the land from land owners is very expensive while getting land from village government is difficult because of unavailable land, bureaucracy and procedures making it difficult for many dry land irrigation farmers to own the land especially those coming from far villages in searching for water to cultivate vegetables. Most of the lands in the villages belong to farm owners (local residence) through customary and traditional laws. In general, land tenure, land rights, types of irrigation farming and size of farm as well as duration of farming may all affects farmers and farming practices when all acts together simultaneously. These factors affects dry season farming and makes dry land irrigation farming schemes in the study area more vulnerable as farmers sometimes fail to cultivate large portion of land and produce more yield, not because of climate change impacts (such as water shortage-less water available, increase in temperature, pest and crop wilting) but rather because of complexity and interwoven nature of land tenure systems and land rights which affects the size of the farm a farmer has to cultivate and duration of farming season and thereby reduce crop yields.

6.6 Summary

This chapter provided a general overview of the dry land irrigation farming schemes in the study area. Information from irrigation farmers, key interviews and participants from FGD's as well as field observation were used to describes different farming season, land tenures and different land rights along the Ruvuma River and Southern Coast Basins. Majority of the interviewed farmers do farm during dry season, however some do cultivate both wet and dry season. Using information from respondents in the six villages studied, four major land tenure systems were identified. The identified land tenure systems includes land under inheritance, under village government authority, buying land from other farmers while others do rent from those who have large patch of land and they are not utilizing whole portion.

Data analysis from farmer's responses indicates that cultural setting in the study area play a big role where men are given high priority when it comes to inheritance compared to women. Thus land rights combined with land tenure, play an important role in vegetable production in the study area. The study found that land tenure and land rights affects the size of the field an individual farmer has to cultivate where those who rent the farm are affected more. The land tenure and land rights also dictate the ownership pattern as well as the duration of farming during the dry season farming thereby making dry land irrigation more vulnerable as farmers who had the ability to cultivate vegetables such as onions twice per season may fail to do so. In much worse scenarios there are no contractual agreements between land owner and farmers which further complicate the dry land irrigation farming schemes as land owners can decide to revoke the right to occupy the land at any time without notice. Qualitative data from participants in FGD's substantiated the findings as they mentioned that sometimes farm owners can also dictate when to release the land hence interfering with farming season (onset and at the end of dry season).

With regards to types of irrigation farming practised in the study area; four types of dry land irrigation farming schemes were identified. Depending on the availability of water sources; farmers have identified four different irrigation farming including the use of ponds *(ndiva/lambo),* dug-out ponds *(vinyungu),* canals *(mifereji)* and others (using *manual pump/soil moisture*). Ponds/wetlands are common around wetlands or collected flood water and dug-out ponds are common in low water table areas while canals around river course. Manual pump is common on both ponds/wetlands and rivers while soil moisture is common around weltands and bottom flooded valleys. Field observations showed similar findings and in most cases farmers use two or more types of irrigation farming so as to maximise outputs.

In this chapter, analysis shows that there are different types of crops grown during dry season farming. The chapter identified several green vegetables as well as fruits being cultivated in the study area. Information from respondents, shows that majority of crops grown during dry season includes green vegetables such as green amaranthus, spinachi, collard green, green pepper, tomatoes, onions, eggplants and okra. Local vegetables produced in the study area includes African nightshades (*Solanum villosum*), jute mallow (*Corchorus olitorius*) cowpea leaves (*Vigna unguiculata*), pumpkins and sweet potatoes leaves. Other crops observed in the study area, though not mentioned by farmers includes fruits and vegetables crops such as watermelon, cucumber, pawpaw, cabbage, carrots, maize, sugarcane, rice and banana. During field visits, some of the fruits (watermelon, banana, sugarcane) were seen planted as trials.

Finally, in this chapter size of the farm and duration of farming during dry season were presented and described. The analysis from this chapter shows how different size of the farms are determined by the existing land tenure systems and how this affects dry land irrigation farming schemes in the study area. Land ownership seemed to be from inheritance which again affects farmers who do not have access to land but would like to practise dry land irrigation farming schemes. Although, most of the information comes from dry land irrigation farmers; field observations and various agricultural reports conformed to the data and information adhered in this chapter.

CHAPTER 7: FARMERS RESPONSE TO THE IMPACTS OF CLIMATE CHANGE ON DRY LAND IRRIGATION FARMING SCHEMES.

7.0 Introduction

In this research study, one of the main focuses was to identify the impact of climate change on dry land irrigation farming schemes in the study area. Using farmer's perception to identifying the impacts of climate change on dry land irrigation farming schemes will not only provided the basis for revealing the vulnerability of irrigation farming schemes but also would help in identifying their implications to the farmers practising dry land irrigation farming schemes, and their adaptation strategies as well as the resilience of the farming schemes. This chapter describes in details the effects of climate change on the dry land irrigation farming schemes by using dry land irrigation farmer's perception. It describes local knowledge farmers have with regards to impacts of climate change and broaden the farmers knowledge by employing farmers perception on the key climate variables (temperature and rainfall characteristics) affecting dry land irrigation farming schemes in the study area.

The chapter describes further the impact of climate change it has on dry land irrigation farming schemes by describing in details the climate change extremes such as floods, frequent dry spell and drought condition. Other climate change impacts in the study area such as soil erosion, soil contamination and weed and pests infestation have also been described here.

Field observation as well as local indicators of climate change and climate change impacts has been documented in this chapter. Finally, the chapter describes information from interviewees and focus group discussion narratives. Various reports, local, national and regional reports coincide with data analysis from farmers, interviewees and field observations as well. The detailed information about the impacts of climate change on dry land irrigation farming schemes in the study area have been described hereunder.

7.1 Farmers Knowledge on Impacts of Climate Change

Results from the six villages studied shows that majority of farmers (93.5%) do understand the impact of climate change on dry land irrigation farming schemes while about 4.8% said no, they do not understand anything about climate change (figure 7.1). The remaining 1.7% mentioned that they have never experienced any changes in climate or weather and everything depend on God in such that all the changes are brought by natural processes and has nothing to do with climate

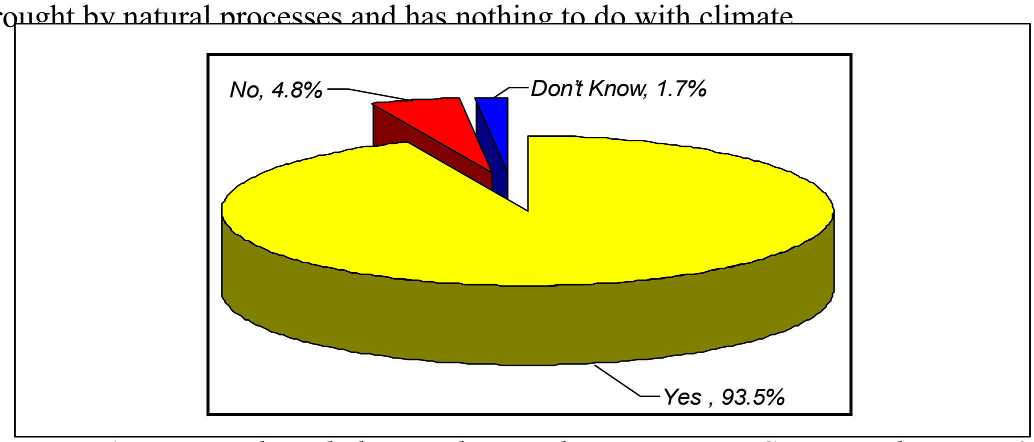

Figure 7.1: Farmers knowledge on climate change impacts. Source: Mhagama, 2014

For those who agreed about having knowledge about impact of climate change; a further question was paused to describe about how climate change affects their dry land irrigation farming schemes? Majority of the farmers (57.1%) described an increase in extreme temperature as the major climate change impact to affects their dry farming schemes as this reduce soil moisture due to excessive evaporation which in return affect crop wilting and reduce crop performance and productivity (see table 7.1). Others (37.7%) described an increase in heavy rainfall which damage crops and soil erosion as well as stagnant water during wet season while others mentioned increase in pests (3.5%) and weed infestation (1.7%) which increase the cost of tending the crops and land preparation. This makes climate change impacts one of the major threats to dry land irrigation farming schemes in the study area due to reduced productivity (crop yield per season) and increased cost of farming per hectares.

Table 7.1: Impact of climate change on dry land irrigation farming schemes.

Variable (Impacts of climate change)	Observation	Percentage
Heavy rainfalls	66	37.7%
Extreme temperature	100	57.1%
Weed infestations	3	1.7%
Pests and crop wilting	6	3.5%

Climate change impacts affects dry land irrigation farming schemes in a complex and unprecedented way which makes it difficult for the farmers to realise and solve the puzzle instantly. For example; the increase in rainfalls causes weeds to grow fast which affect land preparation as more time and labour force will be needed to clear and prepare the land for dry season farming. The increase in weeds infestation simultaneously cause an increase in crop pests (*locust, aphids, and fungi*) especially during wet season and onset of dry season which in turn affects crop productivity and farmers incur a lot of cost in tending the crops. Field observation yielded new findings where during dry season, various large fields in Mbuo, Mpapura and Mkwaya villages were set on fire to reduce the effects of weed infestation and sometimes this poor farm practices has been used as a means of land preparation.

Furthermore, increases in heavy rainfalls which cause floods have advantages and disadvantages to the dry land irrigation farming schemes. For example, field observation in Mkwaya and Mpapura villages showed that farmers with farm plots located adjacent to river banks and bottom valleys had been affected more due to the effects of flooding during heavy rainfalls, however during the dry season the same fields becomes suitable as they have more fertile soil and enough moisture. This is contrally to the farms located at a distance far from the river banks or bottom valleys as these fields becomes unusable during the dry seasons as they lose soil moisture more quickly and the labourer needed to irrigate or watering the crops is so high that some of the farmers cannot afford it. As a result farmers reduce the size of the field or abandon some of the crops that require more inputs (e.g. pesticides, fertilizer and water). The survey data from the field justify the complexity of climate change impacts with regards to type of crops grown where further analysis shows that farmers were affected more depending on type of crops grown as well as farming season with a significance difference of $R=0.84, p<0.582$ at 1*df* with a *Mean of 1.71* and *Std. Deviation of 0.67*.

Impact of Climate change on dry land irrigation farming schemes	***Observation***	***Mean***	***Std. Dev.***	***Min***	***Max***
Types of crop grown	*187*	*1.71*	*0.67*	*1*	*4*

The study also found out that the working force/labour had more knowledge on climate change impacts where about 44.4% (between age group 26 – 27) and 27.8% (between age group 18 – 25) compared to older farmers 22.5% (between age 36 – 45). This is because the working force/labour are more engaged in irrigation farming activities than any group in the society while in terms of gender, women seems to have a good understanding about climate change impact compared to men (see table 7.2). This has much to do with their fully involvement in agricultural production particularly dry farming compared to men. Field observation showed that women had more fields and involved fully in dry land irrigation farming compared to men.

Table 7.2: Age and gender of respondent's v/s climate change knowledge

S/N	**Age**	**Climate Change Knowledge**		**Gender**	**Climate Change Knowledge**	
		N	**%**		**N**	**%**
1	18 – 25	49	28.0	Female	108	61.7
2	26 – 35	79	45.1	Male	67	38.3
3	36 – 45	39	22.3			
4	46 – 55	8	4.6			

Source: Mhagama, 2014.

Information from the dry land farmers presented demonstrated that climate change impacts affects dry land irrigation faming in a different way. Field observation as well as data from interviewees conformed to the result. For example, with regards to extreme temperature; any increase in temperature also does not only reduce moisture and cause crop to wilt but also affects the crop quality and increase the cost of watering the crops twice per day. Information from interviewees in Mpapura, Mbuo and Mkwaya villages highlighted the situation. The participants described that; the changes or increase in temperature does not only affects water or moisture availability; it also affects cropping pattern, time and cost incurred to tend the vegetables until they are ready to take to the market. Furthermore, increase in temperature affects crop performance and productivity in the field resulting in low and poor yield. This in turn affects the quality of crops produced which fail to compete with crops from other villages hence commands low price at the market. During field visits in Mkwaya and Mpapura; few vegetables such green peppers, tomatoes, eggplants and other green vegetables (spinach) were seen sold at a very low price due to reduced quality as a result of wilting and pest or disease infections.

Interview with another respondent (KI, 08); a vegetable farmer in Mkwaya village, clarifies the effects of increasing temperature on crop performance and productivity. She narrated that:-

"I have to change cropping pattern…either planting my vegetables following water course…, as water level decreases I also decrease the size of plots. In some drier months, I have to change type of crops (plant crops that withstand dry condition such as okra and cowpeas) or incur extra cost by hiring labour to help me with tending the crops particularly watering vegetables twice per day; something that I never had to worry in the past 20 years or so.."

Climate change also affects water availability where during the dry season due to increase in temperature; most of the water sources/reservoirs falls below threshold limits. Interviewees described that water levels in many reservoirs were normal in the past due to regular and predictable rainfalls in terms of amount and number of rain days per year and rarely dry season farmers would experience water shortage for their agricultural activities. Participants (KI, 02) from Mbuo village and a member of village water committee commented that:-

"Normally, in the past, we had enough water to grow crops throughout dry season….water shortage was not a problem. However, nowadays we have to make sure that ponds have enough water…otherwise we advise the farmer to reduce inputs or change crop variety, which is not easy because everyone has his/her own targets and changing farming practices it is a length and tedious process.

Most of the data from interviewees do not deviate so much from what was illustrated by farmers and overall overviews of farmer's knowledge on climate change impacts on dry land irrigation farming schemes in the study area are acceptable with national and local reports. Although majority of the farmers agrees climate change affects their farming schemes; its impacts affects individual farmer differently depending on the availability of extra source of income, farming season, farming skills, size of the farm, type of crops grown as well as different livelihoods occupied (subsistence farming, livestock keepers or mixed farming). For example, some slight deviations were observed during field observation where those cultivating tomatoes and green vegetables were affected more by extreme temperatures compared to farmers cultivating okra, eggplants, onions and local varieties of vegetables that withstand harsh condition. Similar studies by Bennett et al. 2015 and O'Brien et al. 2004; explain that impacts of climate change can be unevenly experienced by various similarly exposed groups (genders, ages, classes, societal groups, livelihoods, etc.) based on differential sensitivities. Information from District Irrigation Officer, Mtwara Rural District Council verifies that majority of the subsistence farmers are affected more compared to other farmers. Mtwara District Irrigation Officer had this to say in justification of the responses from the farmers:-

"Climate change affects subsistence farmer's particularly dry land irrigation farmers who have no means of combating and adapting to climate change. Majority of the farmers in Mbuo and Mpapura are affected by shortage of water and increased temperature during dry season which affects the crops grown and consequently crop yield making dry land irrigation faming schemes very unproductive and vulnerable in additional to climate change impacts.

Apart from information from interviewees on climate change impacts on dry land irrigation farming schemes, the study found out that the climate change variability affects dry land irrigation farming schemes and interferes with their farming season by affecting land preparation, planting season and cropping pattern as well as crop management especially during pest and diseases outbreak such as *locust* or *fungi*. The effects of climate change variability such as temperature and rainfall changes over the last 15 years, and how these changes affects their planting season, cropping pattern, type of crops, and outbreak of diseases around the study area are described below.

7.1.1 Farmers Perception on Temperature and Rainfall Characteristics.

In order to explain the impact of climate change on dry land irrigation farming schemes in the study area; it is important to focus on the key climate variables. Therefore in this section, the question was posed to understand how farmers perceived and explain the impact of climate change with regards to changes in temperature and rainfall characteristics over the past 30 years. How these changes perceived have been translated or how they affect their dry farming schemes and daily livelihoods have also been captured and described here. The perception of temperature and rainfall pattern changes is a necessary prerequisite for any kind of climate change adaptation including agriculture particularly irrigation farming as well as natural resource management. In analysing information from the farmers; their perceived threats can have a significant impacts when it comes to predicts the future impacts of climate change using local knowledge as well as farmers experiences in irrigation farming activities.

Results from six villages studied indicate that farmers perceive changes in the trends of temperature and rainfall characteristics and pattern in the study area. Majority of the farmers (57.1%) mentioned that there has been an increase in extreme temperature compared to past 20 years particularly during dry season (August – October) and onset of wet season (November – December) with December being the hottest month ever recorded. Others farmers (37.7%) mentioned about an increase in rainfalls particularly onset of the rain season and mid wet season. The observed increase in rainfalls by farmers has been attributed by short heavy downpour during the month of OND or MAM; since general data from TMA indicates a decrease in rainfalls pattern (amount and number of days). In few cases, farmer's perception has precipitated out the impacts of heavy rainfall (floods) in the study area. For example, some of the heavy floods around coastal low land area are result of heavy rainfall from upland and not from coastal area. During field visits, differences were noted in Mpapura and Mkwaya where most of the heavy floods were results of heavy rainfalls from upland region such as Mbinga, Ruvuma and Ulanga, Morogoro.

Furthermore, during the field survey farmers were asked to describe what effects would these changes in temperature and rainfalls have on dry land irrigation farming schemes in the study area. The response from the farmers' survey indicates that majority of the farmers (see also table 7.1 above) agrees that changes in temperature and rainfall characteristics would affects their dry land irrigation farming schemes where extreme temperature contribute to crop wilting while others mentioned that there have been significant changes on rainfall pattern which cause heavy floods in their respective areas over the past 15 years (figure 7.2). In additional, other farmers mentioned about weed infestation caused by heavy rainfall as well as salt accumulation induced by high evaporation as a result of extreme increase in temperature.

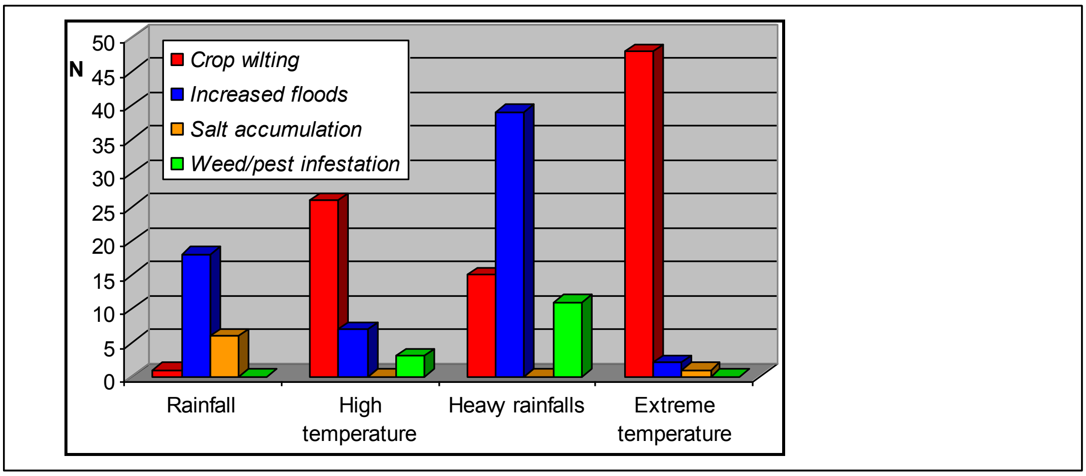

Figure 7.2: Farmers perception on temperature and rainfall characteristics. Source: Mhagama, 2014.

Working or labour force (farmers aged between 26-35) and education status of the respondents (figure 7.3) seems to understand more on climate change and how it affects their dry land irrigation farming schemes in terms of increased rainfall (floods) and extreme temperature (crop wilting). The working or labour force have more knowledge as they are actively involved in economic production on a daily basis accessing and sharing information on irrigation farming. Others 3.4% of the farmers described that there has been increasing weed infestation (increase in flood water) and frequency of pest and disease outbreak (*locust, aphids, fungi and army worms*). These changes significantly affect dry land farming as they affect planting season and reduce crop yield.

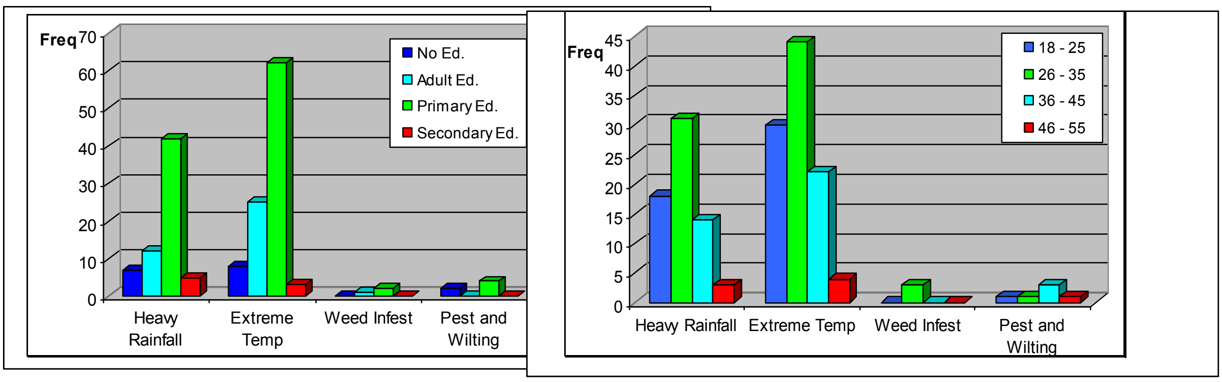

Figure 7.3: Farmers perception on how climate change affects dry land irrigation. Source: Mhagama, 2014.

According to the farmers these changes has been characterized by changes in the rainfall pattern and temperature flux. Although majority of the farmers admitted that rainfall (*pattern, amount, intensity and frequency*) during the rainy season have increased; data from TMA shows that rainfall changes been erratic and unpredictable causing changes in farming season. In few cases some of the farmers in Chimbile A and Chiheko villages have noted small amount of rainfall which rain for a very short period of time while others farmers in Mkwaya, Mpapura and Mbuo villages pointed out that the temperature flux (*amount of sunshine and heat intensity*) has been increasing over the past 20 years where water level drops quickly before the end of dry season. Their response is also affected by geographical location where Chimbile A and Chiheko villages are located on hinterland (about 500m a.b.s) hence effects of altitudes while Mkwaya, Mpapura and Mbuo villages are mile away from coastal shoreline (about 20-50m a.b.s) and hence they are influenced by coastal condition.

The fact that the majority of farmers perceived increasing temperatures over the past 20 years is in line with the information from Tanzania National Meteorological Agency, indicates a significant impacts on current climate change as well as future projected changes and unforeseeable impacts. Majority of the farmers' perceptions of increased rainfall could be attributed due to observing frequent climate extreme events such as ENSO (*El Nino*) which is also in line with last year and this year reports from TMA on occurrence heavy rainfall characterized by strong winds and heavy rainfalls from intertropical convergence zone and intensification of high pressure systems in the Indian ocean (box 7.1). These climate extremes are observed during the months of Dec-Jan and March-April and most affected areas are Mtwara and Lindi coastal areas where Mkwaya, Mpapura and Mbuo villages are also located.

Box 7.1: Tanzania Meteorological Agency, Seasonal Forecast: TMA Press Release, 2015

Climate Outlook for March – May, 2015 and October – December, 2015 Rainfall Season

1. ***Highlights on March – May, 2015:*** *During the long rain season in this period most parts of Bimodal Areas experienced above normal rainfall. However, pockets of normal rainfall were observed Southern Coast.*
2. ***Highlights for October – December, 2015:*** *Short rainfall season indicates that rainfall is expected to be above normal and normal (sufficient rainfall) over most parts of bimodal areas and some parts of unimodal areas. Expected Impacts: Soil moisture levels are likely to be enhanced due to the expected above normal to normal rainfall and likely to affect the cropping season over bimodal areas. River flow discharges and water levels in rivers and dams are likely to increase from their current levels. Short periods of heavy rainfall may cause excessive surface runoff and elevate flood risks during the season.*
3. ***Climate Systems Outlook:*** *There is enhanced warming over Central eastern Equatorial Pacific Ocean which is likely to persist throughout the October to December, 2015 rainfall season indicating the Presence of El Nino.*

Many studies indicate that experienced farmers have a higher probability of perceiving changes in the rainfall pattern and temperature extremes as they are exposed to past and present climatic conditions over the longer horizon of their life span compared to less experienced farmers (Maddison, 2006; Ishaya and Abaje, 2008). According to Deressa et al. (2008) in Southern Africa, there is a perception that most farmers perceive that long-term temperatures are increasing and the overall perception on long term changes in precipitation is that the region is getting drier and that there are pronounced changes in the timing of rains and frequency of droughts. Though farmers in the study area have less experience in dry land irrigation farming practices, majority of the respondents have agreed that the dry land irrigation farming schemes is affected by changes in temperature and rainfall variability which makes their farming vulnerable to climate change while others disagree.

The differences existing in perception of the farmers with regards to changes in temperature and rainfall characteristics were attributed by characteristics such as income status, type of crop farming, and closeness to water sources which influenced the way farmers perceive climate change impacts. Data from field interviewees have similar responses. One respondent (KI,10) from Mnazimoja village mentioned that:-

"I am using manual pump and one of my field/plot is very close to the river bank (Mnazi moja river)…So I have no problem with the effects of increasing temperature because I can abstract and use enough water. The problem is some farmers don't know some crops require more water compared to others…hence they complain about excessive evaporation caused by extreme sunshine but that's not true…".

Field observation showed that those who are able to own manual pumps or having fields close to the river banks or water sources had no problem with the impacts of increasing temperature. Similarly, farmers who cultivate local variety and crops that withstand harsh condition such as okra, cow peas and onions had little to complain regarding the effects of increasing temperature. Although key climate change variables are temperature and rainfall characteristics; climate change impacts is not an outcome of a single variables but rather several other phenomenon occurring over many years. The impact of a climate change can also be attributed by other parameters. In the following section farmers were asked to describe how their irrigation farming schemes are vulnerable to climate change.

7.1.2 Occurrence of Frequent Dry Spell and Drought Condition.

The prevalence of frequent period of dry spells (between January – March) and drought conditions are among the results of climate change impacts perceived by farmers in the study area. This is particularly true due to the fact that frequent dry spells and drought conditions are major constraints to the availability of water in various water sources during dry season (less water) which affects dry land irrigation farming schemes and hence contribute to low yields. According to farmers in the study areas the climate change effects have been noted in the changes in characteristics and pattern of rainfall. These changes include the *start and end of rainfall, amount, intensity and frequency* or *number of raindays,* during the rainy season. The changes in the rainfall characteristics and pattern results in frequent periods of dry spell (*a prolonged period of dry weather with extreme temperature and dry condition*) during the rainy season compared to past 20 years as well as drought condition. Though dry spells is a drown-out period where the weather is dry, for an abnormal season and short, its not as severe as drought condition. However, its impacts have a significant reduction in water availability due to reduced amount of rainfalls and increased evaporations. Analysis from interviewees show that frequent occurrence of dry spells in the study area reduces water availability in various water sources in two ways:-

First, it reduces volumes or amount of rainfalls following months or weeks with no rainfalls which reduces volumes of water in various water reservoirs or water sources such as ponds and river flows. Respondent (KI,03) from Mpapura village said that:-

"In the past years; rain season lasted longer and there were no period of little or no rain during wet season. It normally rained throughout….however, recently, things have changed and within a period long rain season, we have short periods of little or no rainfall at all that cause water volumes around Mkwaya river and Mnazimoja to fell below normal".

Secondly, due to the location of the study area (tropical low lying coastal area) it induces excessive evaporations due to extreme heat or temperature from sunshine or sunlight intensity, which again reduces water levels in various water sources and thereby affecting water availability during dry season. Respondent (KI,15) from Chimbile A village and a member of village water committee mentioned that:-

"There has been increase in period of no rainfalls during mid rain season, accompanied by extreme temperature that causes excessive evaporation….If you had visited Chimbile or any other wetlands in the region, during mid rain season; you would have concrete proof of what I am trying to explain….Whenever, there is frequent occurrence of dry spells; water levels normally drops even during rainy season, which means there is little or no water left for our dry season farming".

Other impacts mentioned is that increase in frequent dry spells induce other effects including diseases attack on crops such as fungi (*rusty-kutu and ukungu*) resulting in crop wilting and significantly affecting dry land irrigation farming by reducing crop production and food security and thereby reducing family income. In Mpapura, Mbuo and Mkwaya villages; interviewees indicated that they also perceived dry condition and windy weathers. This is due to the fact that these villages lies along the coastal area/shoreline and hence dry and windy condition they perceive might be influenced by the influence of prevailing wind (and sea breeze) from Indian ocean.

Although farmers in the study area have knowledge on climate change and how climate change affects their dry farming schemes; many studies have revealed that sometimes farmers are influenced by many factors other than climate change such geographical location, socio-economic issues and agro-ecological condition. For example, the agro-ecological setting of farmers can influences the perception of farmers on how climate change affects their farming where farmers will respond differently depending on agro-ecological condition. A study by Diggs (1991) revealed that farmers living in drier areas with more frequent droughts are more likely to describe the climatic change to be warmer and drier than farmers living in a relatively wetter climate with less frequent droughts. In this case farmer's associates the formation and impact of climate change with relation to agro-ecological condition which in turn will have a biased results in wet condition compared to frequency of drought in drier areas.

7.1.3 Soil Erosion and Soil Contamination

In the study area, both heavy rainfall and extreme temperature variability have resulted in soil erosion (*through floods*) and salt accumulation (*though excessive evaporation*) in many cultivated lands. Absence of vegetation cover due to deforestation and intensive farming in many fields has accelerated the soil erosion problem in the study area. Continuous setting fire in the forest and general land also contributed immensely to the situation while leaving farmers with no choice but continue practising shifting cultivation which immeasurably affects agricultural production and particularly irrigation farming. One of the field observations during peak of rain season in 2015 showed the impacts of heavy floods that washed all the crops away cultivated around river banks and bottom valleys. These are preferred areas due to rich soil fertility and moisture. One of the interviewees (KI,13) from Chimbile A village, mentioned that:-

"In period of heavy rainfalls, we just have to pray to god that our crops can be saved because there is no way….heavy rainfalls cause erosion, damage our crops and sometimes our crops are swept away…if I had no alternatives then that's the end of the story. Sometimes stagnant flood water contaminate the land which makes it unsuitable for agriculture as nothing grows in it..".

This is because stagnant water raises *pH* level of the water that creates acidic condition and contaminates the soil and makes it acidic conditions. At the same time, excessive evaporation leaves salt accumulation which makes the soil too alkaline and hence unsuitable for irrigation farming. Through field observation (figure 7.4), during wet season crops cultivated around the valleys have been washed away by flush floods including top fertile soil while during the dry season some farm plots have been abandoned because of the land is no longer productive because of high alkaline condition resulted from excessive evaporation leaving out salt materials.

Figure 7.4: Crops and soil washed away by floods and contaminated soil by salt intrusion. Source: Mhagama, 2014

7.1.4 Weed and Pests Infestation

Weed coverage and pests infestation in many farms are associated with changes in rainfall pattern (increased rate of rainfall). Through field observation; (wet season) during the period of high rainfall farmers in the study have noted high rate of growth of weeds that constraints farming (rice pads during wet season) as well as vegetables during dry season due to increased cost of weeding as well as pest (aphids) outbreaks that attacks crops. Farmers in the study area narrated that the land becomes unsuitable for cultivation (though this has much to do with labour intensive required to clear and prepare the land rather than climate change impact). On the other hand, high presence of weeds favour growth of various pests such as locusts, termites, insects and flies that affects green vegetables cultivated during dry season. According to Mkwaya Village Executive Officer, presence of weeds affects irrigation farming in two ways:-

"An increase in rainfalls causes weeds to grow fast and tall. This causes an increase in cost of land preparation during dry season due to tall grasses…but also, having weeds around cause an outbreak of pests which attacks crops during wet season as well as vegetables during dry season due to presence of fresh leaves".

Most of the villages in the study area are found along the coastal low land area which has fertile soil and subjected to heavy rainfalls and floods every wet season. This creates a conducive environments for weeds to grow fast and also presence of enough moisture and fodder creating better conditions for other biodiversity (such as pests) to flourish, which in turn affects agricultural production such as irrigation farming.

7.2 Impacts of Climate Change on Crop Productivity and Income of the Framers

Data from farmer's perception supported by interviews from focus group discussion indicates that the state of local climate along Ruvuma Basin (study area) is changing in a number of ways since past 20 years or so. Though with slightly differences in terms of responses; their perception have been justified by climate data from Tanzania Meteorological Station and other national and local climate change reports (NAPA, 2007; URT, 2012; IPCC, 2014) which indicates an increase in temperature and decrease in rainfall. In addition to the increase in temperature and rainfall variability, occurrence of dry spells, soil erosion and weeds and pest infestation; climate change impact is likely to produce various socio-economic consequences to the dry land irrigation farming schemes.

The increase in temperature has effects on the land surface due to increase the rate of evaporation which also affects soil moisture availability for the crops. Low moisture availability and increasing evapo-transpiration makes the crop vulnerable to moisture stress and reduced crop performance and productivity. Poor crop productivity induces poor quality and low yield which affects the price of vegetables in the market (*i.e.* poor farmers cannot compete with other well adapted farmers). During interview with respondent (KI,14), vegetable farmer at Chiheko added that:-

"The extreme temperature affects my produce…sometimes I get poor quality (bell paper) in which buyers refuse to buy at normal price...; maybe they are even cheating on us … but what can we do…even if we say no, we can't compete with farmers from Kitele or Milola (well established farming schemes). So we have to accept any price middle man offer to buy our produce so the life can go on".

Other findings, had similar results in various parts of the country practising irrigation farming (Kaswamila and Masuruli, 2004; Majule and Mwaliyosi, 2007). According to URT, 2012; productivity of most crops in Tanzania seems to have declined due to changing climate, particularly due to the increasing unreliability of rainfall. Furthermore, increase in temperature affects water availability (reduced water volumes) in various water bodies and thereby cause an increase in cost of tending the crops (irrigating or watering crops and pest application) and subsequently affecting number of poor farmers who practising dry land irrigation farming as part of food security (supplementing wet season harvest). Some of the impacts of climate change on dry land irrigation farming schemes have indirect effects, which are difficult to entangle and account for (see table 7.3). Thus a careful understanding of how farmers perceive climatic changes and their linkage to induced effects (whether direct or indirect) is of paramount importance for adaptation as well as sustainability of dry land irrigation farming in the study area.

Table 7.3: Summary of the indirect impacts of climate change on farming.

S/N	Perceived Changes	Induced Effects	Impacts	Indirect Impacts
1	Increase in extreme temperature	Excessive evaporation	Crop wilting, poor productivity	Poor and low yield, low price, low income earned
			Increased cost of farming – watering	Draining farmers income
2	Heavy rainfalls	Heavy floods, soil erosion	Damage to crops and properties	Affects yield, food security, drain farmers income
			Stagnant water raises pH,	Affects crops performance
3	Occurrence of frequent dry spells	Extreme short periods of dry condition	Reduced water and moisture availability, affects crop performance	Less water available for dry season farming, low yield, low income earned
4	Weed and pest infestation	Heavy rainfall	Crop performance, cost of land preparation and tending crops	Poor and low yield, low income earned, Draining farmers income

Source: Mhagama, 2014

As a result, indirect impacts induced by climate change makes faming schemes more vulnerable to climate change impacts than direct or observable impacts of climate change. In general, these changes are expected to likely cause an increased risk of famine and decreased household income particularly during dry season, where irrigation farming schemes was supposed to supplement food production or income of the farmers during dry season.

7.3 Local Indicators of Climate Change Impacts in the Study Area

Through field observation (see figure 7.5 and 7.6 below); the study found out that the dry land irrigation farming schemes is affected by floods (frequent flush floods);

extreme temperature during the month of August – November, with December being at the peak of extreme high temperature ever recorded (hottest month).

Figure 7.5: Parts of Lukuledi River (Mkwaya Village) during dry season and wet season (same location-notice the position of trees in the background).Mhagama, 2014

Figure 7.6: Parts of Mpapura Valley during dry season and wet season (though the flood water originated from far highland areas of Ruvuma region).Mhagama, 2014

The effect of high temperature can be observed on land where there soil moisture stress which affects crop performance depending on the stages of crop growth. In the study area, crops that withstand harsh and dry condition like okra and onions seemed to suffer less yield damage compared to crops that do not withstand extreme harsh condition such as tomatoes and other green vegetables. In few cases, interviewees mention that farmers who practise late planting have to endure water shortage problem and their crops have to encounter water stress at the end of the growing season due to less water available which subsequently leads to low crop yield.

Other changes observed includes frequent period of dry spell (from January – March) during wet season which affects water availability (reduced volume of water) in various water sources during dry season while at the same time during dry season the scorching sun increases the chances of drought and reduces the availability of water in various reservoirs or water sources as well as soil moisture that would have been available for irrigating crops/vegetable during dry season. This affects dry land irrigation farming practices as it determine the size of the farm and the type of crops (vegetables) a farmer has to plant which in turn determine the average yield of the farmers.

7.4 Summary

In this chapter, clearly the impact of climate change on dry land irrigation farming schemes in the study area were identified and presented. In the study area, farmers perception (local knowledge); was used to identify the impacts of climate change on dry land irrigation farming schemes. Majority of the irrigation farmers in the study area seemed to have knowledge about climate change and they know how climate change is affecting their irrigation farming schemes. In general, they described the effects of climate change on dry land irrigation farming schemes in terms of increase in extreme temperature and heavy rainfall. Farmers described that an increase in extreme temperature cause a reduction in soil moisture and water availability due to excessive evaporation as well as cause crop to wilt and thereby reduce crop performance, productivity and total yield per season. The increase in extreme temperature was also noted in various other national (NAPA) and global (IPCC) reports on climate change impacts in Tanzania.

Heavy rainfalls were also described by farmers as effects of climate change impacts which damage crops and soil erosion during wet season and heavy rainfall cause flood water (stagnant water which cause eutrophication) as well as an increase in pest’s outbreak, and weed infestation. Though farmers have perceived an increase in heavy rainfall during wet season but various national (NAPA) and global (IPCC) reports shows that rainfall in Tanzania has decreased in the past 30 years and the country will experience a decrease in rainfall in future. Thus farmers perceptions of increased rainfall could be attributed due to observing frequent climate extreme events such as ENSO (*El Nino*) which is also in line with reports from National Meteorological Agency, TMA. The TMA report (2015) described that most of the observed heavy rainfall in January, March and April are characterized by strong winds and heavy rainfalls from intertropical convergence zone and intensification of high pressure systems in the Indian ocean which cause heavy downpour along the Southern Coast of Tanzania. Various National and global reports as well as projections from various models (Markov Model-NHMM) shows that Africa and Tanzania in particular will experience a decrease in rainfall by the year 2050.

Other effects of climate change described by farmers in this chapter includes soil erosion and the occurrence of frequent dry spells which affects dry land irrigation farming schemes in the study area. Farmers mentioned that frequent dry spells cause reduction in water due to decreased amount of water in various water sources (decrease in volume due to decreased number of rain days). Furthermore, farmers described that increase in weed infestation is manifested in the increase in cost of land preparation for dry season farming while increase in extreme temperature and pest outbreak cause an increase in the cost of tending the crops in the field.

The chapter highlighted how the effects of climate change on dry land irrigation farming schemes is complex and unprecedented which makes it difficult for the farmers to realise and solve the puzzle instantly. For example; information from farmers responses shows how an increase in rainfalls cause weeds to grow fast which affect land preparation and thereby making farmers incur more labour force and time needed to clear and prepare the land for dry season farming. Another complex and unprecedented effects is an increase in weeds infestation simultaneously cause an increase in crop pests (*locust, aphids, fungi*) especially during wet season and onset of dry season which in turn affects crop productivity and farmers had to incur a lot of cost in tending the crops.

This chapter also described how climate change affects crop productivity and thereby alter or affects income of the farmers. The effects of climate change on income of the farmers are contributed by poor crop productivity which results in low crop yield. The poor crop quality and low crop yield, means crops or vegetables fetch low price at the market hence low income earned by farmers. Climate change also affects food security and drain farmer's income when preparing the land and tending the crops in the field. This makes climate change impacts one of the major threats to irrigation farming in the study area due to reduced productivity (crop yield per season) and increased cost of farming per hectares and thereby make dry land irrigation farming schemes the most vulnerable farming business in the study area.

The chapter also had described how women and working force (youth) had more knowledge on climate change impacts compared to older men in the study area which is contributed by the fact that women and youths are more engaging in irrigation farming activities than any other group in the society. Though climate change affects dry land irrigation farming, individual differences were noted. The variation in climate change impacts among individual farmers were also documented where individual irrigation farmers were affected differently by climate change impacts. During field visits, observation shows that cause of variation depends availability of extra source of income, farming skills, size of the farm, type of crops grown as well as different livelihoods occupied (subsistence farming, livestock keepers or mixed farming). For example, farmers cultivating green vegetables and tomatoes were affected more by an increase in extreme temperature compared to farmers cultivating okra, cow peas and onions. Similarly, farmers with large fields size and less irrigation farming skills were seen straggling to cope with the impacts of climate change compared to others with experience and smaller fields.

Field observation also showed similar findings of crop failure (wilting and pest attacks) as well as fast decrease in water level in various water sources (rivers, ponds) during dry season farming. During wet season several crops planted along river banks and bottom valleys were damaged by heavy floods. The chapter has tried to indicate how climate change affects dry land irrigation farming in the study area and thereby making irrigation farming schemes more vulnerable to the future climate changes. Other various local, national and global reports coincide with data analysed from farmers perception, interviewees and field observations as well.

CHAPTER 8: VULNERABILITY OF DRY LAND IRRIGATION FARMING SCHEMES AGAINST CLIMATE CHANGE IMPACTS.

8.0 Introduction

The manifestation of climate change impacts on dry land irrigation farming can be clearly described not only by its impacts it has; but also by how it makes farming schemes (dry land irrigation) exposed and more sensitive to future climate change impacts and other impacts as well. In this chapter the vulnerability (exposure and sensitivity) of dry land irrigation farming against climate change impact is described in depth. The chapter start by presenting general overview about vulnerability of dry land irrigation farming schemes against climate change impacts. Then, it describes how farmers understand vulnerability and how the dry land irrigation farming schemes is vulnerable to climate change. The chapter presents which factors expose the dry land irrigation farming schemes to climate change and explain how potential sensitive factors render the farming schemes more vulnerable to other future impacts.

Finally, the chapter describes risks associated with dry land irrigation farming schemes in the study area as well as analyse key indicators that determine its vulnerability to climate change impacts. Other factors which influence some changes in the farming practices and affects dry land irrigation farmers are also described here. The information from respondents presented here reflects what and how exactly dry land irrigation farmers perceive to be the effects of the climate change impacts that makes dry land irrigation farming schemes vulnerable to climate change. The threshold limits (vulnerability) for dry land irrigation farming schemes against climate change impacts is also described here.

8.1 General Overview of Vulnerability

Dry land farmers were asked to describe vulnerability in different aspects with regards to how their farming schemes experience harm in response to climate variability as well as other internal factors. The results from the analysis of the farmer’s responses showed that dry land irrigation farming schemes is vulnerable to climate change impacts. Farmers in the study area identified several factors that making dry land irrigation farming schemes vulnerable to climate change impacts. The major factor include extreme temperature (53.1%) which cause crop wilting and low yield followed by soil erosion (34.9%) from heavy rainfalls (see table 8.1 below). Other factors mentioned includes weed and pest infestation (8%) that increases the cost of farming and affects crop performance and yield as well as reduced water (4%) from reservoirs due to extreme temperature and frequent dry spells.

Table 8.1: Factors making farming schemes vulnerable to climate change impact

Vulnerability of dry land irrigation farming schemes against climate change	**Main causes**	**Responses**	
		N	**%**
Crop wilting and low yield	Increasing temperature	93	53.1
Soil erosion and crop damage	Heavy rainfall	61	34.9
Reduced water or excessive evaporation	Extreme temperature	7	4.0
Pests and Weed infestations	Heavy rainfall	14	8.0

Source: Mhagama, 2014

Although there are diversity in the response of the farmers based on vulnerability; arguably the degree to which dry land irrigation farming schemes are exposed and susceptible to or unable to cope with adverse effects of climate change impacts have been clearly depicted in the study area. By using basic components of vulnerability in this study; the sensitivity, exposure and ability of the farmer to adapt and cope with the changes have been described. Other factors and conditions determining the vulnerability of farming schemes in the study area have been also considered so as to find out more about the interconnectedness of climate change impact and other influencing factors.

8.2 Farmers Knowledge on the Vulnerability of Dry Land Irrigation Farming Schemes to Climate Change Impacts.

The vulnerability of farming community's particularly irrigation farmers can be quantified using several ways. Before analysing vulnerability, farmer's knowledge on the aspects of vulnerability to climate change impacts is of paramount importance. The main focus is to explore vulnerability of dry land irrigation farming schemes against climate change impacts with an in depth examination of the underlying biophysical and socio-ecological as well as other factors that determine how farmers respond to and cope with climate change impacts along Ruvuma Basin. In this study; farmer's knowledge on vulnerability were presented. The exposure (biophysical factors such as *temperature and rainfall variability*) and socio-ecological (*farming practices, entitlements*) and its (in) ability of a systems or people (*farmers*) to cope with the stress/disturbance (*stressors*) along the Ruvuma Basin, were presented.

The analysis shows that, women in the study area have more knowledge on how dry farming is vulnerable to climate change (62.6%) compared to men (37.4%). During field observation, the study found out that women were more involved in the farming (vegetable production) compared to men which explain about the differences in understanding about climate change. Response from one of the interviewees yielded similar results where respondent (KI,04), a vegetable farmer from Mpapura village has this to say with regarding her knowledge on vulnerability:-

"Our irrigation farming is vulnerable to climate change impacts due to high temperature, lack of water during dry season, strong wind and other factors…Luckily some of us have more knowledge than others. Since our childhood, women in this village have been working on the farm side by side with our mothers. Myself, I learned all problems affecting dry land irrigation and I don't need industrial pesticides or modern technology to encounter the problem….. Through experience, I just simply apply the knowledge I have….For example sometimes I change cropping pattern…either planting vegetables following water course…, or as water level decreases..I also reduce the size of my farm plots so I don't incur too much cost. In some drier months, I have to change type of crops (plant crops that withstand dry condition) or watering vegetables twice per day".

Majority of the respondents (see table 8.1 above) in the study area revealed that dry land irrigation farming schemes is vulnerable to climate change impacts through crop wilting (53.1%) due to extreme temperature followed by increased floods events (34.9%) which cause soil erosion due heavy rainfall and salt accumulation (4%) as well as weed and pest infestation (8%). In terms of different farming schemes existing in the study area, farmers who depend on surface water were seemed more vulnerable to climate change impacts than farmers depending underground water for irrigating crops (table 8.2). Apart from quick and easy access (increased competition from the farmers), surface water in the study area is prone to excessive evaporation due to extreme temperature compared to water from river course (canal irrigation) and ground water (dug-out ponds) sources.

Table 8.2: The Vulnerability of different farming schemes to climate change

Farming schemes practiced	Observation	Percentage
Artifial ponds (*Ndiva or lambo*)	55	31.4%
Small dug-out ponds (*vinyungu*)	44	25.1%
River channels or canals (*mifereji*)	35	20.1%
Others (use *manual pump or soil moisture)*	41	23.4%

Source: Mhagama, 2014

During field walk, observations showed that subsistence farmers in the study area were seemed to be more vulnerable to climate change impacts compared to mixed farmers *i.e* crops and livestock keepers. This is because subsistence farmers require more water (moisture) for their crops due to poor methods of farming practised such as flash and canal irrigations. Their culture of depending entirely on one type of crops or farming only makes farming schemes more vulnerable to climate change impacts compared to mixed farmers-crops and livestock keeper who are well adapted to the existing stimuli.

In general women and casual labour seems to have a good understanding about how their farming systems is vulnerable to climate change impact compared to men since women and working force involve more in agricultural production particularly dry farming compared to men and older farmers. There were complexity and diversity in farmer's responses with regards to the occurrence of vulnerability. When farmers (respondents) in the study area were asked to explain the frequency of the problems mentioned in table 8.1 above (*vulnerabilities of dry land irrigation farming schemes*); majority of the farmers mention that crop wilting occurs once at the end of the dry season farming due to increased dry condition and extreme temperature followed by others mentioning the increase in floods and soil erosion (figure 8.1).

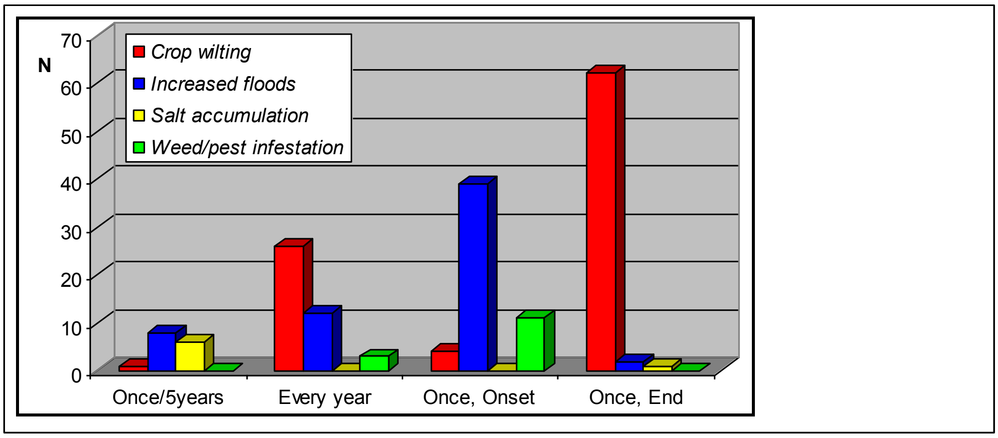

Figure 8.1: Frequency, duration of occurrence of climate change problems. Mhagama, 2014

The diversity and complexity of their responses are signalled by farming experience, water source availability, resource endowment and access to information. For example lack of farm inputs (improved seeds, manual pump) and less experience in farming may make farmers to respond differently with regards to frequency and severity of crop wilting caused by increase in extreme temperature. Farmers with more experience may respond once at the end of dry season farming (due to water shortage) while less experienced farmer might mention every time he/she practise farming. Through discussion with interviewees in Mbuo, Mpapura and Mkwaya villages; respondents mentioned that lack of access to frequent information and knowledge about climate change impacts, improved farming, adaptation measures as well as markets prices; increasingly makes the farmers vulnerable and exposed their farming schemes to other set of stressors such as high cost of production or pests and diseases that attacks crops. One of the respondent (KI,01), a tomatoes farmer from Mbuo village said that:-

"We are used to trial and error type of irrigation farming…this is because majority of us has no connection with other experienced farmers from well-established irrigation schemes like Kitere…I had received very few training or information from agricultural extension officer pertaining to improved farming methods or how to combat pest or any crop diseases…which makes us less adapted to climate change impacts. Our fellow farmers from well-established irrigation schemes gets farm related inputs and trainings for free. We are just on our own".

The information provided by interviewees in Mbuo, Mpapura and Mkwaya villages is contrally to the information provided by District Agricultural Officers from both district visited as they said that they have yearly agricultural calendar and plan of action for each village regarding wet season farming (rainfed farming) and dry season farming (dry land irrigation farming schemes). They narrated that they visit each village and hold meetings with farmers, train them and provide them with new inputs whenever available regardless of the nature and scale of farming. Agricultural Officer from Ruangwa District justified the reality of what they are doing by saying that:-

"Problem with farmers is that, majority of them don't attend meetings once they know the "agenda" (if there is no tangible benefits like cash or free farm inputs). Though some of these meeting are a stepping stone to other benefits or action plans, but other farmers don't take it seriously…, (Ruangwa District Agricultural Officer)".

8.3 Details of Vulnerability of Dry Land Irrigation Farming Schemes to Climate Change Impacts in the Study Area.

In the existing literature there are considerable diversity of theories and definition describing the term *vulnerability*; however, in this study the term focused on the *exposure* and *sensitivity* of dry land irrigation farming schemes to climate variability (*temperature and rainfall*) relative to a threshold of damage (*stress/disturbance*), and (in) ability of *dry land irrigation farmer's* to adapt and cope with these changing conditions. In the study area, the three elements: i.e *exposure, sensitivity*, and *adaptive capacity* were described as follows:-

8.3.1 Factors Exposing Dry Land Irrigation Farming Schemes to Climate Change Impacts in the Study Area

In the study area; farmers were asked to describe what conditions expose the dry land irrigation farming schemes to climate change impacts? Results in table 7.1; indicates that majority of the farmers (57.1%) mention that extremes high temperature condition expose the farming schemes to climate change impacts as high temperature cause excessive evaporation which cause crop wilting and reduce crop productivity as well as crop yield per season. Increased temperature cause excessive evaporation and an increase in time and cost of tending the crop (watering) which increasingly makes irrigation farming schemes less desired by poor farmers and unsuitable. High temperature condition also expose the farming schemes to other set of stressors such as pests and diseases that attacks crops thus increasingly making the farming schemes more risky and vulnerable. With regards to farming season, dry season (35.2%) seemed to be more exposed to high temperature while wet season (18.3%) is affected by frequent dry spells (Table 8.3). Apart from high temperature variability; farmers mentioned that strong winds (8.4%) affect their crops due to loss of moisture.

Table 8.3: Factors exposing farming schemes to climate change impacts.

S/N	**Farming season**	**Factors exposing farming schemes**							
		High temp.		***Dry spells***		***Strong wind***		***Heavy rainfall***	
		N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
1	Wet season	8	4.6	32	18.3	1	0.6	6	3.4
2	Dry season	57	35.2	0	0	8	4.3	1	0.6
3	Both wet and dry season	19	10.7	34	19.3	1	0.6	4	2.1
Percentages		51.5%		37.6%		5.4%		6.1%	

Although study area lies close to the coastal area; prevailing winds seemed to be not a big problem to the dry land irrigation farmers. Farmers in other villages seemed to cope very well with windy conditions. However, during field visits; observation showed that villages in Lindi and Mtwara rural districts are prone to coastal prevailing winds particulary Mbuo, Mpapura and Mkwaya villages. In general both seasons in the study area are more exposed to high temperature, frequent dry spells and strong winds which make dry farming schemes very difficult as both factors contribute to crop wilting, loss of moisture and reduced water level due excessive evaporation. Dry land irrigation farming schemes in Mtwara Rural District (Mbuo, Mpapura villages) and Lindi Rural District (Mkwaya, Mnazi Moja Villages) seemed to be more vulnerable due to its exposure to increased temperature and influence of wind conditions that cause excessive evaporation compared to Ruangwa District (Chimbile, Chiheko Villages) where irrigation farming is more exposed to frequent heavy rainfalls that cause floods, weeds and pest infestation (figure 8.2).

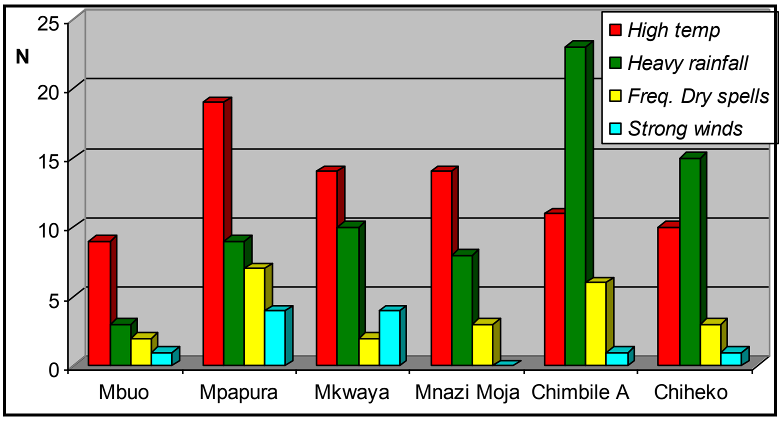

Figure 8.2: Factor exposing dry land farming schemes to climate change. Source: Mhagama, 2014

Though increased rainfall condition occurs during wet season, the impact is felt during dry season as rainfalls cause water stagnant, pests and weed infestation which in turn increase the cost of tending the crops and land preparation during dry season. These conditions are major threats to dry land irrigation farming schemes in the study area as they expose the farming schemes to climate change impacts, which makes it more vulnerable and risky. As a result the farming schemes become vulnerable due to reduced productivity (crop yield per season) and increased cost of farming per hectares or plot of land. Through interview with participants; they mentioned that apart from temperature and rainfall variability; other extreme weather conditions that expose dry land irrigation farming schemes and makes it vulnerable are frequent dry spells and strong prevailing winds. Meteorologist from TMA, Mtwara said that:-

"Frequent dry spells and strong winds take away or absorb all moisture present in the soil; thus reduce water available for maximum crop productivity which makes the farming more vulnerable to disease and pest attacks. Crops also lose value and market due to poor quality…farmers rarely notes the effects of wind".

The exposure of farming schemes to climate change variability cannot affects all farmers equally due to many reasons. Crops produced around wetter areas such as Mnazi moja valley and highland areas Chimbile A and Chiheko villages seem less likely to suffer climatic extremes (particularly high temperature) compared to other villages such as Mbuo and Mpapura which are located on drier areas. In the study area when farmers were asked to describe who is at risk of exposure to climate change impacts; all indicated that they are at risk. However, there were inconsistency in their answers as field observation showed that *location of the farm plot* (those located adjacent to water sources), *resources owned* (owning pump or cash to hire labour) and *experience* (improved farming such as mulching, crop selection) played an immense roles in reducing the risk of exposure to climate change variability particularly extreme temperature. For example, farmers having farm plots located adjacent to river banks and bottom valleys (though affected by flooding during heavy rainfalls); the same farm plots are less exposed to high excessive evaporation as during the dry season same fields becomes suitable as they have more fertile soil and enough moisture. This is contrally to the farms located at a distance far from the river banks or bottom valleys as these fields becomes unusable during the dry seasons as they lose soil moisture more quickly and become arduous as the cost of labourer needed to irrigate or watering the crops is so high that some of the farmers cannot afford it.

The vulnerability of dry land irrigation farming in the study area is also related to the degree at which the farming schemes are constantly exposed to long-term changes in climate conditions (climate variability) including the magnitude and frequency of extreme events such as exposure to high temperature, heavy rainfalls, frequent dry spells and strong winds. The existing temperature data from Climate Portal (TMA) shows that the average annual temperature in Tanzania has already increased by 1.0^0C since 1960 while IPCC (2014) indicate that mean annual temperatures in the country is projected to rise by 2.2^{0}C by year 2100, with increases concentrating over June, July and August. These are expected months for dry season farming practices to take place which indicates the future vulnerability of dry land irrigation farming schemes.

In terms of rainfalls; Mtwara and Lindi regions are areas that receive a unimodal type of rainfall, hence making dry season farming very difficult as majority of the farmers solely relies on availability collected surface water. Any decrease in amount of rainfall affects the available water in reservoirs for irrigation farming during dry season. At the same time the Homogeneous hidden Markov Model (NHMM) has predicted reduction of total annual rainfall (decrease by 2.8mm per month). This reduction is expected to affect total water availability in various water sources needed for dry season farming. This explains that, the larger the changes in the climatic variables, the more difficulty dry land farmers in the country are expected to have in adjusting to these changes and consequently this is going to affects crop performance and hence reduce yield potential making the farming vulnerable to any other stressors.

8.3.2 Sensitive Factors Affecting Dry Land Irrigation Farming Schemes to Climate Change Impacts in the Study Area

Sensitivity is one among the factors identified by the respondents as having a significant impacts in exposing their dry land irrigation farming schemes to climate change impacts and thereby making their farming more vulnerable to existing and future climate change impacts. Although it is increasingly accepted that the vulnerability of dry land irrigation farming community to climatic conditions is solely based on the quantification of biophysical impacts, other factors such as sensitivity (poor farming practices and lack of resources) that exposes farming schemes to climate change impacts should not be ignored. Sensitivity has been described as one of the most important variables attributed to the vulnerability of irrigation farming schemes to climate change impacts (Majule and Mwalyosi, 2007; Deressa et al. 2008). In the study area, the sensitivities of dry land irrigation farming schemes to climate change impacts is represented by social attributes such as *poor soil conditions, poor farming practices, resources owned and entitlements*. These factors coupled with greater frequency of dry spell, extreme dry condition and soil erosion from heavy rainfalls makes farming schemes responds negatively (*i.e.,* reduced yield).

a) Poor Soil Conditions

Respondents in the study area mentioned that *poor soil conditions* such as acidic soil, clay soil and sandy soil affects their dry land irrigation farming schemes (figure 8.3). The acidic soil were common around wetlands Mbuo and Mpapura villages (11.3%) while sandy soil were common around river banks of Mkwaya and Mnazi Moja villages (12.3%) and clay soil was common around bottom valleys of Chimbile and Chihiko villages (17.1%).

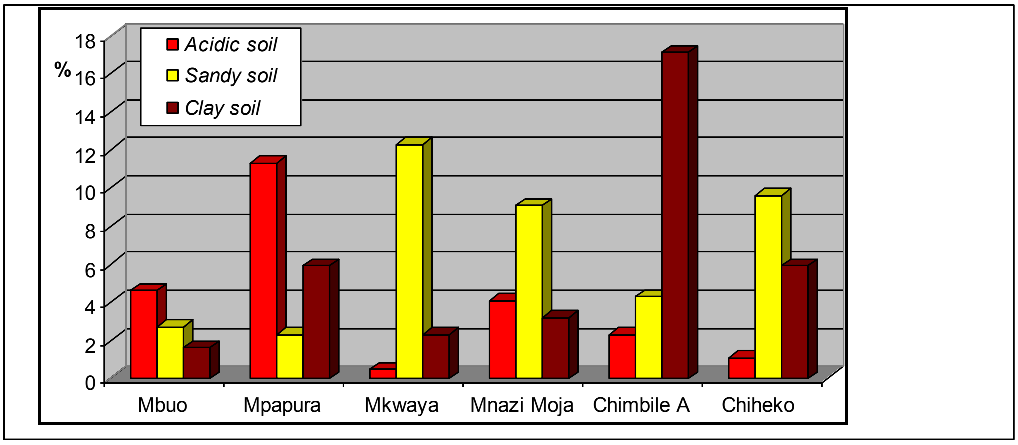

Figure 8.3: Soil distribution and their impacts. Source: Mhagama, 2014

The above mentioned soil conditions such as sandy and clay soil have substantial contribution to the farming community around the study area; however their downside effects are distressing and gloomy in dry farming practices. Lindi Rural District Agricultural Officer justifies the above explanation by narrating that:-

"Riverbanks and flat valleys have sandy soils with poor water holding capacity, hence increased cost of watering crops especially for farm plots located far from water sources. Areas with acidic soil condition have poor fertile soil which affects the growth of crops (it prevent absorption of certain plant nutrients from soil, hence stagnant growth). Bottom valleys with clay soils are fertile, with a lot of humus and are good in retaining water…. However the soils are very sensitive to heavy rainfalls (creates water logging condition-plant rot) and when exposed to high temperature the clay soil dries-out hard and cracks hence not good condition for seasonal crops"

(Agricultural Officer, Lindi Rural District Council).

These soil conditions in the study area makes farming schemes vulnerable as they contain poor nutrients with low moisture holding capacity and are easily prone to soil erosion. Both these factors affect crop productivity and crop yield. Regarding soil conditions; the study area lies along the coastal low land area which is characterised by deep, well drained, sandy soils of low fertility and low moisture holding capacity. Other study findings supplement farmer's perception on soil conditions and their effects on agricultural productions in the study area. Characteristically, the soil is sandy with 88% sand, 2% silt and 10% clay (Naliendele Agricultural Research Institute). The coastal agro-ecological zone is prone to many problems such as poor soil fertility, shifting cultivation, frequent bushfires, deforestation and charcoal production as well as soil erosion. In generally, the soil is strongly acidic (pH 5.30) with possible depletion of most major soil nutrients due to continuous poor farming practices. According to Majule and Mwalyosi, 2003; total soil nitrogen (0.4%), soil organic carbon (0.5%), soil available phosphorus (3.19 mgP/kg) and extractable sulphate (8.96 mgS/kg) are all very low indicating how sensitive the soil is to sustain crop productivity in addition to climate change problem. The soil needs improvement in terms of organic matter, nitrogen and other major nutrients particularly available potassium (P) if crop productivity is to be enhanced and sustained.

b) Poor Farming Practices

With regards to poor farming practices, majority of the farmers in the study area are subsistence farmers cultivating both wet and dry season farming using hand hoes. Crude methods of farming such as shifting cultivation (13.9%) and slash and burn agriculture (11.2%) were very common around study area (figure 8.4 below). Rotational fallow seemed to be practised more in Chimbile A (7.5%) and Mkwaya (4.3%) villages. In few cases, farmers were observed using herbicides to clear the land during midst of rain season for planting crops as well as controlling weeds. These methods exacerbate the effects of climate change by exposing the agro-ecological system (irrigation farming) to the risk of climate change impacts while rendering poor farming communities unable to respond, adapt and cope with ongoing changes.

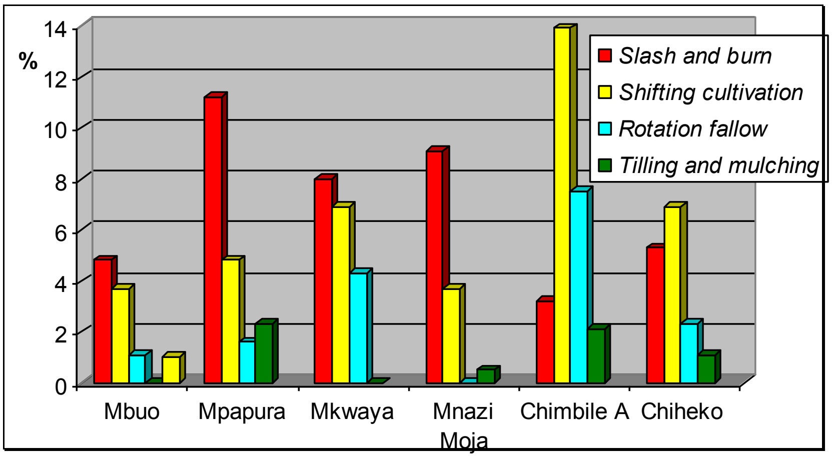

Figure 8.4: Poor farming practices practised by farmers in the study area. Source: Mhagama, 2014.

During field visits, different variety of crops such as eggplants, tomatoes, okra, green vegetables and pumpkins were seen planted all together (zigzag way) in one field (mixed farming). Some farmers indicated that mixed farming is an efficient way of utilizing a plot of land (crop coverage and varieties) as well as in case one crop fail, they still have yield from other crops. However the drawback to these methods contributes to intensive cultivation and depletion of nutrients as some crops require more water and nutrients uptakes than others. Other negative aspects of mixed farming are that when there is an outbreak of crop pest; it always spreads to other crops and makes pest control a bottleneck. Farmers without mixed farming knowledge may refuse to repeat planting similar crops next season fearing crop pest. Thus mixed farming if not careful practised, can make irrigation farming vulnerable as it expose crops to pest attacks that reduces crop performance and crop yield and thereby making farming schemes vulnerable.

Very few farmers practices monoculture under irrigation farming schemes in the study area. Majority of irrigation farmers practices mixed faming, meaning that there are intensive cultivations or land utilization per field which contributes to nutrients depletion as well as soil contamination from salt as a result of excessive evaporation. There is intensive use of land in the six villages studied; however field observation indicates that about 50% of field are utilized while most of the remaining field are left unattended. Though dry season is very short, field observation showed that fallow period being practised where some fields are cultivated once and left unattended for two years or sometimes more than that.

Respondent (KI,18) from Chiheko village (an eggplant and okra farmer) testified the above information by saying that:-

"We don't own large parcel of land…so fallow period is a common practise since we can utilise the same piece of land for both wet and dry season farming…This practise affects our farming as the soil loose fertile very quickly….Moving to a new plots/fields depends on several factors such as loss of soil fertility that is determined by performance of crops on the land (previous cultivation); previous harvest (quantity and quality of volume harvested for a particular crops) and the type of crops planted on previous fields".

Field observation showed that loss of soil fertility in most cases have been contributed by extensive use of field (mixed farming-several crops per fields); continuous shifting cultivation as well as slash and burn agriculture which repeatedly lead to the loss of biomass and inability of the soil to recycle nutrients. Other factors includes erosion of top fertile soil (soft black cotton soils) due to removal of vegetation and application of herbicides that kills all biomass and other organisms responsible for recycling nutrients such as ants and earth worms. Signs of deforestation, logging, and charcoal making were also common in the study area indicating intensive use of natural resources and land degradation. Land degradation reduces the productive capacity of land which consequently affects crop performance and yield hence making a production of a particular crop unsuitable.

In general, poor farming practices makes dry land irrigation farming schemes very sensitive and vulnerable since it expose the farming schemes to the ongoing climate change impacts such as soil erosion from heavy rain falls. Poor farming practices also makes soil not suitable for crop cultivation as well as prone to soil erosion during heavy rain falls and thereby reducing the suitability of the land to produce maximum yield thereby increasing vulnerability of the farming schemes against climate change impacts. Thus without improved farming, the existing farming practices will continue to affects crop performance due to poor nutrients and thus making farming schemes very vulnerable to future climate change impacts.

c) Lack of Resources and Entitlements

From the data, it can be seen that the vulnerability of dry land irrigation farming schemes is not contributed by exposure and sensitivity of the farming to climate change impacts alone but rather by other multiple factors such as lack of resources and entitlements. Poor farmers who are economically disadvantaged and lacks necessary inputs (such as improved seeds, manual pumps) for irrigation farming practices are more vulnerable as they are easily exposed and unable to cope with climate change impacts such as increased temperature and shortage of water. Most of the farmers depends on surface water from ponds, streams or rivers. Thus inability to access water throughout the farming season such as underground water can make a farmer more vulnerable as he/she lacks the means to cope with shortage of water and increased temperature during the midst or end of dry farming season which is the peak of irrigation farming season. Availability of resources means that even when dry land irrigation farming season fail suddenly as a result of increased temperature, crop pest attacks, market failure or water shortage; farmers can still absorb the shock/stress and continue with other livelihoods. Farmers in the study area identified few resources such as livestock's (goats, cattle, sheep, chicken); access to forest products (poles, timber, charcoal); quarrying (sand, pebbles, stones) and other assets which they can sell and use the income earned to offset the emerged shock (figure 8.5).

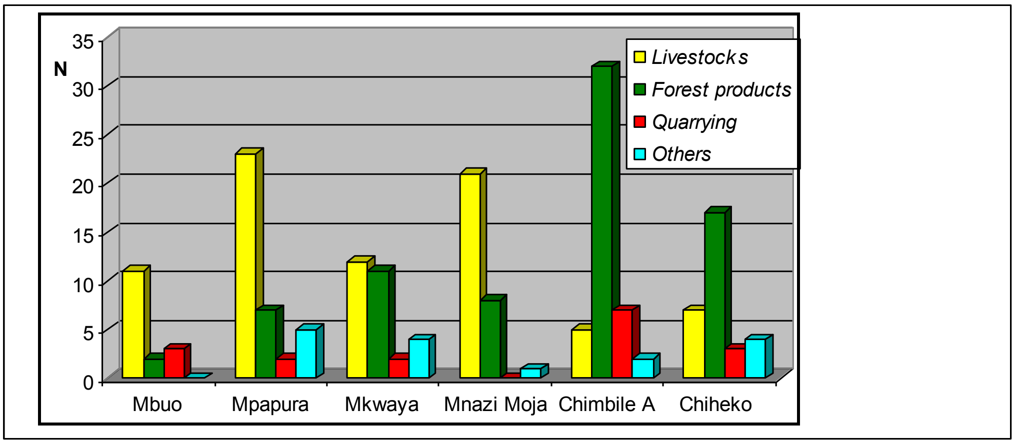

Figure 8.5: Resources owned by farmers in the study area. Source: Mhagama, 2014

The result above also indicates that Mtwara rural district (Mbuo and Mpapura villages) has highest rate of deforestation (land degradation) compared to Lindi rural district (Mkwaya and Mnazi moja villages) and Ruangwa district (Chimbile A and Chiheko villages) as farmers there have abundance forest products such as timber, poles, charcoal that they can utilize in case of failure in irrigation farming. Dependence on one type of resources indicates how vulnerable the farmers are since in case of any disturbances or shock from climate change impacts, it makes the farming scheme more vulnerable due to lack of livelihood diversification.

This also makes farmers scared of repeating farming the next season as justified by respondent (KI,05), a collard green and spinach farmer from Mpapura village who said that:-

"I am known here as the father of spinach, but I once nearly lost everything due to crop pest attach … a small caterpillar that ravaged my entire spinach farm and it was very hot season... The next year, I was afraid of repeating the same crop, so I tried collard green and it worked…the only thing that saved me was chicken…without selling my chicken, life would have been very hard".

During field observation, few farmers in Mbuo and Mkwaya were seen using manual pump to pump water and irrigate crops especially when the water levels falls below threshold points (point that watering the crops using buckets becomes difficult) compared to farmers in other 4 remaining villages. Farmers in Ruangwa district (Chimbile and Chiheko villages) were seen easily accessing underground water (using *vinyungu/dug-out ponds*) and cope better with irrigation farming throughout the dry season compared to Mtwara and Lindi rural district (Mbuo, Mpapura, Mkwaya and Mnazi moja villages) who use surface water (*ndiva/ponds or river/canals*). When there are water shortages or crop failure, farmers without access to other means of livelihoods normally abandons their farming schemes.

In most rural areas; poor farmers without access to other resources or different source of income are often exposed to climate change impacts and are more sensitive as they cannot cope with marginal changes in their yields or income, whereas farmers with diversified income or resources can cushion their loss by depending on savings or sale of some of their assets. An inherent lack of agricultural subsidies (improved seeds, manual pumps) and horticultural trainings from relevant authority as well as other key stakeholders makes the farmers powerless and easily affected by exposure to climate change impacts which affect their farming schemes and crops. Additionally, farmers with no relevant information on climate change are exposed to various effects of climate change impacts such as information on moisture availability, intensity and duration of sunshine during dry season which can affect planted crops negatively. Such lack of advisory agricultural services is serious agenda particularly in dry irrigation farming where water fluxes; temperature variability and pest control are issues of concerns for reducing vulnerability and thereby maximizing crop productivity and yield.

In spite of the different factors making dry land irrigation vulnerable to climate change impacts; exposure to climatic variability (temperature and rainfalls) had emerged to be critical to farmers' perceptions as it affects water availability and contributing to crop wilting which are the core foundation for crop performance, productivity and yield in dry land irrigation farming schemes. Similar studies around irrigation farming communities in Tanzania have produced the same results (Mkavidanda and Kaswamila, 2001; Majule and Mwalyosi, 2003; Sokoni and Shechambo, 2005; Sanga et al. 2013) indicating how vulnerable irrigation farming scheme is to climate change impacts.

8.3.3 Adaptive Capacity of Dry Land Irrigation Farming Schemes.

As identified in the conceptual framework; *adaptive capacity* is 'the whole of capabilities, resources and institutions mechanisms and strategies designed and set-up to implement effective adaptation measures' to cope with exposure to hazards such as climate change impacts. In this case adaptation in the study area is the adjustment in socio-ecological systems (irrigation farming schemes) in response to actual increase in temperature or rainfalls or expected uncertainties such as water shortage, increasing sun intensity (scourging sun) and moisture loss. Thus (in) ability of farmers to implement effective measures to deal with the impacts of climate change variability in the study area can make dry land irrigation farming schemes more vulnerable and fail to respond to climate change impacts and thereby makes farming vulnerable to climate change impacts.

In the study area, few farmers fail to respond, cope and adapt to climate change impacts due to lack of farm resources and lack of farm knowledge or skills as well as due to poor institutional setups which makes farmers to fail in moderating harm from climate change impacts or fail to exploits beneficial opportunities such as flood water resulting from climate change impacts. Chapter 9 provides details of adaptive capacity of dry land irrigation farming schemes to climate change impacts in the study area. Analysis of these details (adaptation and coping strategies and determinant of choice of coping strategies) will determine the vulnerability as well as resilient of dry land irrigation farming schemes in the study area.

8.4 Risks Associated With Dry Land Irrigation Farming Schemes.

Dry land irrigation farming scheme is an inherently risky practices. Generally, irrigation farmers are faced with a wide range of risks such as variability in weather condition, pest infestation and crop diseases that reduces crop quality and crop yield and thereby affects income earned as well as food security. The risk associated with dry land irrigation farming in the study area is very high as the dry land irrigation farming schemes becomes highly vulnerable due to its exposure to climate change variability (temperature, dry spells and rainfalls) and its sensitivity due to poor farming practices as well as lack of resources and inability of farmers to respond and cope with climate change impacts which makes irrigation farming very risky business to undertake in the study area. Farmers in the study area mentioned that risk associated with dry land irrigation farming includes crop failure (11.4%) and reduced yield (7.9%) as well as low crop quality (5.4%) production (figure 8.6).

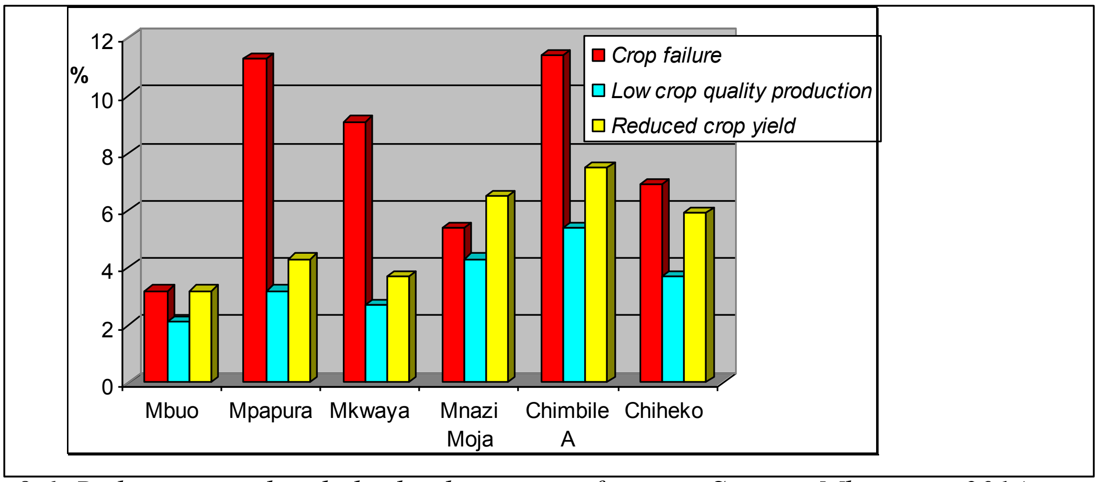

Figure 8.6: Risk associated with dry land irrigation farming. Source: Mhagama, 2014

Although in this study, the risk described is associated with the impact of climate change on dry land irrigation farming schemes but risk can also arise from the combination of an event, its likelihood of occurrence and its consequences. It is difficult to assess who is at risk, at what point and what kind of risk as the farming schemes' exposure to climate change impacts and its sensitivity combined with different set of other stressors can affect individual farmers differently from season to season. This indicates that farmers' perception on risk associated with climate change impacts in the study area is difficult to quantify and their perception did not describe or provide the whole scenario considering other risky events. To ascertain the above dissimilarity in what farmers' perceived and reality; other methods including field observation were very important in verification. During field visits in both villages, it was observed that apart from risk associated with climate change impacts; the risk encountered in dry land irrigation farming schemes are associated with poor decision making stemming from commencement of dry season farming as well as lack of access to raedy market for their freshy produce.

Field observation showed that risk starts with farmer's poor decision in *site selection, land preparation, seed selection* (*type and variety of crop*) and which *farming methods* to employ during crop tending. For example; poor site selection and land preparation might lead to additional cost of tending the crops which affects farmers already constrained income while poor seed selection and poor farming methods might lead to poor crop performances and crop productivity resulting in poor crop quality and low crop yield which automatically affects crop market price (income earned) as well as food security of the farmers. Collectively, these factors increasingly make dry land irrigation more vulnerable and a very risky business in the study area.

The irrigation farming practices becomes even more risky when the crops produced under the effects of climate change impacts (constraints from increasing temperature and crop wilting) affect the crop performance and productivity. This in turn affects crop quality and yield that consequently is incorporated in the market price for the vegetables produced (low price) and low income earned by the farmer. Any small changes in aggregate supply from the farm (in terms of quality and quantity of the vegetables produced) can lead quickly to substantial changes in price which affects farmer's decision for the next farming season. In additional, poor crop produce coupled with low yield and low price can also impact food security for poor farmers which were the primary basis for production. Due to poor quality; most of the vegetables produced by poor individual farmers fail to compete with vegetables produced by farmers coming from other well established irrigation farming schemes. This is due to inability to take risk and learn new and improved methods of farming which produce crops with high quality. Majority of the farmers in the study area are risk averse (avoiding taking risks) while few farmers in the study area are risky takers as they are more open to risky due to their attitudes in testing and trying other option of improved farming practises.

Finally, through interviews and discussion with FGD, the risk associated with dry land irrigation farming schemes in the study area as a result of climate change impacts also surfaced clearly and strongly. During discussion with most interviewees, crop failure, poor crop quality and reduced yield were strongly reiterated with some examples related to the impact in market price for the vegetables harvested. One of the respondent (KI,11), a vegetable and tomatoes farmer from Mnazi moja village to had this emotional story to tell:-

"Though the risk of water shortage and crop wilting due to excessive evaporation and increased temperature during dry season farming is very high; our farming business is not as bad as people think…The only thing that ruin our dry land irrigation farming and makes us penury is poor decision making during farming that arise from lack of knowledge and experience in vegetables farming as well as lack of agricultural inputs, horticultural trainings and good market for our produce".

There were few uncertainties related to farmer's perception on risk resulting from climate change impacts, however field observation combined with qualitative data from interviewees and FDG's provided a clear signal to discern upon the risk associated with climate change impacts as perceived by farmers, interviewees as well as ground observation in the field. This was very important because, though with various set of stressors and threats that affected individual farmers differently; a common message emerged from all their responses and converged at a single point which tends to be more associated with vulnerability (exposure) to climate change risks than from sensitivity and inability to adapt to the ongoing changes.

8.5 Indicators Showing Vulnerability of Dry Land Irrigation Farming Schemes.

Perhaps one of the most neglected aspects of vulnerability assessment is the evaluation of different key indicators showing vulnerability due to their variations and characteristics. In the study area; indicators used in evaluating vulnerability of dry land irrigation farming schemes vary due to different aspects such as type of crops produced, dependence on source of water, farming resources used as well as soil characteristics. Apart from variation, these indicators act as proxies for vulnerability to future changes which makes it difficult test the validity of indicator sets. The usefulness of indicators depends on how they are employed to make decisions on risk. Thus, in vulnerability assessment; common key indices are very important in evaluating the assessment of vulnerability to climate change impacts in livelihood activities such as irrigation farming. Such indices are relevant, particularly in showing how vulnerable irrigation farming communities and their irrigation farming schemes are exposed to climate change impact in the study area.

In order to assess vulnerability in the study area, I used farmer knowledge to identified significant biophysical and socioeconomic factors that influence dry land irrigation farming schemes. Farmers were asked to identify what key indicators which indicate dry land irrigation farming schemes' vulnerability to climate change impacts? Majority of the farmers (39.3%) mentioned extreme temperature and strong winds while others (26.3%) mentioned soil condition (acidic, alkaline or colour) and low crop yield (24.7%) was also mentioned by the farmers followed by reduced surface water availability (9.7%) as an indicators showing failure of irrigation farming or the vulnerability of dry land irrigation farming (figure 8.7).

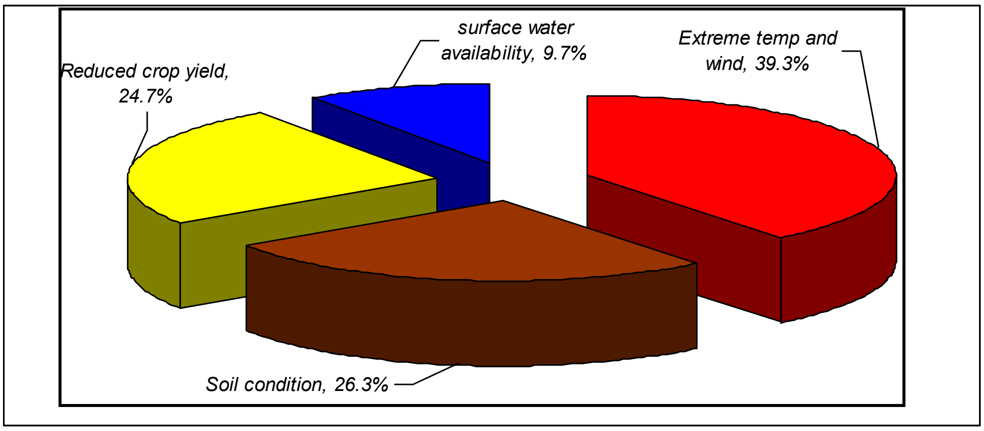

Figure 8.7: Indicators showing vulnerability of dry land irrigation farming schemes.

Source: Mhagama, 2014

To understand further how these indices are used to indicate vulnerability of dry land irrigation farming schemes against climate change impacts in the study area; farmers were asked further to rank and describe why they have perceived those indices as threats and indicator of vulnerability. Analysis in table 8.4 below provide explanation as to why farmers chose the above indices as indictors showing vulnerability to climate change impacts for their irrigation farming schemes.

Table 8.4: Reason for choosing indicators showing vulnerability.

Indicator	**Description of the indicator**	**Unit of measurement**	**Relationship between indicator and vulnerability**	**Anticipated impacts**
***Temperature and strong wind	High temperature (intensity of scourging sun); strong winds (blowing)	Rate of evaporation, rate of irrigation or crop watering	The higher the evaporation, or water used for irrigating crops the higher the vulnerability	Crop wilting, poor crop performance, leading to low yield
*Soil condition	Soil acidic or alkaline; soil characteristics-soil fertility, texture, colour	Soil pH, soil colour, humus, vegetation cover, soil erosion	The poor the soil fertility and poor crop performance the higher the vulnerability	Decreased soil fertility, Poor crop performance
**Reduced crop yield	Low crop yield	The harvested volume per field or per plot (<ha)	The lower the volume harvested the higher the vulnerability	Decreased household income and food security
***Surface water availability	Reduced surface water in the ponds, reservoirs	Water level in various reservoirs and ponds	The lower the water level (midst of dry season farming), the higher the vulnerability	Poor crop performance, low crop yield, cost of watering

**** - Very high vulnerable; ** - High vulnerable; * - Vulnerable*

During field visits, observation shows that areas with more productive soil and more surface water available for the irrigation farming were less vulnerable to adverse climatic conditions and farmers were better adapted to cope with the changes than areas with poor soil and less water. Though majority of respondents in the study area mentioned indicators of vulnerability as describes in table 8.4 and figure 8.7 above; further analysis of field observation showed that farmers with more resources and diversified income like land, livestock's and farm inputs such as manual pump and improved seeds were seen to cope with dry season farming better than their counterpart. Additionally, availability of resources and alternative income to some farmers seemed to cushion them from exposure to vulnerability and makes irrigation farming practices less sensitive to climate change impacts.

Majority of information from interviewees and participants in FGD's disagree with the indicators mentioned by the farmers in table 8.4 and figure 8.7 above. Discussion with FGD's in Mpapura and Mkwaya villages indicates that the indices mentioned above are common characteristics in their farming schemes as they have to overcome these challenges daily in order to reap a good harvest from dry season farming. The FGD's in Mnazi moja and Chimbile villages mentioned that though water levels may fall below threshold during dry season, the high intensity from scourging sun is something they have to encounter yearly though ought their life. Further discussion with FGD's in Mpapura and Mkwaya villages; mentioned that coastal area is affected by extreme hot condition and strong wind which is normally blowing during dry season affecting soil moisture and surface water availability. Both participants agreed that at the end of dry season, the water levels decreases due to excessive withdraw and increased water competition from different competing end users. Discussion with interviewees yielded new information as they described additional indicators to the above mentioned by the farmers. The additional indicators mentioned by interviewees are described in summary as indicated in the table 8.5 below:-

Table 8.5: Indicators of vulnerability as described by interviewees.

Indicator	**Description of the indicator**	**Unit of measurement**	**Relationship between indicator and vulnerability**	**Source of information**
Abandoned farms	Un-used land (fallow) though high demand for irrigation	Number of field plots abandoned or uncultivated	The higher the number of farms abandoned indicate high vulnerability	Mpapura, Mkwaya, Mbuo,
Source of water available	Dependence on one source of water for irrigation	Number of water sources (ponds, rivers, underground)	Lower number of water sources available, increases the vulnerability	Chimbile A, Chihiko, Mbuo and Mpapura
Farm Resources (farm inputs and training)	Availability of key farm inputs (such as pumps, pesticides, seed)	Variety and number of key farm inputs available	Different variety of farm inputs, decreases vulnerability	All villages
Alternative livelihoods	Livestock's, off- farm income	Number of diversified income source	Different sources of income reduces vulnerability	All villages

Other noted indicators during discussion with interviewees and participants are entitlement such as villages or farmers involved in frequent food aid provided by the government as a result of crop failure are also indicated as vulnerability. Food insecurity resulting from low crop yield is an indicator of vulnerability in the study area. In general the various components of indicators described above suggest the complexity of dynamic interactions and interdependencies of these indicators with regards to vulnerability. These factors highlight the need for multidisciplinary scientific approaches that will gather information to identify and assembles all possible indicators of vulnerability and thereby draw conclusion based on specific key indicators, their interaction and the multiplier effects they have on dry land irrigation farming schemes in the study area.

8.6 Summary

In this chapter, the manifestation of climate change impacts on dry land irrigation farming were clearly presented and analysed. The main focus on the vulnerability of dry land irrigation farming against climate change impacts in the study area was described. In general, farmers describes the major factors making irrigation farming vulnerable to climate change are extreme temperature which cause *crop wilting and low yield* followed by *soil erosion* from heavy rainfalls. Other factors mentioned by farmers includes *weed and pest infestation* that increase the cost of farming and affects crop performance and yield as well as *reduced water from reservoirs* due to extreme temperature and frequent dry spells. Farmers also explained the frequency and severity of the major factors making irrigation farming vulnerable to climate change. Majority of the farmers mention that crop wilting occurs once at the end of the dry season farming due to increased dry condition and extreme temperature as well as an increase in floods, pest and weeds infestation that occur once per year.

The diversity and complexity of farmer’s responses is signalled by farming experience, water source availability, resource endowment and access to information. Similar arguments were put forward by interviewees and participants from FGD’s who mentioned that lack of access to frequent information and knowledge about climate change impacts, improved farming, adaptation measures as well as markets prices; increasingly makes dry land irrigation farming schemes vulnerable as it exposes their farming schemes to other set of stressors such as high cost of tending the crops (watering) or controlling pests and diseases that attacks crops.

Specifically, the three elements of vulnerability (*exposure, sensitivity*, and *adaptive capacity*) in the study area were described farmers. Regarding exposure to climate change impacts, farmers in the study area mentioned that dry land irrigation farming schemes are exposed to high temperature, frequent dry spells as well as strong winds which affects their crops due to loss of moisture and makes farming schemes vulnerable to climate change impacts. Farming schemes in Mtwara and Lindi rural district seemed to be more vulnerable, because they are located along shoreline and hence they are more exposed to increased temperature and influence of wind conditions from Indian ocean that cause excessive evaporation compared to Ruangwa district that are more exposed to frequent heavy rainfalls that cause floods, weeds and pest infestation. Data from various National (NAPA, 2007) and global reports (IPCC, 2014) shows that temperature in the study area had increased in the past 30 years and is expected to increase by 2.2^0C by year 2100, with increases concentrating over the month of June, July and August. These are expected months for dry season farming practices to take place which indicates the future vulnerability of dry land irrigation farming schemes in the study area.

Regarding sensitivity, farmers mentioned that attributes such as *poor soil conditions, poor farming practices, resources owned and entitlements*. Other sensitive factors such as land degradation and fluctuating market prices for vegetable produce are among major stresses that shape irrigation farming schemes making it vulnerable to climate change impacts in the study area. These factors coupled with greater frequency of dry spell, extreme dry condition and soil erosion from heavy rainfalls makes farming schemes responds negatively (*i.e.,* reduced yield). In spite of the different factors making dry land irrigation farming schemes vulnerable to climate change impacts; exposure to climatic variability (temperature and rainfalls variability) had emerged to be critical as it affects water availability and contributing to crop wilting which are the core foundation for crop performance, productivity and yield in the study area with respect to irrigation farming.

The chapter also showed how few farmers in the study area failed to respond to climate change impacts due to lack of farm resources and lack of farm knowledge or skills as well as due to poor institutional setups which makes farmers to fail to moderate harm from climate change impacts or fail to exploits beneficial opportunities such as flood water resulting from climate change impacts. Lack of advisory agricultural services is a serious agenda particularly in dry irrigation farming where water fluxes; temperature variability and pest control are issues of concerns for reducing vulnerability and thereby maximizing crop productivity and yield.

The chapter clearly elaborated risk associated with dry land irrigation farming as mentioned by farmers which included crop failure, reduced yield and poor crop quality production. Field observation showed that risk encountered in dry land irrigation farming schemes are associated with poor decision making from commencement of dry season farming rather than from climate change impacts alone. These include farmer's poor decision in site selection, land preparation, seed selection (type and variety of crop) and which farming methods to employ during crop tending. In the study area, one of the inevitable aspects of vulnerability observed during field visits is that during rainy season bottom valleys are not suitable for cultivation as they are flooded and the soil is not suitable for rice farming. At the same time during dry season the amount of water (moisture requirement) is low (due to excessive evaporation) in such a way that it's not enough to cultivate large portion of land based on crude farm inputs they have, thus the cultivated land is so small making irrigation farming a subsistence farming without assurance for its sustainability. Finally, indicators of vulnerability such as crop wilting, soil condition (acidic, alkaline or colour) and low crop yield were mentioned by the farmers as well as reduced surface water availability. Discussion with interviewees yielded new information as respondents described additional indicators of vulnerability such as abandoned farms, dependence on one source of water for irrigation, availability of farm resources (farm inputs and training) and alternative livelihoods.

CHAPTER 9: RESILIENCE OF DRY LAND IRRIGATION FARMING SCHEMES AGAINST CLIMATE CHANGE IMPACTS.

9.0 Introduction

The previous chapter has highlighted the vulnerability (exposure and sensitivity) of dry land irrigation farming schemes against climate change impacts. This chapter describes farmer's knowledge on resilience of dry land irrigation farming schemes to climate change impacts. The chapter highlights the needs to fully understand farmer's knowledge regarding resilience in the study area before describing different adaptation and coping strategies used by the farmers. Several efforts taken by individual's farmers to cope with and adapt to multiple stresses from exposure to climate change impacts have been described here.

The main focus in this chapter is to describe the nature and extent of processes involved in adaptation and coping strategies used by the farmers in the study area in making irrigation farming resilient to climate change impacts. Different strategies used by farmers to adapt and cop with the effect of climate change in study area have been described here while factors determining the choice of those coping strategies have been identified and explained by the farmers. The chapter provides analysis of life stories from interviewees who provide an indication of the different resilient strategies and mechanisms used by farmers to adapt and cope with climate change impacts.

Despite several efforts made by farmers in responding, adapting and coping with climate change impacts; this chapter identifies different livelihood diversification strategies that have increasingly made farmers remained impoverished due to lack of sustainability. The chapters finally describe the complexity and diversity of poor livelihood strategies in the study area, including a lack of alternative income generating activities, poor market, rural poverty and lack of agricultural entitlement which may limit the adaptive capacity of the farmers. Other factors shaping adaptation and coping strategies have also been describe in this chapter.

9.1 Farmers Knowledge on Resilience of Dry Land Irrigation Farming Schemes Against Climate Change Impacts in the Study Area.

Farming households in many parts of Tanzania, are faced with many changes and challenges in agricultural production such as declining soil fertility and crop yields (Mnenwa and Malit, 2010); spiking price of farm inputs (Evans et al. 2012); poor market access and constrained access to land and water resources (Devkota et al. 2015). This cause a continuous decline in agricultural production and a rise in both poverty levels and household food insecurity. Climate change impacts is adding another heated discussion on top of these challenges which makes farming practices such as irrigation farming more vulnerable. As these changes and challenges makes farming (such as irrigation farming schemes) more vulnerable, some studies (Adger et al. 2004; Cardona et al. 2012) suggest that they also make farmers slowly responding and adjusting to these changes while coping with the ongoing situation.

Thus, such ongoing changes and challenges resulting from climate change impacts can be significantly reduced through a deep embedded farmer's knowledge on resilience and adaptation strategies. To understand how irrigation farming is adapting and coping (becoming resilient) in the study area; farmers were asked to describe the term with regards to their irrigation farming schemes and climate change impacts. Very few farmers (6.7%) did not understood the term resilience, which also indicated they are new in irrigation farming business. Of those who said yes (93.3%); majority of the farmers (49.7%), expressed resilience as *having support* (particularly *access to information and resources*) they get from relatives, other farmers, government and other key stakeholders that helps them to carry on irrigation farming even in the face of climate change impacts (water shortage and extreme temperature). Other farmers (26.9%) described resilience as the *level of preparedness* and *ability* to *react* and *take action* to prevent further damage from climate variability (reducing crop damage and wilting) while the remaining farmers (23.4%) understood resilience as *becoming accustomed* to the changes brought about by climate change impacts (table 9.1).

Table 9.1: Farmers knowledge on resilience of irrigation farming schemes.

Meaning of resilience by irrigation farmers	**Observation**	**Percentage**
Getting support (information and farm resources)	87	49.7%
Preparedness and ability to react and take action	47	26.9%
Becoming accustomed to ongoing climate changes	41	23.4%

In other scholarly work, the term resilience have been described as ability to react and take action (*respond*) as well as becoming accustomed (*adapt*) to the ongoing climate changes (Ludwig et al. 1997; Folke et al. 2006) while support and entitlement from key stakeholders have been termed as part of adaptive capacity (Agder et al. 2004; Deressa et al. 2008; Perez et al. 2015). This is also supported by IPCC (2007) which consider the term adaptive capacity to be *"a function of wealth, technology, education, information, skills and access to resources"* which makes socio-ecological systems more resilient to external and internal stimuli. Thus irrigation farmer's ability to respond, adjust themselves and cope with ongoing changes (extreme temperature and shortage of water or loss of moisture) by using local knowledge has been perceived as resilience of dry land irrigation farming against climate change impacts in the study area. In Chimbile A and Mnazi moja villages; interviewees have acknowledged that local knowledge and practices as well as their experience in irrigation farming have helped them to cope with and respond to floods and increasing temperature for many years since they have started irrigation farming.

Majority of farmers who correlated resilience with having support (particularly access to information and farm resources) from relevant key stakeholders; were asked to describe further, how do they access relevant information and farm resources that helps them to cope better with the climate change impacts during dry season farming? Majority mentioned they only use local knowledge and depend on resources from a friend or family while others mentioned they are supported by agricultural extension officers or other donors and the rest get information and resources to cope with climate change impacts from local, national media and social networking (figure 9.1).

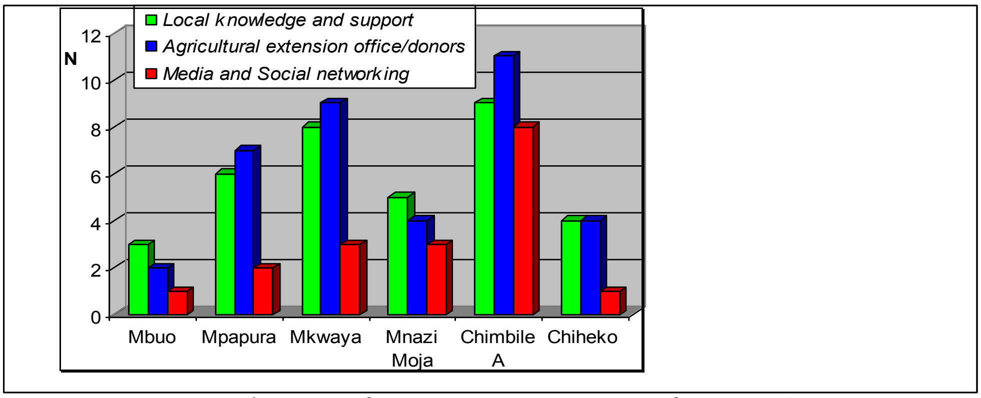

Figure 9.1: Farmers access to relevant information on irrigation farming. Source: Mhagama, 2014.

Discussion with participants have reinforced farmer's perception with regards to importance of access to information and farm resources regarding resilient of dry land irrigation farming schemes against climate change impacts in the study area. Strikingly, a more perspective analysis were obtained as participants from FGD's described what kind of information have helped them to carry on irrigation farming by responding, adjusting and coping with ongoing climate change impacts. They described further the importance of access to information and farm resources from various agricultural stakeholders. Participants in Chimbile A mentioned that having information in advance have helped them to know when to start farming and participants in Mnazi moja mentioned the availability of improved seeds, seed variety and other farm inputs (watering can, pumps) have helped them to increase production in the face of climate change while participants in Mkwaya and Mpapura mentioned that using media has helped them to know which vegetables is more valuable in the market and what crops takes shorter time. Other participants in Mbuo and Chiheko mentioned that having farm inputs (pump and herbicides) has helped them to ensure water availability and to combat pest as well as how to reduce the effects of increasing temperature and windy condition.

Field observation yielded parallel result with information obtained from discussion with participants in FGD's. During field visits, farmers with enough information on improved farming and better farm resources such as manual pump; crop variety and improved seeds as well as prior irrigation farming skills and techniques were seemed to respond and cop better with the effects of increased temperature and water shortage in ponds or rivers (as a result of impacts of climate change) compared to other farmers with less farm resources and lack of agricultural trainings. Thus based on the above responses (both individual and participants responses); the term resilience seemed to be complicated to the farmers due to diversity among farmers regarding use of the term resilience in dry land irrigation farming schemes. Given the slightly diversity in responses among individual farmers and participants in the FGD's; hence, understanding the resilient of dry land irrigation farming schemes to climate change impacts and how irrigation farmers in the study area respond to these effects, adjust themselves and cope with ongoing changes is critical not only to the vegetable production (income) but also to food security and the existence of dry land irrigation farming schemes in the study area.

9.2 Details of Resilience of Dry Land Irrigation Farming Schemes Against Climate Change Impacts in the Study Area.

In the existing literature, there are several definition and evolution of the concept resilience such as ecology (Gunderson and Holling, 2001) and socio-ecological systems (Folke et al. 2006). However, in this research, I used Folke et al. 2006 ideas; who described the evolution of the concept's meaning in social-ecological systems such as dry land irrigation farming schemes. Using analysis from farmers responses; here resilient is described as the capacity of irrigation farmers to respond to climate change impacts and reorganize themselves using different innovative response mechanisms to counteract the effects of climate change impacts so as their irrigation farming practices can continue to provide maximum yields and withstand further shocks/stresses from climate change impacts. The details of concept resilient of dry land irrigation farming schemes against climate change impacts in the study area has been described below by adaptation and coping strategies irrigation farmers use to mitigate climate change impacts to their irrigation farming schemes:-

9.2.1 Farmers Adaptation Strategies in Response to Climate Change Impacts.

Adaptation strategies refer to all responses to climate change that may be used to reduce vulnerability (Burton et al. 1998). In agricultural production such as irrigation farming, adaptation strategies can be developed, tested and used by farmers as result of response from exposure to shock/stress or they can be initiated by governments or other key stakeholders (such as research body) and embedded in some planning processes. Any adaptation strategies seeks to moderate or avoid harm or exploit beneficial opportunities which reflect a long-term strategies; however the most effective adaptation strategies are the one that have been developed by local farmers and tailored towards local context, including the biophysical setting, socio-economic conditions of the farmers and their cultural and traditional setting.

Farmers in the study area have been testing and adopting different adaptation strategies in their response to the adverse effects of climate change impacts but most of these strategies have proved failure over many years due to many reasons experience and farmers skills as well as their perception towards effectiveness of the adopted strategy. In order to better understand what different adaptation strategies farmers use to respond to adverse effects of climate change; respondents were asked to describe how do they respond to climate change impacts, particularly with the effects of increasing temperature, excessive evaporation and water shortage? Majority of the farmers mentioned different adaptation strategies such as using crop varieties (41.5%); use of improved farming methods (24.7%); use of soil and water conservation (19.9%) while other farmers (13.9%) mentioned other adaptation strategies such as using manual pumps to irrigate crops and using available soil moisture by planting crops at the bottom valley. The details of adaptation strategies used by irrigation farmers in the study area have been summarised below (table 9.2).

Table 9.2: Adaptation strategies used by irrigation farmers in the study area.

Farmers adaptation strategies	**Details of adaptation strategies used**	**Farmers main focus**	**Preferred crops**
Using different crop varieties	Drought resistance crops,	Reduce effects of temperature, increase crop productivity and income	Okra
	Shorter cycle crops		Amaranthus
	Higher yielding crops		Tomatoes
	New crop variety		Eggplants
	Good market price (vegs)		Watermelon
Use of improved farming methods	Mulching, crop cover	Water and soil conservation, reduce effects of temperature	Tomatoes
	Early planting		Onions
	Intercropping		Okra, maize
	Contour farming		Cowpeas
Soil and water conservation	Using drip irrigation	Water and soil conservation, reduce effects of temperature, increase crop productivity	Tomatoes
	Abandoning flash irrigation		Green vegetables
	Planting around river bank		Pumpkins,
	Using soil moisture		Cowpeas
Other adaptation strategies	Using manual pumps	Exploiting moisture, reduce effects of temperature, increase crop productivity	Collard greens
	Increase rate of irrigation		Tomatoes
	Using available soil moisture (bottom valley farming)		Cow peas, okra, pumpkins,

Source: Mhagama, 2014

At farm level, the scale and magnitude of testing and adopting these strategies have been slip-up trials where farmers are constantly changing one strategy after the other every farming season. For example, soil and water conservation practices such as mulching and organic manure can be observed this year while next year farmers can concentrates on crop cover and tilling as a strategy to address increase in temperature and water shortage. Though these strategies have been practised as trials; they are essential adaptation strategies as they have the greatest payoff in terms of increased crop productivity and yield in the study area. This in turn reduce vulnerability and there by enhancing resilience of dry land irrigation farming schemes as well as improving the capacity of irrigation farmers, especially those who depend on surface water for irrigating crops.

The discussion from interviewees and participants from FGD's about adaptation strategies were ascertained through guided questions about what different changes have been made in irrigation farming and why these changes have been made over the past 20 years? The results from the information of the interviewees and participants from FGD's showed that dry land irrigation farmers had been making various changes in their farming practices in the study area, however information shows that these changes were made merely for increasing crop productivity, crop yield and securing good market and earning a sizeable income rather than counteract the adverse effects of climate change impacts in the study area. The table 9.3 below shows summary of the identified changes by participants:-

Table 9.3: Qualitative responses on changes made in irrigation farming.

Changes made in irrigation farming	Reason for making such changes	Commonly practised in
Tilling, harrowing, adding organic manure	Soil fertility improvement and increase crop performance	Mpapura, Mkwaya, Chimbile A villages
Mulching, crop cover	Reducing evaporation and increasing crop performance	Mpapura, Mbuo, Mkwaya villages
Intercropping	Efficient utilization of field (okra, tomatoes, eggplant, pepper, pumpkin, banana, sugarcane)	Mkwaya, Mnazi moja, Mpapura, Chiheko Villages
Shorter cycle crops	Reducing growing length and possibility of having second harvest such as amaranthus, onions	Mpapura, Mkwaya, Chiheko, Chimbile A villages
New crop varieties	Crops that are highly demanded and command higher price in the market (watermelon, cucumber)	Mpapura, Mkwaya, Chiheko, Chimbile A villages
Higher yielding crop varieties	Offer farmers higher yields instead of the traditional breeds that takes long duration and low yield	Mnazi moja, Mpapura, Mkwaya, Chimbile A villages
Application of pesticides	Reducing crop pest and ensuring maximum yield per harvest	Mpapura, Mkwaya, Chimbile A villages
Using drip irrigation, manual pump	Efficient use of water, exploiting water for fields that are located far from water sources	Mpapura, Mkwaya, Mbuo villages

Although analysis of response from farmers and interviewees concludes different adaptation strategies used by farmers to respond to the effects of climate change in the study area; some of these changes or practices are part of daily farming strategies used by the farmers to enhance crop performance and increase crop yield annually. Thus some farmers in the study area do not describe them as strategies rather part and parcel of their farming skills. During study visits, few farmers in Mpapura and Mkwaya villages were seen trying different crop variety other than green vegetables (such onions, egg plants, passion, cucumber, watermelon) which were not common around the study area. Surveyed farmers in the field were seen also adopting different range of improved farming practices such as mulching; drip irrigation, utilising soil moisture and crop cover to save water in response to perceived water shortage and increase in temperature. Use of manual pump, water pipes, and other irrigation equipments were seen on various fields visited (in Mbuo, Mkwaya and Mnazi Moja villages) indicating farmers efforts to adapt to the effects of increasing temperature, excessive evaporation and water shortage by increasing water inputs.

Other actions taken by irrigation farmers in the field as part of adaptation strategies includes reducing the size of the field as well as increase rate of irrigation (twice per day) early in the morning and in the evening where the amount of water per crop/seedling/plot was seen higher than normal. During field survey in Chimbile A and Mkwaya villages, a new perspective emerged where farmers were seen planting higher resistant crops to dry condition especially at the end of the farming season particularly after the first harvest, they change the type of crop (*i.e* after harvesting onions or tomatoes, they plant okra, cowpeas or African nightshades). Other crops observed planted at the end of dry season farming are jute mallow, amaranthus, eggplants, lettuce and sweet potato leaves. In few cases in the field (Mpapura and Mnazi moja villages), banana, sugarcane, papaya and maize were seen planted as property boundary in each field (see figure 9.1 below). Furthermore, farmers were also observed planting less resistant crops nearer the water sources (along the water course/river banks) in Mkwaya and Mnazi moja villages while other high resistant crops on periphery or far end of the field.

Figure 9.1: Vegetable crops and fruits planted together as observed in the field.
Source: Mhagama, 2014.

In general, analysis shows that farmers that are more innovative, i.e. in terms of changing their farming practices to adapt with (or better exploit) their changing circumstances, are more likely to counteract the effects of climate change impacts and adapt to the existing situation than less innovative farmers. Similar findings were found in other parts of Tanzania practising traditional irrigation farming. For example, in Iringa and Morogoro local farmers have been adapting to climate change impacts by planting drought resistant crops and seed varieties, intercropping, irrigation, changed planting dates, increased use of water and soil conservation techniques, diversification from farm to off-farm activities such as casual labour and moving to other places (Mary and Majule, 2009; Shemsanga et al. 2010; Kihupi et al. 2015).

Hence, from the analysis, it indicates that all adaptation strategies and actions taken by the irrigation farmers to respond to the effects of climate change; whether planned or autonomous, are important strategies to reduce vulnerability as they moderate the potential damage from climate variability and enhance the resilience of dry land irrigation farming against climate change impacts in the study area. As a result, adaptation strategies taken by irrigation farmers in the study area to counteract the effects of climate change are therefore considered long-term response embedded in dry season irrigation farming practices. Furthermore, as these strategies and actions are embedded in daily irrigation farming practices during dry season; they become essential strategies to help irrigation farmers to build their irrigation farming schemes becoming more resilient and assist farming livelihoods to cope better with existing climate variability as well as capacity to adapt to any future climate change impacts.

9.2.2 Farmers Coping Strategies in Dealing with Climate Change Impacts.

According to IPCC (2014) coping refers to use of accessible skills, resources and opportunities to address, manage, and overcome adverse conditions so as to achieve short-term and medium-term necessities. In this study, coping refers to adaptive capacity represented by different coping strategies used by dry land irrigation farmers to respond to immediate climate change impacts in the study area. In this case farmers coping strategies are determined by the adaptive capacity or capacity of farmers to respond to the changes brought about by climate variability indicating short-term strategies. The coping strategies here are described as the ability of dry land irrigation farmers to adjust to a disturbance, moderate potential damage, take advantage of opportunities, and cope with the consequences of a transformation that occurs thereafter. Thus, farmer's adaptations in the study area are manifestations of adaptive capacity and coping strategies.

The strategies or changes in the irrigation farming practices that makes irrigation farming schemes capable of dealing better with problems of exposure and sensitivities to climate change impacts, reflects coping strategies or adaptive capacity (resilience). The essential quality of resilience of dry land irrigation farming schemes in the study area is described by the capacity of irrigation farmers to effectively utilise adaptation strategies during difficult farming seasons especially in the face of climate change impacts (such as increase in extreme temperature, excessive evaporation, water shortage, frequent dry spells, disease outbreak and crop failure) and rebuild farming schemes so as to continue provide same functions (supplement yield and income during dry season).

In order to understand how irrigation farmers are coping with the impact of climate change, the question of what coping strategies farmers use to mitigate the increase of temperature and water shortage in the study area was posed? Farmers mentioned different coping strategies (attributes to resilience) including different mechanisms developed by farmers to counteract the effects of climate change impacts. Majority of the farmers mentioned that they engage in selling livestock's-chickens (33.8%) and use effective soil and water conservation techniques-mulching (30.9%) while other farmers mentioned they engage in alternative enterprises-craft works (24.1%) and intensifying farming (11.3%) such as intercropping and cultivation on both sides of the river bank. At village level, Chimbile A and Chiheko seemed to cope better with the impact of increasing temperature and water shorgate by utilizing effectively soil and water conservation techniques while Mpapura, Mkwaya and Mnazi Moja seemed to cope better with the same effects by engaging in alternative enterprises such as disposing craft works, hawking and small scale business as well as selling labour (figure 9.2).

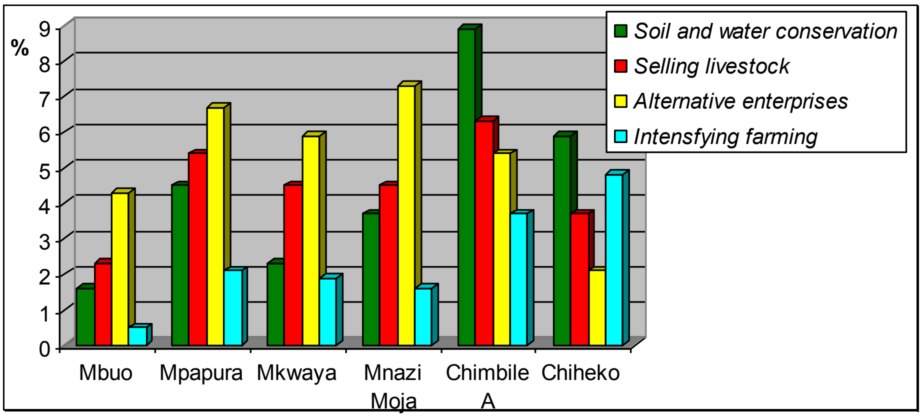

Figure 9.2: Coping strategies use by farmers to cope with climate change impacts. Source: Mhagama, 2014

In figure 9.2 above, though selling livestock's was universally identified as an alternative source of income in additional to irrigation farming during dry season in all six villages studied, slightly differences were noted in intensifying farming activities (*e.g.* intercropping, cultivating on both sides of the river bank and reducing size of the field) which was found to be common in Chiheko and Chimbile A villages. Field observation indicates that majority of the farmers who were engaging in both farming and other off-farm activities have earned extra income which helped them to cater food and income shortage as well as buying other households items and thereby coping better with climate change impacts.

During field visits; some farmers were seen engaging in alternative enterprises activities such as petty trading and craft works (weaving) to compromise losses in vegetable production and to supplement income during dry season farming. Farmers were observed involving in petty trading and vending items such as selling raw salt, cashewnut-locally made snacks, wild fruits and other household consumables while craft work (weaving) includes buskets, mats, rags, hats and other decorative items made of papyrus (*Cyperus papyrus*) and roofing materials from coconut leaves.

Common petty trading and weaving were observed in Mnazi moja, Mpapura and Chimbile A villages. Most farmers located along the main road (Mtwara-Dar es Salaam road) seem to be engaged more in alternative enterprises activities than farmers located in the interior mainland or where there is no access to main road. For example farmers at Mpapura, Mkwaya and Mnazi moja villages can easily sell their fresh produce from the farm, wild fruits and other handcrafts items to the market centres along the road, compared to farmers at Chimbile A and Chiheko villages who needs to travel to the market or sell their produce to middlemen. Though farmers located along the main road can easily sell their produces and other forest products to the consumers but there were no relationship between access to main road and increased farmers output (outputs products from farm and off-farm activities).

In few cases, some farmers (particularly men, youth) have migrated to the nearby town, especially Mtwara Urban due to recently opened cement factory as well as cashew nut processing factories in search for a job. Though migration did not surface in the questionnaires responses nor interviews and discussion as part of the strategy to cope with impacts of decreased crop yield as a result of climate change in the study area, it is seen as livelihood diversification strategies to earn income and send money (remittance) home to buy food and other household needs. Those who cannot be able to migrate to urban area (particularly women and elders); do involve in alternative enterprises activities such as petty trading, crafts works, selling livestock's and labour so as to increases sources of household income. Generally, the presence of alternative income generating activities provides another indicator of the ability of dry land irrigation farmers in the study area to shift to other economic activities in response to reduced yield and low income resulting from adverse climatic conditions such as extreme temperature and water shortage.

Discussion with participants from FGD's indicated that the income earned from engaging in alternative enterprises activities is spent on buying foods (commonly millets, maize, cassava, beans, cowpeas, dried sardines/fish) and other food stuffs such as cooking oil, salt, sugar from nearby shops/market. In addition, FGD's from Mbuo and Chiheko villages mentioned that the coping strategies used by irrigation farmers depends on farmers primary objectives and perception as well as access to natural resources while FGD's from Mpapura, Mkwaya, Mnazi moja and Chimbile A villages associated coping strategies with access to farm resources-inputs and markets availability for the resource or products produced. Whether planned or unplanned, analysis shows that capacity to adapt have helped farmers to cope better with climate change impacts. Field observation indicated that irrigation farmers who implemented adaptation strategies effectively in all aspects of irrigation farming; have managed to cope better with the impacts of climate change with minimum risks compared to others who do not use adaptation strategies effectively. While not all types of coping strategies are relevant to all villages studied, responses or perception from the farmers have offered us a snapshot of what kinds of coping strategies irrigation farmers have been using in their farming practices and how these coping strategies have substantial impacts in enhancing irrigation farmers capacity to adapt and cope better with the impacts of climate change and thereby increase resilience in dry land irrigation farming schemes. Whether planned or autonomous, the choice of these coping strategies depends on many factors as described below.

9.2.3 Factors Determining the Choice of Adaptation and Coping Strategies

Over the past 20 years, farmers in the study area have developed adaptation and coping strategies to shield them against the impacts of climate change such as extreme temperature, excessive evaporation, water shortage and disease outbreak. Different adaptation and coping strategies developed and used by farmers have been intended for increasing crop productivity and crop yield as well as sustaining or safeguarding irrigation farming practices throughout their life. Thus, from the analysis above (section 9.2.2 and 9.2.3), it seems that the impacts of climate change in the study area has entirely affected farmers decision making in terms of site selection, which crop to produce (at what level and scale) and what farm management practices they have to choose to ensure high crop performances, crop productivity and hence a guaranteed maximum crop yield while using as little efforts and cost as possible when adapting and coping with the impacts of climate change in the study area.

To understand different factors affecting the choice of the adaptation and coping strategies mentioned in section 9.2.2 and 9.2.3 above; irrigation farmers were asked to describe what are the determining factors influencing the choice of adaptation and coping strategies they use when facing the impact of climate change. Analysis from farmers response indicates that the factors that determine the choice of adaptation and coping strategies used to counteract the effects of climate change impacts includes farming skills (41.5%); difference resource owned (31.7%); land and water availability (19.9%) and farmers perception (6.9%). At village level, skills and experience in irrigation farming seemed to be a dominant factor affecting the choice of adaptation and coping strategies implemented by farmers across all six villages studied, followed by resources owned especially farm resources such as irrigation equipments, improved seeds, seeds that with stand drought conditions and other assets such as livestock's, land and other resources (see figure 9.3 below).

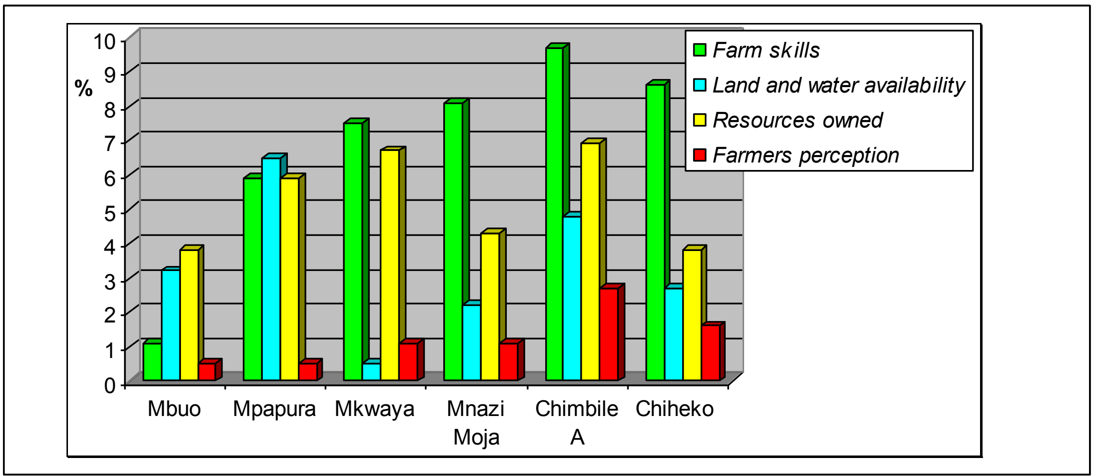

Figure 9.3: Factors determining the choice of adaptation and coping strategies.

Source: Mhagama, 2014

Land and water availability seemed to be influencing farmers choice of adaptation and coping strategies implemented in Mbuo and Mpapura villages due to their dependence on surface water (*ndiva-ponds*), however similar results have been mentioned in Chimbile A and Chiheko villages and this is due to their dependence on ground water (*vinyungu or dug-out ponds*) as well (access to ground water is a problem due to use of crude methods-hand dug well). In Mkwaya and Mnazi moja villages, water availability seems to be not a big problem due to the presence of Mkwaya and Mnazi moja rivers respectively which have enough water throughout and hence creating safety nets or security in terms of water resource availability for irrigation farming. Farmers perception also played a small role in influencing farmers choice across all six villages due to sensitivity and views about the adaptation and coping strategies to be used or adopted by the farmer and its implication in terms of cost, time and application as well as whether the practices are user friendly or not.

Each of the determinant factors discussed above has an influence to the irrigation farmers during decision making regarding the choice of coping and adaptation strategies implemented and in few cases these determinant factors may depend or may be influenced by other factors as well. For example, water availability coupled with high demand of a particular crop in the markets can dictates the type of crop a farmer has to produce throughout the season. For example a farmer may choose to change type of crops (*e.g.* change from green vegetables) after the first harvest depending on water availability by choosing crop (*e.g.* to okra, eggplants or peppers) that require less water at the end of dry season when moisture and water level drops below thresholds. High demand and better price for a particular crops in the market (such as tomatoes, watermelon, green peppers) may also motivate the farmers to choose the type of crop or choose what adaptation and coping strategies they need to produce more crop yield that is more demanded and command higher price at the market.

Though water availability may dictate what crop can be produced, field observation indicated that farming skills and experience can also influence how farmers utilise water in adapting and coping to climate change impacts. Other factors such as availability of farm inputs may also facilitate or smoothen the adoption of such coping strategy. Thus, what is important for the uptake of adaptation and coping strategy implemented by irrigation farmers' is the availability of that technology to be adapted, experience and skills of the farmers as well as affordability of such techniques. When response from farmers were cross-tabulated, age and education of irrigation farmers seemed to have little influence on the choice of adaptation and coping strategies implemented by farmers. This is because according to the National Bureau of Statistics, 2012 illiteracy level and poverty is very high in the region.

Apart from factors mentioned by farmers, vulnerability and resilience literature indicates other possible factors influencing farmer's choice of adaptation and coping strategies. Little empirical evidence exists related to what determines farmers' individual adaptation decisions and how adaptation can be measured quantitatively (Yohe and Tol, 2002). According to Deressa et al. (2008); farmers who undertake any adaptation at all, the choice of specific method depends on a number of elements, including socioeconomic, environmental and institutional factors, as well as the economic structure of the country. Additionally, the author mentions that the choice of adaptation methods depends on a range of variables which are considered important for the availability, accessibility and affordability of particular adaptation technology and its procedures. Ndunda and Mungatana (2013) add that household size, farming experience, access to credit and improved seeds and inputs, crop income and awareness to wastewater hazards significantly influence the farmers' choice of low-risk measures in irrigation farming.

Other studies mention that education of the head of household, livestock ownership and extension for crop and livestock production, availability of credit, water availability and temperature are factors influencing choice of adaptation (Brooks et al. 2005; Cardona et al. 2012; Kihupi et al. 2015). Shongwe et al. (2014) concludes that adaptation and coping strategies used by farming households were significantly influenced by age of household head, occupation of household head, land category, access to credit, access to extension services and training, high incidences of crop pest and disease, high input prices, high food prices and perceptions of farming households towards climate change impacts.

Though not mentioned by farmers, but high income earned from previous sales for a particular vegetable produced may also influence farmer's choice to increase output or intesify farming for that particular vegetable. Hence, higher income from previous sales may also influence farmer's choice in the next season farming to adapt and cope with any difficult condition when raising or cultivating particular vegetables in the field in order to harvest good yield and gets higher income due to higher sales from selling crop produce. This was observed in the field, at Mkwaya and Chimbile A villages when farmers were incoherently straggling to cultivate watermelon and carrots while Mpapura and Mbuo had similar situation cultivating green peppers though both villages experienced water shortage and temperatures were so high particularly at the end of dry season farming. This is because at the market level, these crops command higher price and there is high demand for these crops, whereby some of produce are imported far from Dar es Salaam and Iringa regions, hence forcing farmers to struggle in cultivating the aforementioned vegetables.

9.2.4 Different Livelihood Diversification Used by Farmers in the Study Area

Other different coping strategies in the study area used by irrigation farmers to adapt and cope with the impacts of climate change includes livelihood diversification from irrigation farming to off-farm activities such as charcoal and firewood production, casual labour, fishing activities and coastal gathering and migration to the nearest town in search for jobs particularly cheap labour. Majority of these activities used by irrigation farmers are conducted during dry season farming and do contribute to increased household income. During discussion with one of the interviewees in Mnazi moja village, the above off-farms activities practised in the study area strongly resurfaced. The respondent (KI,12) narrated that:-

"My son is a masonry… since the construction of cement industry started in Mtwara town in 2013, he seized the opportunity and now he is working as a cheap labour in construction and housing projects…Others here (particularly youth) had moved in town and now works in industries such as cements (Mtwara and Dangote cement factory) and cashew nuts processing industry".

Though some youth migrate to town in search for jobs; field observation indicated that some farmers do offer or sell their labour within the villages. Some of the casual labour still available in the villages during dry season includes land preparation, repairing worn-out houses, tending of cashew nuts farms and harvesting cashew nuts. Income earned from selling casual labour is used to buy food and other household's consumables. In few cases, farmers were observed involving in charcoal production, selling firewood and building poles. Although farmers could not verify the increase in the rate of forest harvesting (in the six village studied) for charcoal, building poles and firewood, through field visits it was observed that firewood, building poles and charcoal production had been one of the dependable secondary source of income for many farmers in the villages. This leads to forest degradation which has irreversible effects in terms of contributing to loss of biodiversity, greenhouse gas emissions and climate change impacts let alone land degradation and depletion of soil nutrients due to reduction in biomass and nutrients recycling. This in turn affects irrigation farming as depletion of soil nutrients leads to loss of soil fertility which affects crop productivity.

Farmers who have fields located near the water sources such as along the river banks or around wetlands and ponds do intensify their irrigation farming activities, for example by cultivating on both sides of the river. Farmers located around coastal lagoons do involve in production and sales of salt commodity while those within the reach of Indian ocean do supplement their income by engaging in fishing activities. During discussion with Lindi Rural District Agricultural Officer; parallel answers came up, mostly confirming the type of activities and income irrigation farmers depended on outside irrigation farming practices (vegetables production) during dry season farming.

The district agricultural officer from Lindi Rural District Council justified the above statements by saying that:-

"In years where water level falls below thresholds and rivers run dry…., farmers do reduce the size of the farm and intensifying their farming activities by cultivating on both sides of the river banks and concentrating on small piece of land (with mixed crops)…. Furthermore, other farmers do abandon their fields due to water shortage and excessive evaporation while other farmers do engage in salt production; engage in fishing along the coastal area and providing casual labour services".

Fishing and coastal gathering, though a traditional and culture for coastal community, particularly those within the reach of Indian Ocean; these activities are also considered as part of coping strategies to cater the effects of reduced crop yield as they supplement income (sales from fish catch) and food protein (gathered coastal products such as sea cucumber and other mollusc). Women in Mbuo, Mpapura, Mkwaya and Mnazi moja villages do involve in coastal gathering during low water tide while men in these villages do fishing activities due to their proximity to Indian ocean. Depending on the type of fishing activities (*e.g.* diving, hand lines, traps, canoeing); fishing and coastal gathering have an added advantage as they provide some ample time that can be used by the farmers for farming activities or other off-farm activities and household chores. For example, some fishing activities that are mostly conducted during the night or setting traps; can help fisherman to use some of the time available in other on-farm and off-farm activities while in coastal gathering which is conducted during low water tide, women may use up to 4 hours on average; thus giving them extra time for farming activities and other household chores.

Response from interview with a respondent (KI,09); from Mkwaya village, strongly echoed fishing as a coping strategies to the effects of climate change impacts. He mentioned that:-

"Fishing is my part of life job…however, during times of water shortage and failure in irrigation farming…fishing and coastal gathering have supported us immensely. When I do fishing, my wife and my two children also do involve in coastal gathering…. I can sell the fish I caught to the market and buy food and household items while my wife collect enough for cooking food and the surplus she sometimes sell to a local market or neighbour and the money earned we use to buy rice and maize…I believe fishing and coastal gathering have helped us with the burden of food shortage whether during dry or wet season farming" (Fisherman, Mkwaya village).

Although irrigation farming practices is undertaken to generate income and supplement food during dry season; at some points in discussion with interviewees, some results emerged where they described that in some cases they coped with low yield by changing food preference (consuming more cassava and millets than rice and maize), buying additional food and receiving food aid from neighbours, government support or relatives. In a rare case, this point was strongly rejected by two farmers in Mpapura and Mnazi moja villages, perhaps it is a shame for people to receive food aid from government as it is seen a sign of weakness and state of poverty, something farmers in these villages they don't want foreigners to perceive them. In addition, some farmers generate income through selling cashew nuts (locally made snacks), performing off-farm labour-casual labour, and selling chickens or involve in quarrying (sands, pebbles or stones). Household income earned from off-farm activities, usually increase the probability of irrigation farmers to afford different adaptation measures such as buying manual pump, improved seed variety, pesticides or paying labour for watering vegetables during extreme high temperature which helps farmers to cope better with the impacts of climate change. Thus farmers, with less sources of income are more vulnerable and less resilient compared to those who engage more in off-farm activities and hence earn higher income.

Other farmers depend on remittance from relatives or families working or doing small scale business in town. In one case, discussion with FGD's from Mpapura; participants mentioned that during difficult harvest (low yield, resulting from extreme temperature and water shortage), they borrow money or food from shop keepers and expect to pay-off when they receive mobile cash transfer from their relatives in town. The reason behind for this mutual trust is that the shop owners knows some of their relatives in town, so when they send money, some of it pays the debt and the remaining, farmers use it again to buy food groceries and other household items.

In all six villages studied; selling labour to a friends and neighbours is very rare, however in contrast to a lesser degree (*e.g.* in well established villages like Chimbile A, Mpapura, Mbuo and Mnazi moja); some farmers may help others in collecting local materials (poles, thatches) for rebuild their houses and expect to get support such as financial or food (maize, rice, millets) as a token of appreciation. The support provided here to a certain degree, can cater for food insecurity while the money earned can be used to buy food, seeds, other farm inputs or used in land clearance preparing for the next farming season. Selling fruits (*papaya, sugarcane, and watermelon*), wild fruits (*mabungo, vitolongo*) and root tubers (*ming'oko*) were seen as another coping strategies used by farmers to enhance family income. Evidence of satellites sales points or centres have been seen along the Mtwara – Lindi main road in Mbuo, Mpapura, Madangwa and Mnazi moja villages. Despites presence of several sales points along Mtwara – Lindi main road, the results from discussion with interviewees and participants from FGD's shows that there was no relationship to justfy this activity with coping strategies (resilience of dry land irrigation farming).

Other studies from Mtwara have revealed a large consumption of root tubers (*ming'oko*), during food shortage and farm preparations (URT-Vi, 2012; URT-Vh, 2012). However, in discussion with FGD's in Mpapura and Mkwaya villages, they said ming'oko is a wild root tuber freely available and has been consumed as a preferred traditional food for many generations and it's also preferred even by locals residing in town. Local brew such as *tembo* made from coconut juice and *nipa/ulaka* from cashew nut fruits – mabibo has been seen in few local pubs in the six villages studied, though no respondents has been able to verify it being used as alternative enterprises to increase household income or used as a coping strategy. This might have been influenced by the fact that local brew is a bitter and sensitive subject and brewers as well as farmers are worried of providing information that might compromise people involved in the business.

Most of the literature agrees that engaging in different livelihood diversification or working in different alternative enterprises have helped farmers to spread risk and manage uncertainty resulting from climate change impacts. Ellis (2000) asserts that livelihood diversification has become an effective and reliable survival strategy for rural households in developing countries. With ongoing climate change impacts, subsistence farming alone cannot provide sufficient means of survival in many rural areas without diversifying income or engage in other alternative enterprises. Although livelihood diversification is seen as cushion for supplementing income or a measure for adapting and coping with climate change impacts; care should be taken since most of the rural economy is subsistence-based which is linked to agricultural production hence any alternative or diversified activities taken by farmers should focus on sustainability rather than creating a new or future problem such as accelerating deforestation, land degradation as well as affecting the rural economy particularly agricultural production. Some of the examples of livelihood diversification with haziness future include charcoal production, deforestation and migration.

The concept of livelihood diversification is similar to migration where farmers do migrate to town from rural area in search for a job. This is a common phenomenon and it has some benefits when those who move to urban centres get some jobs and can send some money back home (remittances). However to some extent; this is not always the case especially when availability of jobs in the urban centres becomes a serious challenge for the immigrants who have no other means of survive. When this happen, the most affected people are elderly and women in rural areas who are compelled to shoulder the roles of taking care of the whole family responsibilities including those who are in town. One of the participants from FGD's discussion (a shopkeeper in Mpapura village), justifies the above situation by saying that:-

"Sometimes I have to provide goods (household groceries from my shop) to some of my fellow villagers without expecting anything ….Just praying that some day they will pay back…. Because they (parents) are complaining that their children are not helpful at all even when they ask for money…. their children tell them that they have no money because they have no permanent jobs in towns and life is hard even for them…. But with ongoing economic trend in the country, I wouldn't blame them".

Thus in general, livelihood diversification has short-term and long term benefits as well as several unforeseen problems that might arise in the future and brings other multiple effects or further the problem of climate change impacts. Thus farmer's needs to be careful advised to properly select suitable and sustainable alternative livelihood strategies without compromising the future rural economy particularly agricultural and livestock production.

9.2.5 Indicators of Resilience of Dry Land Irrigation Farming Schemes

Using knowledge from irrigation farmers in section 9.2.1 and 9.2.2; the analysis of responses from the farmers indicates that farmers are adapting and coping with the impacts of climate change by using several adaptations and coping strategies. However, when the question of which indicators is suitable to shows the resilience dry land irrigation farming against climate change impacts was posed, farmers responses were indistinctly leading to doubtful about their answers. Through analysis their responses were undecided between household resources (including income of the farmers); diversification of livelihood activities, farmer's knowledge on irrigation and the size of the field under irrigation which made it further difficult to verify or measure these indicators mentioned. This might have been contributed by the fact that resilience is a very complex term and difficulty to capture in a single entity whether as ability to respond, adapt and cope to the ongoing climate changes (Ludwig et al. 1997; Walker et al. 2004; Folke et al. 2006) or having support and entitlement (Agder et al. 2004; Deressa et al. 2008; Perez et al. 2015).

Although farmers were entangled between which are the best suitable indicator to show the resilience of dry land irrigation farming schemes against climate change impacts; field observation showed presence of several indicators such as availability and continuous use of manual pump, variety of seeds (crop resistance), soil and water conservation practices (mulching), livelihood diversification and reduced farm size as well as intensification of irrigation farming (see table 9.4 below). These improved farming practices, presence of farm inputs to enhance irrigation rate and reduce evaporation as well as engaging in alternative enterprises and diversifying of livelihood activities to other off-farm activities are good indicators showing how dry land irrigation farming is straggling with ongoing effects of climate change impacts particularly increased temperature, excessive evaporation and water shortage just to mention few.

Table 9.4: Indicators of resilience as observed in the field.

Indicator	Description of the indicator	Unit of measurement	Relationship between indicator and resilience	Source of information
Manual pump	Presence of water pump used for irrigating crops in the fields	Number of water pump and watering cans available in the field	The higher the number of watering equipments for crops indicate high resilience	Mnazi Moja, Mpapura, Chimbile A and Mbuo
Variety of seeds	Presence of variety of seeds that are resistance to drought, diseases as well as crops taking shorter period to mature	Different variety of seeds (crop resistance)	Higher number of crop resistance seeds increases farmers resistance and ability to cope with harsh condition	All villages
Soil and water conservation practises	Improved farming methods (contour farming, mulching, conservation tillage)	Variety and number of improved farming methods	Different variety of improved farming methods increased farmers resilience to climate change impacts	All villages
Farming intensification and livelihood diversification	Intensive crop cultivation, Livestock's keeping and off-farm income generation	Reduced farm size, livestock Number of diversified income source	Increased number of crops per plot/field, Livestocks keeping and different sources of income increases resilience	All villages

In the long run, these indicators needs to be monitored over time, so as one can conclude how these indices shows resilience of dry land irrigation farming against climate change impacts. During the process of monitoring and follow-up on farmers, several issues should be taken into consideration such as how farmers should effectively and timely respond and adapt? When should they adapt and against what effects as well as what resources should they use to cope with the effects of exposure to internal and external stimuli or hazards? Apart from the above mentioned indicators, other scholars have identified several resilient indicators such as literacy level, access to credits, farm income, size of the field, farm assets and availability of alternative income generating activities (Turner et al. 2003; Gbetibouo and Ringler, 2009; Malone, 2009).

9.3 Farmers Failure to Adapt and Cope with Climate change Impacts.

In general, people always expect that farmers who recognize climate change will take some actions to cushion themselves against its adverse effects. For example, according to Deressa et al. (2008); several agricultural adaptation measures such as the use of crop varieties, planting trees, soil conservation, changing planting dates, diverging from crops production to livestock keeping, and irrigation were reported to be most adaptation methods used by farmers in African countries. However, in the same study, it is clear that, for various reasons, not all farmers have responded and adapted to effects of exposure to the impact of climate change. Some of the irrigation farmers had no idea about climate change impacts and hence did not know what to respond to and adapt to the adverse effects of climate change? For those who responded to the adverse effects of climate change, some of their adaptation strategies have been slip-up trials while some of coping strategies undertaken by irrigation farmers in the study area have negative consequence on environments in the long run (future) such as increase rate of deforestation and biodiversity loss.

Perhaps one of the most neglected aspects of climate change impacts are barriers and challenges associated with adaptation and adaptive capacity (resilience). Though some of these barriers are deep rooted within the community and individuals (in terms of ecological, socio-economical, cultural and political); they are consistently tied to measure of experience, inadequate farm resources, skills and technology as well as access to information and poor institutional set up in supporting poor farmers. At village level; these barrier play a bigger role when farmers are making decision to effectively respond and adapt to the effects of exposure to climate change impacts.

In most cases farmers have failed to make proper decisions regarding measures to ameliorate their farming practices, nurture vegetable production and maximize crop yield throughout. A good example of failure in decision making during dry season farming can start with poor land preparation (shifting cultivation or slash and burn agriculture) which means loss of soil nutrients and failure of conserving water due reduction in humus and dry matter (crop cover) leading to low crop quality produced. Poor seed selection can result in low yield and poor crop quality as well while poor crop tending and inability to add manure can also affects crop yield. Unsustainable use of water such as flash irrigation may result in water shortage and thereby compromising the harvesting season. All these poor decisions can make farmers to fail to respond and adapt to any exposure to external or internal stimuli affecting their crops such as increase in temperature, water shortage or crop and pest attacks.

In the study area, similar barriers were observed during field visits and strongly surfaced during discussion with FGD's. Analysis in section 9.2.1 and 9.2.2 shows that in a very rare cases, few farmers seemed to have failed to understand particularly what are they adapting to and how should they effectively adapt so as to achieve maximum crop yield per season with little inputs and cost involved in vegetable productions. This has been contributed by lack of awareness or knowledge (1.7%) on climate change impacts and vulnerability (3.9%) of dry land irrigation farming in terms of how much farming is exposed and (or) become sensitive to climate change impacts as well as how they (irrigation farmers) have responded and how irrigation farming schemes is coping with the effects of exposure to climate change impacts. Similar findings were reported by Chikodzi et al. (2012) where the author argued that a major problem for any adaptation initiative, particularly at the local level is insufficient information about what to adapt to and how to adapt?

Lack of knowledge on what to adapt to and how to adapt are the common factors that made farmers to fail from time to time when trying to adapt and cope with the impact of exposure to climate change in the study area. Thus their irrigation farming schemes have failed to adapt to the new changes not only due to lack of knowledge on climate change but also due to limited livelihood options, few basic farm inputs and resources and inadequate access to information, skills and technology which automatically affects their farming practices and thus take time to cope with the effects of increase in temperature, excessive evaporation, water shortage and crop failure/low yield. During field visits, few farmers were seen straggling with farming where they had small fields (<10m^2 plot). Analysis from the fields shows that poor soil fertility coupled with shortage of water and lack of market for fresh produce may have also influenced farmers to fail to adapt and cope with the impacts of climate change. Gbetibouo and Ringler, 2009 underline that among other things, the main factors that promote adaptive capacity are farmers' income, the size of the household, farmers' experience, and engaging in off-farm activities. Thus low income, large household size, little experience in irrigation farming and limited options in off-farm activities makes farmer vulnerable and contribute to farmer's failure in adapting and coping with the effects of exposure to climate change impacts.

9.4 Policy Implication and Intervention

The study shows that irrigation farmers in the study area have been testing and adopting different adaptation strategies (use of crop varieties, soil and water conservation, improved farming methods) to encounter the effects of climate change impacts over many years; however their adaptation strategies have been implemented in small scale and mostly tested as trials due to lack of experience, knowledge, skills and resources which affects their outputs and sustainability. At the same time, although farmers have been using different coping strategies (selling livestock's, engaging in alternative enterprises, diversifying livelihoods and intensifying farming); several factors have been mentioned to hinder the choice of relevant and best coping strategies due to farmers' perception, lack of resources, experience and skills. Furthermore, the sustainability of alternative or diversified activities (charcoal production, deforestation and migration) taken by farmers as part of coping strategies have been questioned due to their uncertainty and haziness future as they create other problems or accelerate the impacts of climate change.

Thus, the impact of exposure to the effects of climate change and inability of farmers to respond, adapt and cope with these effects can last throughout farmers' life time if they are not exposed to any intervention like providing improved farming skills, education awareness or empowerment for entrepreneurship that could give them necessary skills for improving their irrigation farming as well as their alternative livelihood activities. It's in this context that potential long-term policy and strategic actions regarding existing adaptation options and future coping strategies taken by farmers are critically needed to support irrigation farmers to reduce their vulnerability and enhance their adaptive capacity (resilience) to the adverse effects of climate change impacts and climate variability in the study area. Furthermore, Komba and Muchapondwa, 2015; emphasise the need to understand the adaptation options taken by irrigation farmers which would help to craft appropriate policy responses. This is because vulnerability and sensitivity of irrigation farming schemes vary across farming due to many factors such as farm resources and experience, crop produced, different adaptation methods used as well as duration of farming.

In light of this, the government needs to assist dry land irrigation farmers in the study area to overcome the adverse effects of climate change impacts by encouraging and supporting irrigation farmers to adapt to climate change and to promote particular adaptation methods and coping strategies. Several studies suggest that intervention in irrigation development has verified to boosts crop production 3-4 times than that of rainfed agriculture (URT, 2005; URT, 2006; URT, 2009). However if intervention and implementation of policy related to adaptation and coping strategies for safeguarding irrigation farming schemes has to occur and succeed indefinitely; then using local farmers' knowledge and experiences particularly those involved deeply in irrigation farming is of paramount importance.

During discussion with farmers on the need for policy intervention and implementation regarding adaptation strategies in the study area; farmers explained what should be done to help them to better adapt to the impacts of ongoing climate change and improve irrigation farming. Majority of the farmers (47.7%) mentioned they need support on training improved farm skills and innovation in irrigation farming while other farmers (36.7%) mentioned that they needs to support on water harvesting technology particularly construction of large pond/reservoirs for storing storm water from surface runoffs. The remaining farmers (17.6%) mentioned they need provision of farm resources such as improved seeds and irrigation equipments such as irrigation pumps.

It is interesting to find that majority of respondents in the study area identified training skills on improved farming and innovation on irrigation farming as an important aspects that can support them to enhance their adaptive capacity and long-term resilience to the adverse effects of climate change and thereby sustaining irrigation farming. This is good sign that farmers are interested more in knowledge, skills, agricultural technological innovation and awareness which are part of long-term solution and strategies in addressing the adverse effects of exposure to climate change impacts rather than focusing on aid support from government such as food and cash money. At village level, training skills and innovation in irrigation farming surfaced more in Chimbile A, Mkwaya and Mnazi moja villages (figure 9.4 below). This is due to the fact that these villages have been invested heavily in irrigation and they would like to extend irrigation farming for to commercial production. The support for water harvesting technology was mentioned more by farmers in Mpapura, Chiheko and Mbuo villages while provision of farm resources and farm subsidies seemed to surface in each village studied. The need to develop and strengthen water management innovations (water harvesting technology) mentioned by irrigation farmers in the study area is to address the risk of moisture deficiencies and increasing frequency of dry spells.

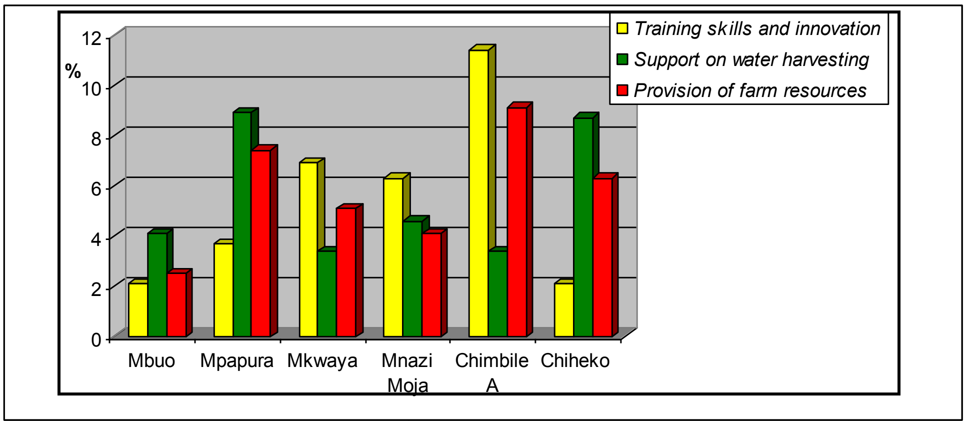

Figure 9.4: Farmers' opinions on adaptation interventions. Source: Mhagama, 2014

Farmers in the study area did not mention the need for research and develop on irrigation farming as well as development and strengthening early warning systems for timely weather forecasts, predictions and their dissemination of results to the farmers. Though these are most important aspects of policy interventions regarding adaptation strategies; several reason such as lack of awareness, low literacy rate, nature and scale of farming, ground practicability and application of such research and systems development in the study area might have attributed towards this perception. Further more integrated water resources surface in any discussion in the study area due to the fact that there are few competing end users in water resources. The main water users in the study area are domestic consumption, agricultural production (rainfed) and irrigation farming (dry season).

On medium and short-term basis farmers mentioned several coping strategies they need to cope with ongoing adverse effects of climate change such as authority to provide alternative jobs (36.1%); creating market for crop produces (34.3%);

provision of food aid (21.1%) during low or bad harvest season as well as free access to natural resources (8.5%) such as forest products and sea/ocean (fishing and coastal gathering). At village level, the need for creating market for crops produced as one of the intervention to cope with the effects of climate change strongly echoed at Mbuo, Mpapura and Chimbile A villages while provision of alternative jobs during low harvest as adaptive capacity strongly surfaced at Mkwaya, Mnazi moja and Chiheko villages (figure 9.5 below). Provision of food aid during low or bad harvest was universally addressed among six villages studied while free access to natural resources appeared more in Chimbile A, Mnazi moja and Mkwaya villages.

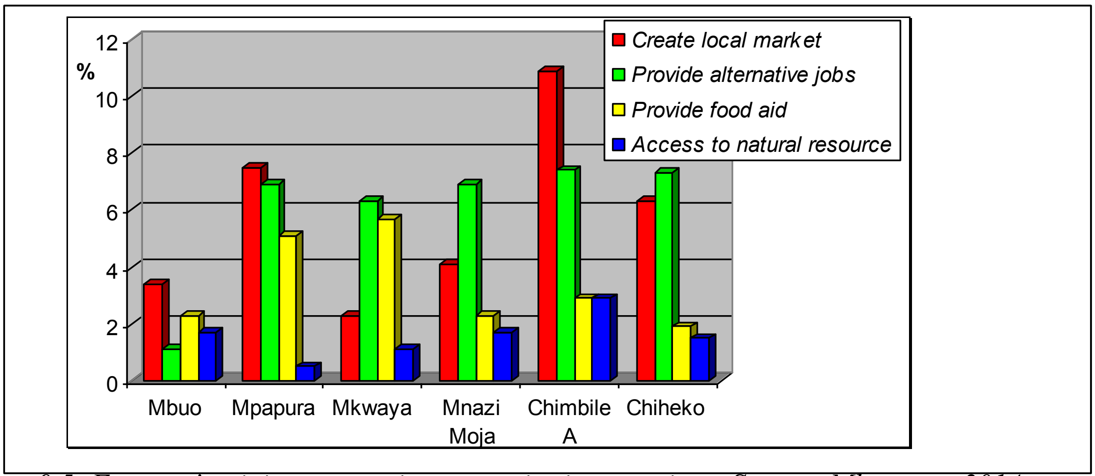

Figure 9.5: Farmers' opinions on coping strategies interventions. Source: Mhagama, 2014.

The focus of policy intervention and implementation in safeguarding dry land irrigation farming schemes should focus on both coping strategies (short-term and medium term efforts) and adaptation strategies (long-term endeavours) so as to maximizing yield and sustain irrigation farming. Though government interventions (future plans and programmes) are critically important, during field visits, observation showed that the presence of social capital within irrigation farmers is also an important adaptation strategy due to availability and easy support a farmers can receive from relatives or friends during farming practices without delay or bureaucracy. As farmers can easily receive technical support about adaptation to encounter effects of climate change from both the government and community groups; care should be taken to avoid duplication and overlapping of efforts.

Government intervention is of great importance particularly in irrigation farming, especially now that Tanzania is implementing the *"Kilimo Kwanza Policy"* and has invested heavily in irrigation farming through National Irrigation Master Plan (2002); District Irrigation and Water Harvesting Project, 2005 and National Irrigation Policy (2009); which both documents seeks to promote sustainable growth in the agricultural sector particularly promotion and investment in irrigation farming schemes. Articulation of national irrigation action plans described in these documents at village level is of great importance to enhance implementation and ensure sustainability. This can also help farmers to easily incorporate their adaptation strategies into national adaptation plans and strategies. Other policy interventions regarding adaptation of irrigation farming to climate change impacts have been indicated in various national reports includes National Strategy for Growth and Reduction of Poverty (NSGRP-Cluster III, 2005); Agricultural Sector Development Programme (ASDP, 2006); National Adaptation Programme of Action (NAPA, 2007) and Tanzania National Irrigation Policy (2009) and Southern Agricultural Growth Corridor of Tanzania (SAGCOT, 2010). These documents need to be articulated in district irrigation development programmes so the adaptation interventions can be implemented effectively and successful.

Each policy document has focused on ensuring irrigation in the country is fully developed and area under irrigation potential is fully utilized to supplement agricultural production and ensure food security and household income of many poor farmers. For example in National Irrigation Master Plan (2002); the document focuses on irrigation and water development where the proposed possible interventions includes rehabilitation of existing irrigation schemes, development of new irrigation schemes' and acquisition of individual low lift pumps (treadle pumps or motorized pumps). Similar work can be done in the study area to develop irrigation infrastructures (irrigation canals and water reservoirs) and providing manual pumps to groups of farmers so as to encounter the effects of water shortage and increasing temperature.

In NSGRP – Cluster I – Promoting Sustainable Broad – Base Growth (2005); one of the identified strategic action is to increasing the number of irrigation schemes (such as dry land irrigation farming schemes) and area under irrigation as well as promoting rainwater harvesting. In the study area, various rainwater harvesting technology can be introduced to help farmer to harvest rain water (surface runoffs) and improve water availability for dry season farming. Other programmes (ASDP, 2006) focuses on investing and financing small-scale irrigation schemes (sub-component I and II) where small scale projects such as dry land irrigation farming will be funded. Farmers in the study area can be supported through these schemes; however investments to be made should be in accordance with local needs which can be determined through local participatory planning and budget processes with a focus in inclusive planning where both food insecure and vulnerable groups have participated. Thus intervention earmarked to boost irrigation farming infrastructure at district level such as constructing and maintaining water ponds/reservoirs and irrigation canals will benefits dry land irrigation farmers and their farming schemes in the study area hence reduce vulnerability from shortage of water due to extreme evaporation and loss from surface runoffs as well as poor infrastructure (poorly constructed earth canals). Furthermore, utilization of alternative water sources such as river and underground water from deep water aquifers will enhance adaptation measures by reducing farmers' overdependence on surface water which is extremely variable due to temperature and rainfall variability.

In NAPA (2007); the primary objective is to identify and promote activities that address urgent and immediate needs for adapting to the adverse impacts of climate change. In 14 priority projects identified by NAPA, agriculture sector was ranked the top priority for adaptation measures, with increasing irrigation farming to raise maize production across all regions the most urgent goal (NAPA, 2007). The efficiency use of water in irrigation crop production so as to boost production and increase food security was also among priority goals. The existing adaptation activities earmarked by NAPA includes small scale irrigation, research and development on drought tolerant seed varieties, growing different types of crops on different land units and water harvesting technology to reduce vulnerability and encounter the effects of climate change impacts. Most of the adaptation measures mentioned in NAPA have been also strongly mentioned by irrigation farmers in the study area, which clear the way forward for implementation. All these adaptation activities if implemented in the study area will reduce vulnerability of dry land irrigation farming against exposure to climate change impacts and thereby increase farmers resilient while maximizing crop production through irrigation farming. The document also suggest potential future adaptation activities such as increase irrigation farming to boost maize production in selected areas, drip irrigation for specific regions, better use of climate and weather data and promote new water serving technologies in irrigation.

Additionally, the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) provide similar adaptation measures to reduce vulnerability to climate change impacts and boost irrigation farming in Southern Tanzania. The document provide a detailed investment blueprint for SAGCOT initiative which contribute to *Kilimo Kwanza's vision* of a major expansion of commercial agriculture in the corridor, including irrigated and rain-fed farming with associated processing and storage facilities. The SAGCOT initiatives also describe the benefits of commercial agriculture where smallholder farmers will have the opportunity to become emergent or commercial farmers with affordable access to irrigation and other agricultural support services. In most cases, policy intervention and implementation of these programmes have been successful particularly in large scale irrigation projects and well established and experienced irrigation farmers. However, several factors such as inadequate resources, remoteness and location of farming villages, poor infrastructures, shortage of water and arable land as well as farmers willingness and experience in farming might in turn limit effective policy intervention and implementation for sustainable irrigation farming.

Respective district council in the study area via district agricultural and irrigation officer are responsible for providing advice and support to the irrigation farmers on improved farming activities so as to adapt and cope with existing and ongoing climate change impacts. They should also equip irrigation farmers with knowledge and skills on how to solve other irrigation farming problems such as poor soil fertility, soil and water conservation techniques and controlling crop pest and adding value to the crops produced. This will contribute to increased crop or vegetable production which is currently highly demanded in market due to various socio-economic growths in the two regions. There seems to be a high potential for socio-economic development in the study area tied to on-going natural gas development activities (LNG Plant in Lindi) and the long awaited Mtwara Development Corridor (MtDC) Project. Following this and other opportunities related to coastal tourism development, industrial development and urban settlement; food production particularly vegetables and fruits production will be highly demanded in the study area (Mtwara and Lindi town). This calls for an immediate policy intervention to help poor irrigation farmers producing at a very small scale to enhance production and cater for the existing and future vegetable and fruit demand as many people are arriving in Mtwara and Lindi in search for job and land.

Institutional support particularly research and provision of subsidies to help irrigation farmers to adapt and cope with the effects of climate change impacts is desirable so as to maximise crop production and sustain dry land irrigation farming throughout. For example, district council in coordination with other key stakeholders such as large projects in the study area (Liquidified Natural Gas - LNG project in Lindi, Mtwara Corridor Development projects) as well as other local and multinational investors (Mtwara and Dangote cements) should mobilise some investment and resources to support dry land irrigation farming schemes in the region. This will not only benefits farmers but it will also reduce the cost incurred by other logistics company supplying food services to these multinational companies by relying on local produce and supply. Additionally, supporting local farmers means enhancing food baskets and this makes the study area become self-sufficient since most of the fresh produce found in various main market in Mtwara and Lindi, collectively comes from local farmers in the study area. The consistent request from irrigation farmers through questionnaire responses as well as through interviewees and FGD's from participants for help in getting access to information and training skills pertaining to irrigation, access to farming inputs, subsidies and local markets for fresh produces are both evidence of utmost needy for policy interventions for decreasing vulnerability and enhance resilience in irrigation farming in the study area.

Several studies have suggested similar policy interventions to help smallholder farmers to reduce their vulnerability to climate change impacts and enhance their capacity to sustain agricultural farming. For example, similar findings to the study above were put forward by Deressa et al. (2008) and Gbetibouo and Ringler (2009) where they argued that in order to support farmers in terms of adaptation, it is important for the government and other stakeholders to provide adequate agricultural extension information services to local farmers as well as access to market and stimulating both agricultural intensification and diversification of livelihoods especially within the large subsistence farming sector. In a nutshell, access to market, extension services and information pertaining to irrigation farming practices are very important as they bring awareness to the farmers and empower them to make informed decisions such as what crop is profitable and at what time to plant (depending on local condition and agro-ecological zone) as well as how to tend the crops so as to maximize crop yield.

On the other hand, Mkavidanda and Kaswamila (2001) suggested the need of establishing farmer groups for easy access to credit for buying farm inputs and advisory services while Chikodz et al. (2010) emphasized the need for water harvesting to ensure water storage for crop production during dry season and other human activities. Other studies such as URT (2005); IFAD (2007) and Msaky et al. (2010) recommended that farmers' education and awareness on agricultural production and climate change related information should be given priority by responsible key stakeholders. For effective policy interventions, local participatory approach and market-based outcome should be emphasized. In general, the study findings from various literatures share some similarities with those mentioned in this study due to the fact their findings and suggestions have been identified by irrigation farmers in the study area as necessary interventions which can reduce farmer's vulnerability to climate change impacts and enhance their adaptive capacity and long-term resilience.

9.5 Summary

The detailed adaptive capacity (resilience) of the farmers in the study area was described in this chapter. By using farmer's knowledge, the resilience of dry land irrigation farming schemes to climate change impacts in the study area were explained in details. In this chapter, farmers described how irrigation farming is adapting and coping (becoming resilient) to climate change impacts. In this study, majority of the farmers expressed resilience as having support (particularly access to information and resources) they get from relatives and government that helps them to carry on irrigation farming even in the face of climate change impacts (water shortage and extreme temperature). Other farmers described resilience as the level of preparedness and ability to react and take action to prevent further damage from climate variability (reducing crop damage and wilting) while the remaining farmers understood resilience as becoming accustomed to the changes brought about by climate change impacts. Similar findings were also noted in other scholarly work where the term resilience have been described as ability to react (respond) as well as becoming accustomed (adapt) to the ongoing climate changes while support and entitlement from key stakeholders have been termed as part of adaptive capacity.

The details of resilience in the study area were described in terms of different adaptation and coping strategies as well as different livelihoods diversification. The findings shows that farmers in the study area have been testing and adopting different adaptation strategies that have helped their irrigation farming practices to respond to climate change impacts over many years. Different adaptation strategies used by farmers in the study area includes using different crop varieties (drought resistance crop-okra and shorter cycle crops-amaranthus); use of improved farming methods (mulching, tilling); use of various soil and water conservation techniques (crop cover) as well as increase rate of irrigation and using available soil moisture by planting crops at the bottom valley.

Differences were noted in each village regarding the adaptation strategies adopted by farmers. For example, few farmers in Mpapura and Mkwaya villages were seen trying different crop varieties other than green vegetables (such green pepper, egg plants, passion, cucumber, watermelon) which were not common around the study area while the use of manual pump, water pipes, and other irrigation equipments were seen on various fields visited (in Mbuo, Mkwaya and Mnazi Moja villages) indicating farmers efforts to adapt to the effects of increasing temperature, excessive evaporation and water shortage by increasing water inputs. These different adaptation strategies used by farmers are essential for irrigation farming as they have the greatest payoff in terms of increased crop productivity and yield which in turn reduce vulnerability and thereby enhancing resilience of dry land irrigation farming schemes as well as improving the capacity of irrigation farmers, especially those who depend on surface water for irrigating crops.

Information from the interviewees and participants from FGD's yielded similar findings though they described that the adaptation strategies that were made on the farm were merely for increasing crop productivity, crop yield and securing good market so as to earn sizeable income rather than counteract the effects of climate change impacts. In this chapter, different coping strategies (attributes to resilience) were used by farmers in the study area. These includes engage in selling livestock's-chickens, use effective soil and water conservation techniques-mulching, engage in alternative enterprises-craft works and intensifying farming such as intercropping and cultivation on both sides of the river bank. At village level, Chimbile A and Chiheko village were seemed to cope better with the impact of increasing temperature and water shortage by utilizing effectively soil and water conservation techniques while Mpapura, Mkwaya and Mnazi Moja villages were seemed to cope better with the same effects by engaging in alternative enterprises such as disposing craft works, hawking and small scale business as well as selling labour.

Several factors that influenced the choice of adaptation and coping strategies were also described by farmers in this chapter. These include farming skills and experience, different resource owned, farmer's perception, land and water availability. Other empirical evidence that exists related to what determines farmers' individual adaptation decisions includes households income, size and age of households, occupation of household head, access to credit, access to extension services and training, high incidences of crop pest and disease and perceptions of farming households towards climate change impacts. In this chapter, other different coping strategies in the study area used by irrigation farmers to adapt and cope with the impacts of climate change includes livelihood diversification from irrigation farming to off-farm activities such as charcoal and firewood production, casual labour, fishing activities and coastal gathering and migration to the nearest town in search for jobs particularly cheap labour. Those migrated to urban area, used remittances to help relatives back at home to buy food and cope with low yield.

The chapter also indicated how some of the farmers failed to adapt and cope to climate change impacts due to lack of experience in irrigation farming activities, inadequate farm resources and access to information. Furthermore, field observation showed that few farmers who have failed to adapt and cope to climate change impacts seemed not to understood particularly what are they are supposed to adapt to and how should they effectively adapt so as to achieve maximum crop yield per season. Analysis from field observation, showed several indicators such as availability and continuous use of manual pump, variety of seeds, soil and water conservation practices, livelihood diversification and reduced farm size as well as intensification of irrigation farming.

Despite several efforts made by farmers in responding, adapting and coping with climate change impacts; the complexity and diversity of poor livelihood strategies in the study area have increasingly made farmers remained impoverished due to lack sustainability and thereby limiting farmer’s adaptive capacity. Thus, potential long-term policy interventions and strategic actions regarding existing adaptation options and short term coping strategies are critically needed to support irrigation farmers to reduce their vulnerability and enhance their adaptive capacity (resilience) to the adverse effects of climate change impacts and climate variability in the study area.

Farmers in the study area mentioned several short-term and long term interventions to help them to adapt and cop with the adverse effects of climate change impacts so as to reduce vulnerability and enhance resilient of dry land irrigation farming schemes. On the longer term basis, adaptation interventions needed includes support on training improved farm skills and innovation in irrigation farming; water harvesting technology particularly construction of large pond/reservoirs for storing storm water from surface runoffs as well as provision of farm resources such as improved seeds and irrigation equipments such as irrigation pumps. On medium and short-term basis, coping interventions needed by farmers includes provision of alternative jobs; creating market for crop produces; provision of food aid during low or bad harvest season as well as free access to natural resources such as forest products and sea/ocean (fishing and coastal gathering).

The availability of various government policy document such as National Irrigation Master Plan (2002); District Irrigation and Water Harvesting Project (2005) and National Irrigation Policy (2009) all seeking to promote sustainable growth in the agricultural sector particularly promotion and investment in irrigation farming schemes. This indicates the importance of various stakeholders’ willingness to support irrigation farming and boost agricultural production. Other available policy documents in the country include National Strategy for Growth and Reduction of Poverty (NSGRP-Cluster III, 2005); Agricultural Sector Development Programme

(ASDP, 2006); National Adaptation Programme of Action (NAPA, 2007); Tanzania National Irrigation Policy (2009) and Southern Agricultural Growth Corridor of Tanzania (SAGCOT, 2010). These documents can provide interventions to enhance irrigation farmer's adaptation to climate change impacts and enhance resilience once implemented effectively and successful. Similar findings related to the policy interventions as indicated by irrigation farmers in the study area and various national reports were put forward by several other studies indicating the importance of policy interventions to reduce vulnerability and enhance resilient of dry land irrigation farming against adverse effects of climate change impacts.

CHAPTER 10: CONCLUSION AND RECOMMENDATION

10.0 Introduction

This chapter presents conclusion and recommendation for the study. It presents the salient findings of the study regarding vulnerability and resilience of dry land irrigation farmin schemes against climate change impacts in Southern Eastern Tanzania. The purpose of this study was to assess factors that expose dry land irrigation farming to climate change impacts and its sensitivity that makes irrigation farming vulnerable while exploring the adaptive capacity of farmers that makes them resilient to climate change impacts. The effects of exposure to climate change impacts and inability of dry land irrigation farming schemes to cope with ongoing changes has been the motives for undertaking this research study. Furthermore, the study assessed other factors such as poor methods of farming, lack of farm inputs and access to information and overdependence on surface water that makes farming sensitive and increase its vulnerability to climate change impacts.

The study also uncovered that while irrigation farmers are striving to pursue alternative livelihood activities, their vulnerability is increased as some of the diversified economic activities are unsustainable. Failure of responsible institutions to make follow-ups and address the inherent weakness of farmers main livelihoods in the study area have, in turn, made irrigation farmers to resort to activities with low potential to improve their living standards and thereby continue to be in poor state of poverty. The aim of assessing the above described factors was the quest to address the challenges facing dry land irrigation farmers (vulnerability) in the study area and their ability to respond to the ongoing impacts of climate change. Therefore, this will help policy and decision makers in the study area to makes informed decisions regarding vulnerability of dry land irrigation farming schemes against climate change impacts. Through various planning and development programmes; both policy and decision makers can take strategic actions to intervene and support farmers efforts to combat adverse effects of climate change impacts in the study area. This will help irrigation farmers adapt to the effects of ongoing climate variability and enhance crop productivity, food security and income as well as socio-economic growth at local level and countrywide.

10.1 Summary of the Key Findings

The results show that the state of local climate in the study area is changing and these changes have been occurring over the past 25 – 30 years. The temperature and rainfall data (key climatic variables) from Tanzania Meteorological Agency (2015) and Climate Portal shows that temperature had been increasing particularly intensity of sunlight while rainfall characteristics have changed, in terms of amount, distribution since 1930. The number of rain days per year has decreased as well with unpredictable rainfall and increasing frequency of dry spells period. These changes coupled with wind movement have tremendous effects on dry land irrigation farming schemes as they affects soil moisture balance which influence crop productivity. Furthermore, the influence of localised weather effects due to close proximity to the Indian ocean, higher demands for water consumption and poor land use changes in the region, exacerbate the already existing climate change effects.

Responses from farmer's perception and key interviews on changes in the state of local climate conformed to the analysed data from Tanzania Meteorological Agency. As irrigation farmers perceived changes in the state of local climate; key interviews compared these changes over the past 25 – 30 years and how they affects irrigation farming while experts (zonal irrigation officer and water basin officer - RSCB) compared the level of water availability in Ruvuma River during the dry season in the past 10 years and described that it keeps on decreasing every year. These changes reduce water availability and soil moisture balance which in turn affects irrigation farming schemes (crop wilting, pest outbreak) during the dry season. This contributes to low crop productivity and yield, thereby compromising irrigation farming schemes as this makes farming practices vulnerable and reduces adaptive capacity of farmers.

The vulnerability of dry land irrigation farming in the study area is due to *exposure* and *sensitivity* to adverse effects of climate change impacts. *Exposure* of irrigation farming is manifested due to extreme temperature and moisture loss which cause crop wilting and low yields. Irrigation farming practices using surface water from ponds (*ndiva/lambo*) and rivers (*mfereji*) are prone to excessive evaporation and infiltration while dug-out ponds (*vinyungu*) are affected by falling water-tables thereby intensifying the vulnerability effects. The analysis shows that changes in the state of local climate have complex and unprecedented effects on dry land irrigation farming schemes which makes it difficult for the farmers to realise and solve the problem instantly. For example; an increase in rainfalls cause weeds to grow fast which affect land preparation and thereby making farmers incur more labour force and time needed to clear and prepare the land for dry season farming. On the other hand crop wilting does not only contribute to poor crop productivity and low crop yield but also contribute to poor crop quality which affects household income of the farmers as produced vegetables fetch low price at the market hence low income earned to the farmers. One of the major threats making irrigation farming practices most vulnerable farming business in the study area is adverse effects of climate change impacts.

The frequency and severity of crop wilting, pest and weeds infestation were among the major factors making irrigation farming more risk business. Analysis from respondents shows that crop wilting were common in Mbuo, Mpapura, Chiheko village while pest and weed infestation were observed in Mkwaya, Chimbile and Mnazi moja villages. The vulnerability of irrigation farming schemes to the adverse effects of climate change impacts is not uniform across all six villages studied. The diversity and complexity of farmer's perceptions regarding vulnerability are signalled by farming experience, water source availability, resource endowment and access to information. For example farmers in Mbuo, Mpapura and Chiheko villages had less access to agricultural extension services which made them more vulnerable compared to Mkwaya, Mnazi moja and Chimbile A villages. Similar arguments were put forward by interviewees and participants from FGD's who mentioned that lack of access to frequent information and knowledge about climate change impacts and adaptation measures; increasingly makes dry land irrigation farming schemes vulnerable as it exposes their farming schemes to other set of stressors such as high cost of tending the crops (watering) or controlling pests and diseases that attacks crops. This information was rejected by District agricultural officers as they narrated that they have plan of action which follows each village agricultural calendar and that agricultural extention education services are offered free of charge.

Sensitive factors that affects dry land irrigation farming in the study area includes *poor soil conditions, poor farming practices, resources owned and entitlements.* In spite of the different factors making irrigation farming practices vulnerable to climate change impacts; exposure to climatic variability (temperature and rainfalls variability) had emerged to be critical as it affects water availability and contributing to crop wilting which are the core foundation for crop performance, productivity and yield in the study area with respect to irrigation farming. In this study, risk associated with dry land irrigation farming includes crop failure, reduced yield and poor crop quality production. Field observation showed that risk in dry land irrigation farming is more associated with poor decision making that stems from commencement of dry season farming rather than from climate change impacts alone. Among the risk associated with poor decision making include farmer's poor decision in site selection, land preparation, seed selection (variety) and which farming methods to employ during crop tending. In the study area, one of the inevitable aspects of vulnerability observed during field visits is that during rainy season bottom valleys are not suitable for cultivation as they are flooded by heavy rainfalls (not suitable for rice farming) while during dry season the land is exposed to moisture stress from excessive evaporation.

Despite the exposure and sensitivity (vulnerability) of dry land irrigation farming schemes to adverse effects of climate change impacts; farmers described different adaptive capacity (resilience) in the study area such as having support from relatives and government, taking action to prevent further damage from climate variability and becoming accustomed to the ongoing climate changes. Results shows that farmers in the study area have been testing and adopting different adaptation strategies that have helped farmers to respond to climate change impacts over many years. Adaptation strategies includes using different crop varieties (drought resistance crop-okra and shorter cycle crops-amaranthus); use of improved farming methods (mulching); use of various soil and water conservation techniques (crop cover) as well as increase rate of irrigation and using available soil moisture by planting crops at the bottom valley.

Differences were noted in each village regarding the adaptation strategies adopted by farmers. For example, few farmers in Mpapura and Mkwaya villages were seen trying different crop varieties other than green vegetables (such green pepper, egg plants, passion, cucumber, watermelon) which were not common around the study area while the use of manual pump, water pipes, and other irrigation equipments were seen on various fields visited (Mbuo, Mkwaya and Mnazi Moja villages) indicating farmers efforts to adapt to the effects of increasing temperature, excessive evaporation and water shortage by increasing water inputs. These different adaptation strategies used by farmers are essential for irrigation farming as they have the greatest payoff in terms of increased crop productivity and yield which in turn reduce vulnerability and thereby enhance farmer's resilience to climate change impacts. At village level, Chimbile A and Chiheko village were seemed to cope better with the impact of increasing temperature and water shortage by utilizing effectively soil and water conservation techniques while Mpapura and Mnazi Moja villages were seemed to cope better with the same effects by engaging in alternative enterprises such as disposing craft works, hawking and small scale business as well as selling labour.

Several factors had influenced the choice of adaptation and coping strategies such as farming skills and experience, different resource owned, farmers perception, land and water availability. Other different coping strategies such as changes from farm to off-farm activities were mentioned by farmers in the study area. These include charcoal and firewood production, hired labour, fishing activities and coastal gathering and migration to the nearest town in search for jobs particularly casual labour in construction industry. Those migrated to urban area, used remittances to help relatives back at home to buy food, diversify farming and cope with low yield.

Analysis also indicated how some of the farmers have failed to adapt and cope to climate change impacts due to lack of experience in irrigation farming activities, inadequate farm resources and access to information and poor institutional setups which makes farmers fail to moderate harm from climate change impacts or fail to exploits beneficial opportunities such as flood water resulting from climate change impacts. Lack of advisory agricultural services is a serious agenda particularly in dry irrigation farming where water fluxes; temperature variability and pest control are issues of concerns for reducing vulnerability and thereby maximizing crop productivity and yield. Despite several efforts made by farmers in responding, adapting and coping with climate change impacts; the complexity and diversity of poor livelihood strategies in the study area have increasingly made farmers remained impoverished due to lack of sustainability in off-farm activities and thereby limiting farmer's adaptive capacity. Thus, potential long-term policy interventions and strategic actions regarding existing adaptation options and short term coping strategies are critically needed to support irrigation farmers to reduce their vulnerability and enhance their adaptive capacity (resilience) to the adverse effects of climate change impacts and climate variability in the study area.

10.2 Implications of the Findings

Vulnerability and resilience of dry land irrigation farming schemes to the climate change impacts is complex and diverse. This is because of interlinkages between exposure and sensitivity of irrigation farming schemes as well as (in) ability of the farmers to respond, adapt and cop with the adverse effects of climate change impacts; factors which have been incompletely considered to date. An interdisciplinary approach is needed for a better understanding of their susceptibility and adaptive strategies. The vulnerability and resilience assessment was used to examine factors that expose dry land irrigation farming to climate change impacts and its sensitivity that makes irrigation farming vulnerable while exploring the adaptive capacity of farmers that makes them resilient to the ongoing climate change impacts. The study combined various quantitative data (Tanzania Meteorological Agency, National and Regional Reports) and qualitative data (farmers perceptions, experts interviews, field observation) to understand the vulnerability and resilience of dry land irrigation farming to the adverse impacts of climate change. The study contributes to knowledge of irrigation farming practices as it unearthed several factors that makes farming practices vulnerable to adverse effects of climate change impacts. These includes exposure and sensitivity of dry land irrigation farming schemes due to changes in climatic variables affecting water availability and soil moisture balance which in turn affects irrigation farming schemes through crop wilting and pest outbreak as well as reduction in crop yield which compromising the farming practices and thereby making it vulnerable and reduces adaptive capacity of farmers.

The main causative factor, *i.e* changes in the state of local climate, have complex and unprecedented effects on dry land irrigation farming schemes which makes it difficult for the farmers to realise and solve the puzzle instantly as these changes happens slowly and takes time to emerge and reveal. Despite these changes and effects; farmers in the study area have been testing and adopting different adaptation strategies such as using different crop varieties (drought resistance crop-okra); shorter cycle crops-amaranthus); use of improved farming methods (mulching) and use of various soil and water conservation techniques (crop cover) that have helped farmers to respond to climate change impacts over many years. At the same time, several factors have affected farmer's ability to respond, adapt and cope with ongoing changes. Failure of responsible institutions to make follow-ups and address the inherent weakness of farmers main livelihoods in the study area have, in turn, made irrigation farmers to resort to activities with low potential to improve their living standards and thereby continue to be in poor state of poverty. With such indepth analysis of all factors affecting irrigation farming (*vulnerability*) and ability to farmers to respond, adapt and cope with adverse effects (*resilience*); this research study adds to a growing body of scholarly works wherein topics that would otherwise follow single-discipline boundaries are examined through multiple theoretical approaches. The research contributes significantly to the local, national and international ongoing efforts in addressing adaptation strategies particulary in agricultural production.

Based on the above findings, interventions to support irrigation farmers' adaptation and coping strategies to the adverse effects of climate change would help decision-makers to craft appropriate policy responses. These interventions need to consider local farmers' knowledge and experiences particularly those involved deeply in irrigation farming practices. A number of appropriate potential long-term policy interventions and strategic actions regarding existing adaptation options such as training on improved farming skills; development and strengthening of water management innovations (*water harvesting technology*) are critically needed to support irrigation farmers adaptation strategies to reduce their vulnerability and enhance their adaptive capacity (*resilience*) to the adverse effects of climate change impacts and climate variability in the study area. Different short-term coping strategies such as off-farm activities (*e.g craft works*) and diversified livelihoods strategies (*e.g fish farming, agro-forestry*) must be careful identified, recognized and addressed considering their varying attributes to socio-economic development and sustainability. Alternative jobs and enterprises, local market for crop produces and access to natural resources that will cushion farmers bad harvest season (low crop yield) and maximize farmer's ability to cope and improve their livelihood conditions and contribute to sustainable development should be addressed and encouraged through various agricultural extension services.

These interventions should focus on the nature and scale of different irrigation farming schemes since farmers may share similar agro-ecological characteristics but do not share similar farm production considerations due to various factors such as resource owned, type of crops produced and water availability. Introduction of crop varieties such as higher yielding crops (okra, green peppers, and tomatoes) and new crops that command higher market price (watermelon, cucumber, egg plant) would be beneficial to enhance household income of the farmers. Impediments such as lack of access to agricultural information, farm inputs and institutional failures, should be minimised through formulation of policies that aim at broader sectorial interventions that strengthen human and financial capital so as to effectively build adaptive capacity along the irrigation farming villages in South Eastern Tanzania. Other important measures includes various planning and development programmes such as development of local infrastructure (access to roads and local market) that would contribute to socio-economic growth at local level and countrywide.

Various objectives, goals and targets mentioned in different government policy documents such as National Irrigation Master Plan (2002); District Irrigation and Water Harvesting Project (2005); National Strategy for Growth and Reduction of Poverty (2005); Agricultural Sector Development Programme (2006); National Adaptation Programme of Action (2007); Tanzania National Irrigation Policy (2009) and Southern Agricultural Growth Corridor of Tanzania (2011); regarding irrigation farming practices countrywide should be articulated and mainstreamed at village level development programmes and action plans so as to stir-up effective implementation, monitoring and evaluation. Deliberate efforts should be taken by other stakeholders such as Lindi and Mtwara Agricultural Program - LIMA, Aghakan Foundation and other local NGO's playing a key role in assisting households to reduce vulnerabilities and enhance resilience by providing training on improved irrigation farming practices, farm inputs (improved seeds, pesticides and irrigation equipments) and help farmers to realise their aspiration of supplementing food security and household income. National Adaptation Plans (2007) can be used as a guideline in addressing policy interventions and strategies. While NAPA (2007) is designed primarily to identify and promote activities that address urgent and immediate needs for adapting to the adverse impacts of climate change; the recent developed UNFCCC, NAP-Agriculture has the potentials to support various adaptation endeavours particularly in agricultural sectors alone and enhance adaptation efforts and long-term resilience of the irrigation farmers in South Eastern Tanzania and the rest of the country.

10.3 Recommendation

10.3.1 Policy recommendation

Specific the research suggest the need for irrigation policy to address various issues affecting dry land irrigation such as crop pest and disease control; development of plans to assist with mainstreaming dry land irrigation farming practices into various agricultural development programmes at district and local level and updating of district irrigation plans to consider water availability and climate change problem as well as development and management water resources and provision of simple water harvesting technologies. There is potential for further improvement of dry land irrigation farming practices in the study area given the comparative advantages in terms of soil quality, irrigation potential and water availability. Various stakeholders in the study area such as GoT, Agakhan Foundation, LIMA, PASS, ASDP, NARI, SAGCOT and Southern Zonal Irrigation, RSCB as well as respective district council can help irrigation farmers to respond, adapt and cope with ongoing climate change impacts through providing support such as improving basic mechanisation, use of improved seed variety (high yielding seed), training on improved farming skills and water harvesting technology and storage facilities as well as organising contract farming and training on value addition.

Furthermore, irrigation farmers should be supported to access to reliable bulk water supply for irrigating crops with a small dam/storage reservoir and distribution systems so as to fully utilizing land resources and maximize yield per ha per season. Use of organic fertilizer, integrated pest management including and seed money for purchasing seeds and irrigation equipment such as manual pumps, pipes (drips) and watering cans. Additionally, capacity building to groups of irrigation farmers and entrepreneur/middlemen involved in vegetable and fruits market in the study area is of paramount importance. The capacity building can be in form of farm management skills (improved irrigation farming practices); training on yield increase and post harvest technology for green vegetables and other crops grown in irrigated areas.

Other trainings include agro-processing and packaging training for produced vegetables in the study area as well as operation and maintenance of irrigation equipments and storage facilities. Farmers in the study area should also be assisted with creating local market (satelites outlets) within the villages and link those market with main market or buyers in Lindi and Mtwara town as well as linking them with commercial bank or financial institutions for accessing loan. Others recommendation includes improvement of access to information pertaining improved farming skills, improved seeds, intergrated pest management and affordable irrigation equipment such as small-scale irrigation pumps and simple greenhouse equipment through access to microfinance schemes.

10.3.2 Recommendation on Future Research

The study has made an attempt to address vulnerability and resilience of dry land irrigation farming schemes to the adverse effects of climate change impacts in South Eastern Tanzania. While this study contributes to both knowledge and policy, it was limited in terms of climate variables covered (only temperature and rainfall); thus it was not exhaustive and has limitations. In order to fill unidentified gaps; it is worth mentioning here that the limitations of this study can be considered when designing future research work that may supplement the current work. The study provides few recommendations below that can help to provide more information and pave the way for improving farmer's adaptation and coping strategies.

Firstly the study recommends further research on long-term changes in the state of local climate specifically how these changes manifest themselve on dry land irrigation farming practices. This is contributed to the fact that lack of empirical studies on vulnerability and resilience to climate change impacts in the study area made this study not to explore enough empirical evidence on the exposure of farming schemes and adaptive capacity of farmers. Ideally, the availability of information (data from Tanzania Meteorological Agency) on long-term adverse effects of climate change impacts would have helped to strengthen early warning systems and provide weather forecasts and predictions to farmers who are the most decision makers on irrigation farming practices regarding what to plant, when to plant and how to tend the crop, thereby increase crop productivity and improve crop yield.

Secondly, as this study did not model any changes in climate variables against farming practices and crop productivity to clearly identify the extent to which changes in the state of local climate economically affect crop yield and household incomes; its recommend that research should focus developing models to show how this interrelationship occurs and affects dry land irrigation farming schemes. In similar aspects; the contribution of household income from several off-farms activities (such as charcoal making, animal keeping, selling labour, remittance) were not economically identified and estimated which argues the need for further research to fill the gaps. Furthermore, it would be indispensable to identify vulnerable farmers amongst irrigation farming communities and ascertain which type of interventions would be instrumental in assisting their adjustment when opting for an alternative income generating activities. This is because exposure and sensitivity to climate change vary across irrigation farming comunities and the type of crops produced.

Thirdly, due to availability of abundance non-forest products such as wild fruits, roots, building materials and papyrus from wetlands; the study also recommend sustainable harvest of natural resources. The study recommend that farmers should be encouraged to sustainably harvest wild fruits (*mabungo, vitolongo*) and wild roots (*mingoko*) as well as utilizing simple technology to harvest, process and dry fresh mangoes so as to increase food options and security during harsh conditions.

Finally, though concern on poor vegetable market and lack of agricultural inputs as well as training from extention officers expressed by respondents were nullified by district agricultural officers; this should not be ignored and left unattended. Transformation of irrigation farming through research on market chain and value addition for fresh vegetable production should also be among district councils' agenda so as to produce a clear view on how farmers can enhance crop productivity and increase income earned from irrigation farming. Due to diversity and complex nature of adaptation and coping strategies, this implies that there is no single approach for assessing, planning, and implementing adaptation measures. Future adaptation assessments must therefore flexibly apply different methodological approaches to produce knowledge that is relevant in a particular decision context.

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Date : ..../....../2014 Time :......hrs

Questionnaire No :……………….

APPENDEX 1: Research Questionnaire for Local farmers/household.

PhD Report: Vulnerability and Resilience of Dry Land Irrigation Farming Schemes Against Climate Change: A Case of Ruvuma Basin, South Eastern Tanzania

Section 1: General Information of Respondent.

1. Name of the District: ………………………Village: ………………………..

2. Farming Season:…………………… Size of the Farm: ………………………….

3. Name: ………………………..Relationship with the Head………………………...

4. Age?
   i. 18 – 25 ☐
   ii. 26 – 35 ☐
   iii. 36 – 45 ☐
   iv. 46 – 55 ☐
   v. 56 and above ☐

5. Sex?
   i. Male ☐
   ii. Female ☐

6. Marital Status?
   i. Single ☐
   ii. Married ☐
   iii. Divorced ☐
   iv. Widowed ☐

7. Education level?
   i. No Education ☐
   ii. Adult Education ☐
   iii. Primary Education ☐
   iv. Secondary Education ☐

8. Occupation?
   i. Subsistent farmer ☐
   ii. Livestock keeping ☐
   iii. Livestock and farming ☐
   iv. Green vegetable vendors ☐

9. How many sources of income do you have?
   i. None ☐
   ii. 1 - 2 sources ☐
   iii. 3 - 5 sources ☐
   iv. More than 5 ☐

Section 2: Different Type of Dry Land Irrigation Farming Schemes

10. What type of farming systems do you practice?
    i. Rainfed farming systems ☐
    ii. Dry farming systems (Irrigation) ☐
    iii. Alternet farming systems (rainfed and irrigation) ☐
    iv. Others (specify please) ……………… ☐

11. What type of crops grown in your farm or plots?
    i. Green vegetables (amaranthus, cabbage, speenach) ☐
    ii. Tomatoes, egg plants, bellpapper ☐
    iii. Onions, greenpea, okra ☐
    iv. Others (specify please) ……………… ☐

12. What model of dry land irrigation farming schemes do you practice?
    i. Ndiva – bwawa/lambo (large artificial pond) ☐
    ii. Vinyungu – dug out pond ☐
    iii. Mfereji – river channel/canal ☐
    iv. Others (specify) ………………………………… ☐

13. What type of land tenure systems do you practised in your village?
    i. Inherited from family ☐
    ii. From village government ☐
    iii. Buying ☐
    iv. Renting ☐

14. What is the size of your farm land (plot)?
    i. Less than one ha ☐
    ii. 1 – 2 ha ☐
    iii. More than 2 ha ☐
    iv. Others (specify) ……………………………….. ☐

15. For how long have you been practising dry land irrigation farming schemes in the Mtaa/Village?
    i. Less than one year ☐
    ii. 1 - 10 years ☐
    iii. 10 - 20 years ☐
    iv. More than 20 years ☐

16. What is your major source of livelihoods in this village?
    i. Peasant (farming) ☐
    ii. Livestock keeping ☐
    iii. Livestock and farming ☐
    iv. Green vegetable and crop vending. ☐

Section 3: Communities' Knowledge on Vulnerability of Dry Land Irrigation Farming Scheme Against Climate Change

17. Do you know if there are any changes in your farm plot because of climate change?
    i. Yes ☐
    ii. No ☐

18. If yes, describe how climate change is affecting dry land irrigation farming schemes practised in your village?
    1…………………………………………………………………………………
    2…………………………………………………………………………………
    3…………………………………………………………………………………

19. Do you know if your irrigation farming schemes is susceptible to vulnerable condition?
    i. Yes ☐
    ii. No ☐

Table 1:
20. If yes, describe how dry land irrigation farming schemes practised in your area is vulnerable to climate change?

S/N	Responsible Factors	Attributes				Overall	Comments
		1	2	3	4		
1							
2							
3							
4							

Code: 1= Risk, 2= Sensitive, 3= susceptible, 4=No problem (nil)

Table 2:
21. What major problems affect dry land irrigation farming schemes in your village with regards to climate change?

Problem category	**Severity/ranking**					**Overall**	**Comments**
	1	**2**	**3**	**4**	**5**		
Floods							
Diseases outbreak							
Drought condition							
Soil erosion							
Lack of market							
Lack of funds							

Code: 1=most severe, 2=very severe, 3=least severe, 4=not a problem (nil)

22. What are the typical frequency and duration of occurrence of the problem mentioned above?
    i. Once every five year ☐
    ii. Every year and throughout the farming season ☐
    iii. Once and onset of the farming season ☐
    iv. Once and at the end of farming season. ☐

23. What are the sensitive factors exposing dry land irrigation farming schemes to climate change in your village?

1……………………………………………………………………………………

2……………………………………………………………………………………

24. What are the risks associated with dry land irrigation farming schemes in your village?

1……………………………………………………………………………………

2…………………………………………………………………………………….

Section 4: Communities' Knowledge on Resilience of Dry Land Irrigation Farming Schemes Against Climate Change

25. Do you know the term "Resilience"?

i. Yes ☐

ii. No ☐

Table 3:

26. If yes, describe how dry land irrigation farming schemes practised in your area is responding, coping and adapting to climate change?

S/N	Responsible Factors	Attributes				Overall	Comments
		1	2	3	4		
1							
2							
3							
4							
5							

Code: 1= Responding, 2= Coping, 3= Adapting, 4 (nil)

27. If dry farming systems will be affected (risk) to climate change; then describe how dry land irrigation farming is responding/coping to climate change in your village?

1……………………………………………………………………………………

2……………………………………………………………………………………

28. What strategies do you use to rescue dry land irrigation farming schemes from the effect of climate change in your village?

1……………………………………………………………………………………

2……………………………………………………………………………………

3……………………………………………………………………………………

29. What mechanisms do you use to rescue dry land irrigation farming schemes from the effect of climate change in your village?

1……………………………………………………………………………………

2……………………………………………………………………………………

3……………………………………………………………………………………

30. What determine the choice of coping strategies for your dry land irrigation farming schemes in your village?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………

31. How is dry land irrigation farming schemes in your village is coping to climate change effects?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………

32. What opportunities can be realised as a result of effect of climate change in your village?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………

Section 5: Key Indicators Showing Vulnerability of Dry Land Irrigation Farming Schemes Against Climate Change?

33. What are the key indicators showing vulnerability of dry land irrigation farming schemes against climate change?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………
4……………………………………………………………………………………

34. Do the key indicator mentioned above have a threshold limit or a point where they no longer provide services to human?

i. Yes ☐
ii. No ☐

35. (a) If yes, mention them and explain when and how the threshold limit occur?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………
4……………………………………………………………………………………

36. Apart from climate change problem; What other challenges or problems affecting the dry land irrigation farming schemes in your village?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………
4……………………………………………………………………………………

37. How do you access relevant and timely information that helps you to cope with the problems mentioned in question 22 and 23 above?

i. Using local knowledge ☐
ii. Using information from agricultural extension services ☐
iii. Media and networks ☐
iv. Meteorological stations. ☐

38. In your opinion what should be done to combat the climate change problem and improve dry land irrigation farming schemes in your village?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………
4……………………………………………………………………………………

Thank You Very Much/Aksante Sana!

Date : ..../....../2014   Time :......hrs

Interviewee No :………………………

APPENDIX 2: Guideline for Interviews

PhD Report: Vulnerability and Resilience of Dry Land Irrigation Farming Schemes Against Climate Change: A Case of Ruvuma Basin, South Eastern Tanzania

1. **General information required:** *Long term changes in climate parameters (rainfall, temperature and wind) in the village over past 25 years:*
   1. ………………………………………………………………………………
   2. ………………………………………………………………………………
   3. ………………………………………………………………………………

2. **Specific information asked?** *Explain past and present changes and how these affects dry land irrigation farming schemes in your village?*
   1. ………………………………………………………………………………
   2. ………………………………………………………………………………
   3. ………………………………………………………………………………

2 (a). Describe changes in rainfall, temperature and wind pattern in your village in the past 25 years?
   1. ………………………………………………………………………………
   2. ………………………………………………………………………………
   3. ………………………………………………………………………………

2(b). Why do you think there are changes in your village and what causes these changes?
   1. ………………………………………………………………………………
   2. ………………………………………………………………………………
   3. ………………………………………………………………………………

2(c). Will these changes affect dry land irrigation farming schemes in your village?
   1. ………………………………………………………………………………
   2. ………………………………………………………………………………
   3. ………………………………………………………………………………

2(d). Mention key indicator showing how these changes expose dry land irrigation farming schemes to the impact of climate change in your village?
   1. ………………………………………………………………………………
   2. ………………………………………………………………………………
   3. ………………………………………………………………………………

2(e). In your opinions; what efforts are you taking to improve dry land irrigation farming schemes practices and improve livelihoods in your village?
   1. ………………………………………………………………………………
   2. ………………………………………………………………………………
   3. ………………………………………………………………………………

Thank You Very Much/Aksante Sana!

Date : ..../....../2014   Time :......hrs

Group No :………………………

APPENDIX 2: Guideline for Group Discussion

PhD Report: Vulnerability and Resilience of Dry Land Irrigation Farming Schemes Against Climate Change: A Case of Ruvuma Basin, South Eastern Tanzania

i. Name of the Village.
ii. Name of the moderator.
iii. Place of Discussion.
iv. Composition of the discussion panel (in gender perspective)
v. Existing vulnerable group in the village.
vi. Types of dry land irrigation farming schemes
vii. Climate change problems
viii. Climate change coping strategies
ix. Choice of coping strategies
x. Local livelihoods problems.

1. Mention types of dry land irrigation farming schemes practised in your village?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………

2. How do the problems mentioned above affects dry land irrigation farming schemes in your village?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………

3. How do the dry land irrigation farming schemes exposed to climate change in your village?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………

4. How sensitive dry land irrigation farming schemes is to the climate change in your village?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………

5. What are the risks associated with dry land irrigation farming schemes in your village?

1……………………………………………………………………………………
2……………………………………………………………………………………
3……………………………………………………………………………………

6. What are the key indicator showing the vulnerability dry land irrigation farming schemes against climate change in your village?

1…………………………………………………………………………………
2…………………………………………………………………………………
3…………………………………………………………………………………

7. In your opinions, what should be done to improve dry land irrigation farming schemes practices and improve livelihoods in your village?

1…………………………………………………………………………………
2…………………………………………………………………………………
3…………………………………………………………………………………

8. In your opinions, what should be done to combat the problem of climate change in your village?

1…………………………………………………………………………………
2…………………………………………………………………………………
3…………………………………………………………………………………

Thank You Very Much/Aksante Sana!