ECONOMICS OF CLIMATE CHANGE ADAPTATION IN SMALLHOLDER RICE PRODUCTION SYSTEMS IN WAMI-RUVU BASIN, TANZANIA

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

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ABSTRACT

The aim of this study was to assess the economics of climate change adaptation in smallholder rice production systems. The study covered three smallholder rice production systems including irrigation, rainwater harvesting system and upland rainfed rice systems in Mvomero and Morogoro rural Districts. The specific objectives were: (i) To assess the perceptions of farmers on climate change impacts in different rice production systems, (ii) To analyse the determinants of rice productivity and profitability on land; (iii) To estimate the impact of climate change on net revenue from rice enterprise under different emission scenarios and iv) To estimate the costs and benefits of adaptations strategies in different rice production systems. The data for this study were collected using a structured household questionnaire that was administered to a random sample of 150 households composed of equal sub-samples from the three rice production systems. Descriptive and quantitative methods were used to analyze the data. Likert scale, an average production function based on Ordinary Least Square (OLS) estimation approach, Regression-based prediction and cost-benefits analysis were used in data analysis. Results indicated that smallholder farmers were aware of the impact of climate change by contributing to crop infestation and diseases, higher food costs and low yields. Irrigation was identified as the most preferable adaptation having higher net present value of Tshs 12 491 951/ha followed by rainwater harvesting Tshs 2 665 769 /ha and rainfed Tshs 1 199 253/ha. The cost-benefit ratios were 1.22; 1.14 and 1.16 in irrigated, rainfed and rain water harvesting systems, respectively. Therefore, the government and other private institutions should invest more in irrigation as it tends to boost up production during drought period or when there is low rainfall.

DECLARATION

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

_________________________ ____________________

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(MSc. Candidate)

The above declaration is confirmed

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Dr. K. D. S. Mutabazi Date

(Supervisor)

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DEDICATION

This dissertation is dedicated to my father, Professor Jovin K. Mugula and my mother, Mrs. Scholastica-Elizabeth Mugula, whom together laid the foundation for my education.

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LIST OF ABBREVIATIONS

A2	IPCC’s A_2 scenario
Adj. R-sq.	Adjusted R-Square
AOGCM	Atmospheric Global Circulations Models
ASDP	Agriculture Sector Development Programme
B1	IPCC’s B_1 scenario
BCR	Benefit-Cost Ratio
C	Carbon dioxide
^{O}C	Degree Celsius
CCC	Canadian Climate Centre
CRDB	Cooperative Rural Development Bank
Coeff.	Coefficient
ECA	Economic Commission for Africa
ECAW	Enhancing Climate Change Adaptation in Agriculture and Water Resources in the Great Horn of Africa
FAO	Food and Agriculture Organization of the United Nations
Fig	Figure
FGD	Focus Group Discussion
F-Stat	F-Statistics
GDP	Gross Domestic Product
ha	Hectare
ICRAF	World Agroforestry Centre
IDRC	International development Research Centre
IFAD	International fund for Agricultural development
IFPRI	International Food Policy Research Institute

IPCC	Intergovernmental Panel on Climate change
ISDR	International Strategy for Disaster Reduction.
Km	Kilometre
Kg	Kilogram
kg/ha	Kilogram per Hectare
L	Litre
l/ha	Litre per Hectare
m	Metre
MAFC	Ministry of Agriculture, Food security and Cooperatives
mm	Millimetre
MT/ha	Metric Ton per Hectare
n	Sample Size
NAPA	National Adaptation Programme of Action
NASA	National Aeronautics and Space Administration
Nerica	New Rice for Africa
NPV	Net Present Value
OLS	Ordinary Least Square
P	Probability
PCM	Parallel Climate Model
Person-days/ha	Person Days per Hectare
RLDC	Rural Livelihood Development Company
R-sq	R-Square
SRI	System of Rice Intensification
Sign.	Significant
RWH	Rainwater Harvesting

Std. Dev.	Standard Deviation
SUA	Sokoine University of Agriculture
Tshs.	Tanzanian Shillings
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
URT	United Republic of Tanzania
USAID	The United States Agency for International Development
USD	United States of America Dollar
Yrs	Years
%	Percentage

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Climate change has already begun to transform life on Earth. Around the globe, seasons are shifting, temperatures are climbing and sea levels are rising. According to the Food and Agriculture Organization (FAO) (2011), global climate change has already had observable effects on the environment. The rise in global temperature by 4^oC forecast to occur towards year 2100 is likely to occur if mitigation efforts do not work out (FAO, 2011).

In the last 40 years, issues related to climate change have shifted from being the concern of a small number of environmental activists and specialized scientists to being the focus of broad scientific, political and community interest and activity (Lefroy *et al*., 2010). This is because climate change is expected to influence crop and livestock production, hydrologic balances, food systems, input supplies and other components of agricultural systems. However, the nature of these biophysical effects and the human responses to them are complex and uncertain. For example, according to Adams *et al*. (2008) crop and livestock yields are directly affected by changes in climatic factors such as temperature and precipitation and the frequency and severity of extreme events like droughts, floods and windstorms. In addition, carbon dioxide is fundamental for plant production; rising concentrations have the potential to enhance the productivity of agro-ecosystems. Climate change may also change the types, frequencies, and intensities of various crop and livestock pests; the availability and timing of irrigation water supplies; and the severity of soil erosion (Silayo *et al*., 2008).

All countries and ecosystems in the globe will face the consequences of the changing climate. However, the seriousness of the effects will definitely vary from country to country or across ecosystems. In Tanzania, for example, according to the National Adaptation Programme of Action (NAPA) (URT, 2007) the adverse impacts of climate change are already having their toll on the livelihoods of people and on sectors of the economy. All these changes will aggravate the situation leading to increased vulnerability of the communities to the impacts of climate change and affecting sectors of the economy, especially agriculture, water, energy, health and forestry.

Experience has shown that agriculture is already well adapted to the range of weather extremes that have been commonly observed within living memory but may be ill adapted to intensification of these extremes under climate change (FAO, 2011). Subsistence crops like maize and rice, which provide a third of the national daily calorific intake and are grown by half of the farmers, could be particularly affected by climate change. NAPA (URT, 2007) indicated that with an increase in temperature and reduced rainfall, as well as change in rainfall patterns, the average yield would decrease by 33% countrywide.

In Tanzania, rice cultivation is predominantly dominated by smallholders under rainfed and irrigated conditions (Country report, 2007). Approximately, 29% of the total area is under traditional irrigation, while 71% of the rice-cultivated area is under rainfed conditions mainly under rainwater harvesting systems, making it vulnerable to the climate change (RLDC, 2009). Therefore, to reduce over-dependence on rainfed agriculture, irrigation is envisioned as a strategy to revamp the African Green revolution through national initiatives such as Comprehensive Africa Agriculture Development Programme, Kilimo Kwanza and Agriculture Sector Development Programme that contribute towards agriculture transformation into a modern and commercial sector in a bid to ensure that the nation attains reliable and sustainable crop production for food security (Mbilinyi *et al.*, 2010).

1.2 Problem Statement and Justification

Tanzania's economy is dependent on the climate, because a large proportion of GDP is associated with climate sensitive activities, particularly agriculture. As a result, current climate variability such as droughts and floods, lead to major economic costs in Tanzania. For example, Wami-Ruvu basin could experience a 10% decrease in run-off while rice yields decline by 10% for every 1^{o}C increase in mean night-time temperature (Lasco *et al.*, 2011; Watkiss, 2011).

Furthermore, the occurrence of dry-spell any time during the growing season as impact of climatic changes often exposes crops to moisture stress, hence farmers usually face problems of both too much and little moisture (Watkiss, 2011). These effects have necessitated changes in the way smallholder rice farmers make decision to adapt to their environment (Ajetomobi *et al.*, 2010). Therefore, farmers apply different strategies to adapt and cope with the challenges of climate change and the strategies opted are for example; combining less productive drought-resistant cultivars with high yield but water-sensitive crops (Kuponiyi *et al*., 2010; Mbilinyi *et al*., 2010).

Even though there are several studies on climate changes in agriculture, and crop sub sector in particular (Mbillinyi *et al.,* 2010; Herath *et al*., 2011; Nhemachena *et al*., 2010; Rowhan *et al*., 2011) still little is known regarding the farmers' perceptions, economic impacts of climate change under different emission scenarios, costs and benefits of adaptations in different smallholder rice production systems in Tanzania. These include the rainfed upland rice, the lowland water harvesting-based and the irrigated systems.

This study aimed at contributing in addressing these knowledge gaps by quantifying impact of climate change on farm returns under B1 and A2 emission scenarios; and costs and benefits of different adaptation measures in the rice production systems. Understanding how climate change may cause impacts at the local scale is crucial for the development of long-term adaptation and mitigation strategies that may minimize negative impacts of climate change on the livelihoods of vulnerable communities. Findings from this study therefore, will contribute to a pool of knowledge for policy makers and other stakeholders in climate change and related institutions. This will eventually lead to emphasis on adaptation strategies that contain sound measures to reduce the climate risks and the vulnerabilities farmers under different rice production systems.

1.3 Research Objectives

1.3.1 Overall objective

The main objective of the study was to assess the economic impacts, costs and benefits of climate change adaptation in different smallholder rice production systems in the Wami-Ruvu basin of Tanzania.

1.3.2 Specific objectives

i. To assess the perceptions of farmers on climate change impacts in different rice production systems.
ii. To analyse the determinants of rice productivity and profitability on the returns to land.
iii. To assess the impact of climate change on net revenue from rice enterprise under different emission scenarios.

iv. To estimate the costs and benefits of adaptations strategies in different rice production systems.

1.4 Research Hypotheses

i. Farmers in different rice production systems have different perceptions on the impacts of climate changes on rice production systems.

ii. Rice determinants have no effects on productivity and profitability of land.

iii. There is no significant difference of net revenues from the rice enterprise under different climate emission scenarios.

iv. The net benefits of adaptations decrease with the extent of vulnerability in different rice production systems entailing irrigation, water harvesting and rainfed systems.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of Key Concepts

2.1.1 Climate change

Climate change refers to ongoing changes in the global climatic system resulting primarily from anthropogenic global warming as a consequence of the increased and continuing emissions of greenhouse gases, and the loss of vegetation cover and other carbon sinks (FAO, 2008). It can also be defined as gradual changes in climate norms, notably temperature and changes in the frequency, extent and severity of climate and weather extremes, explained as a persistent change in the mean and variability of climate variables such as temperature, rainfall, humidity and soil moisture (Krishna, 2011). It can be attributable directly or indirectly to human activities that alter atmospheric composition and price (Kutua, 2008). Climatic change manifests itself as a shift in mean conditions or as changes in the variance and frequency of extremes of climatic variables such as temperature and precipitation (Compass Resource Management, 2007). All these can contribute to climatic variability.

2.1.2 Climate variability

Climate variability is a long term summary of weather conditions taking into account short term fluctuations happening from year to year such as severe storms. It is also a function of the character, magnitude, and rate of climate change and variation to which a system is exposed; its sensitivity and its adaptive capacity (Bhrusal, 2009). Moreover, the degree to which geo-physical, biological and socio-economic systems are susceptible to and unable to cope with adverse impacts of climate change including climate variability and extremes are defined as climate variability (IPCC, 2007).

2.1.3 Adaptation

Adaptation is defined as adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damage (or benefit from opportunities) associated with climate change (Ramsey *et al.*, 2008). Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation. Examples of adaptation measures include vegetating slopes threatened by flood erosion and maintaining the natural biodiversity of ecosystems to reduce their vulnerability. Forestry and agriculture sectors are important elements in climate change adaptation, mainly through maintaining functions such as biological and crop diversity and water generation cycles that help determine an ecosystem's ability to withstand climate change.

2.2 Local Perception on Climate Change Effects

The impact of global climatic change on agriculture has recently become a subject of increasing importance though it was a difficult proposition for many to accept that farmers have the ability to perceive the changes in climate that have already occurred (Dhaka *et al.*, 2010). Bhrusal (2009) defines perception as the process by which we receive information or stimuli from our environment and transform it into psychological awareness that influences the way we act. A certain situation or phenomenon can be inferred differently by most people using the same or different sets of information. Perception can be influenced by age, education, experience, type of economic organization. These are key factors in increasing likelihood or affecting farmers' decisions on their perceptions and attitudes towards climate risk (Antle, 2010), while fertile soil and access to water for irrigation decrease the likelihood of perceiving climate change (Gbetibouo, 2009 as cited by Acqua *et al*., 2011).

Maharjan *et al*. (2010) analyzed perception of farmers to climate change and their adaptation in Nepal and reported that farmers perceived climate risks and hazards as being on the increase in terms of magnitude; frequency and severity of impacts. Also 90% of the people perceived that risk and uncertainty of the climate have increased. For example, the occurrence of climatic stresses like flood, drought, river bank erosion and wind storm have increased in recent years as compared 25 to 30 years back, even drought has increased 2 to 3 times flooding in a single season.

According to Acqua and Onumah (2011), people of Dunkwa in Ghana held various perceptions towards climate change and adaptation in the study area. Furthermore, Mary *et al*. (2009) asserted that farmers in Tanzania had high awareness on climate change impact leading to risk of crop failure and rising of production cost due to re-planting and re-ploughing of crops. Senkoro *et al*. (2007) revealed that 60% of population in Maswa district perceived that the fluctuations of rice production trend were due to low rainfall, lack of improved seeds, and lack of adequate run-off water.

Furthermore, indigenous people have values, which play part in addressing climatic change, specifically, on the way they think towards climatic change. For example, Daninga (2011) analysed farmers perception about climate change indicators affecting agriculture in Morogoro region and the study revealed that weather variability patterns like changes in March-May rain season *(Masika)* and October-December rain season *(Vuli)* were perceived by indigenous people in Morogoro as the punishment from angry gods because people have stopped making sacrifices to gods and due to increase in evil deeds. Although the capacity to deal with climate change is still low, but some smallholder farmers in rural areas have some knowledge, ideas and information on how to cope and adopt strategies to mitigate the climatic change impacts.

However, the perception of farmers on the climate change impacts and adaptation options in different production systems in Tanzanian context have not been analysed. Most of the studies concentrate on causes and impacts of climate change with little attention paid on perception and adaptation options in different production systems. The present study employed Likert scale to analyse farmers' perception and adaptation in different production systems.

2.3 Rice Production and Profitability

2.3.1 Rice production systems

Approximately 16% of Tanzanian farmers grow rice, 94% of those farmers are smallholders and 6% are large farmers. Smallholder farmers cultivate an average farm size of ranging between 0.9 to 3.0 hectares. About 70% of Tanzania's crop area is cultivated by hand hoe, 20 % by ox-plough and 10 % by tractor. About 74 % of total rice area is under rainfed low land rice mainly under rainwater harvesting, 20 % is upland rice and 6% is under irrigation (RLDC, 2009).

Rainfed rice production is located in poorly drained soils and is often far away from residential areas. The fields are banded to keep the water in the field. Land preparation is done mostly by using ox ploughs, with some using hand hoes and very few farmers renting tractors. The major constraint facing the agriculture sector is the falling labour and land productivity due to application of poor technology, dependence on unreliable and irregular weather conditions. Both crops and livestock are adversely affected by periodical drought (RLDC, 2009).

Ajetomobi (2010) found that increase in temperature due to extreme climatic events may undermine any positive effects by reducing the net revenue for dry land rice farms whereas increase revenue for the irrigated rice farms due to the fact that, irrigation buffers the crop from rainfall shortages. Precipitation had similar effects on rice net revenue in dry land and irrigated production systems or hilly regions in semi-arid regions (Ajetomobi *et al.*, 2010; Thapa, 2010). Increase in the frequency of drought and floods are projected to affect crop production negatively especially in subsistence sectors at low latitudes (IPCC, 2007). With irrigation water omitted, climate change is strictly beneficial, and with water inclusion, climate changes are beneficial while drastic climate change in the long run are harmful (Fleischer, 2007). Irrigation practice is regarded as one of the effective approaches offering prospects for expanding total cultivated area, increasing and stabilizing food and cash crops, extending growing seasons as it reduces the impacts associated with variability of rainfall (temporal and spatial rainfall availability) and temperature hence ensuring stable and higher food security with and without climate change (Fleischer, 2007).

According to URT (2010) under national irrigation master plan, irrigation is defined as the application of a specific amount of water at a particular location in order to meet the requirements of a crop grown at the location, in an amount that is appropriate to the crop's stage of growth. It can also be defined as the application of water in amounts necessary to bring soil to the desired moisture prior to crop planting. Tanzania has an irrigation potential area of 29.4 million hectares, out of which 2.3 million hectares are classified as high potential; 4.8 million hectares as medium potential and 22.3 million hectares as low potential. Only 1% of the total irrigation potential (310 745 hectares) had been harnessed by 2009 (RLDC, 2009). In total, there are about 192 660 acres of rice under irrigation schemes. All together, these schemes are farmed on very small plots which, however, produce only one season in a year due to the rain water-dependent irrigation.

Rice productivity in irrigated areas is variable depending on location but on average, is higher in irrigated than non-irrigated areas. The average yield in non-irrigated areas is about 2 tons per hectare for rice while for irrigated rice it is about 4 to 6 tons per hectare (NAPA, 2011). From the study conducted in Tanzania, Ahmed *et al*. (2011) observed that with increase in temperature, maize had a 12% yield loss per degree Celsius; rice had a 17% yield loss and sorghum had a 7% yield loss over a six-month growing season. Therefore, in response to climate change, irrigation systems are particularly useful in low rainfall areas, even though access to irrigation varies by region. For example, in Kilimanjaro 21% of households irrigate at least some of their fields, while in Ruvuma only 2.1% do so. However, this is consistent with the higher rainfall variability in Kilimanjaro (Ahmed *et al*., 2011).

The reasons behind the poor performance of irrigation systems include falling prices of main agricultural commodities, shortage of small, medium and large water storage dams for irrigation for controlling floods, high maintenance costs, diminishing water resources as observed in Wami-Ruvu basin as a result of climatic variability; increase in demand due to increase in population and absence of an effective policy implementation and strategy framework for irrigation and flood development (URT, 2010).

Moreover, if best agricultural practices in rice farming are employed, one hectare should be able to yield between 1.8 and 6 tons of rice, between 13 and 26 tons of onions and between 5 and 18 tons of tomatoes per hectare (Mbilinyi *et al.*, 2010). According to Food and Agriculture Organization, in Tanzania rice-growing area rose from 439 300 hectares in 1997 to 720 000 hectares in 2010 of which 90% is managed by small-scale farmers with holdings of 0.5 to 3.0 ha of land each. At the same time, rice production increased from 550 000 MT of un milled rice (equivalent to 330 000 MT of milled rice) in 1997 to

1 104 890 MT (equivalent to 662 934 MT of milled rice) in 2010, representing a growth of 13.1% per year. Tanzania's productivity did not change much and varied from 1.2 to 2.4 MT/ha. The low yield is mainly caused by the use of low-yielding varieties, drought, low soil fertility, weed infestations, and the prevalence of insect pests and diseases and birds (Somado, 2008).

The Agriculture Sector Development Programme (ASDP), Kilimo Kwanza and National Irrigation Master Plan identified irrigation as a one of the strategies for increased agricultural productivity and income and generation to improve the livelihoods of the commodity value chain stakeholders for growth, and poverty reduction.

Land is a necessary input for agricultural production as it enables production activities to take place and ultimately to provide benefits attained through its exploitation. Rice outputs or yields depend not only on climatic factors, such as temperature and rainfall, but also on other predictors or necessary factors for rice production improvements such as field management, capability of crops, irrigation and fertilizers. Other factors necessary for rice production improvement include area, solar radiation and temperature (Herath and Kewasaki, 2011). Temperature, capital, labour force, seed varieties and maintenance of soil fertility such as use of organic manure or organic waste, reducing burn agriculture are also important factors in improving rice crop (Herath and Kewasaki, 2011). The research carried out by Agom *et al.* (2009) on upland rice farmers in Nigeria asserted that in the efficiency analysis, land and labour were over utilized while seeds and fertilizer were under-utilized. Rice profitability was largely influenced by socio-economic attributes such as farmer's age, plot size, hiring costs, household's education, farming experience, farm credits accessed, water or irrigation expenses recorded by the farmer (Huy, 2011; Onoja and Herbert, 2012).

However, inadequate water supply during the dry season and lack of credit hinder farmers' ability to obtain the necessary resources for crop production (Somado, 2008). Smallholder farmers operate with limited resources and thus fail to meet transaction expenses and fail to utilize the information they have for production ending up with low returns or nothing to harvest especially the farmers located in dry areas (Hassan and Nhemachena, 2007).

2.4 Future Emission Scenarios

In the climate scenarios provided to the National Climate Assessment, primarily two emission levels (A2 and B1) developed by the IPCC special report on emission scenarios representing a range of estimates that are being used to illustrate differing possible impacts of changing emissions in the future (Garnaut *et al.*, 2008). Assumptions underlying the development of the two scenarios include; population growth, economic development, the evolution of technology, decisions about environmental protection which give rise to different patterns of energy production and use, agriculture and other activities that change land use, which in turn lead to different levels of the greenhouse gas emissions that cause the human component of climate change (Rogner *et al*., 2007).

The "A2 scenario" has higher emissions and results in high levels of climate change; also it is characterized by high population growth, low economic growth, slower technology improvements and diffusion, and other factors that contribute to high emissions and lower adaptive capacity (Garnaut *et al.*, 2008). Moreover, the "B1 scenario" represents a world with lower population growth, higher economic development, a shift to efficient energy technologies that are diffused rapidly around the world through free trade, and other conditions that yield slower growth of greenhouse gas concentrations and reduce the rate and level of changes in climate averages and extremes and increase capacity for adaptation (Mbilinyi *et al*., 2010; Rogner *et al.*, 2007).

However, with two scenarios (A2 and B1), Indonesian rice production tends to increase in year 2000 to 2030. However, with the climate projection and if there is no changes in rice management, rice production will decrease until year 2050. These scenarios assume that there will be high decentralization of rice plantation migration to outside of Java Island (Widiyant, 2009). In Tanzania, temperatures are predicted to rise 2–4^{o}C by 2100, warming more during the dry season and in the interior regions of the country (Rowhan *et al*., 2011) while under scenario A2 temperature is expected to increase 2-5^{o}C in the western side and by 1.5 to 2^{o}C in the eastern side of the country in year 2030 and 2070. The interior regions are also expected to experience a reduction in precipitation by 20%, prolonging the dry season and increasing the risk of drought, whereas in eastern Tanzania and the regions around Lake Victoria, rainfall and temperature are expected to increase by up to 50%, during this time period increasing the frequency and severity of floods (Paavola, 2008).

2.4.1 Economic impacts of climate change under different emission scenarios

The impact of climate change is higher in developing countries than in developed countries as it impacts more of the natural resources. For example an economy-wide simulation model results show that with increase in irrigated area for cereal production (50%) and annual economic growth rate in Ethiopia might increase from 1.9 to 2.1% by 2015 and this might increase the GDP by 3.6% per year (Diao and Pratt, 2007). Moreover, with climate change, rice production in developing countries is expected to decline by 11.9% in 2050 due to over- dependence on rainfed agriculture, of which will reduce revenue to smallholder farmers compared to farmers in developed countries with irrigation facilities, controlled humidity and temperature. With no climate change rice production might have increased by 455.2% and 434.9% in developed and developing countries, respectively, by 2050 (Krishna, 2011). Parallel Climatic Model also predicts a 2^{o}C increase in temperature and 10% increase in precipitation in 2100. The results showed marked variation in the net-revenues for dry land and irrigated rice farms. With increase in temperature by 2 to 6^{o}C will increase the net-revenue per hectare by 3.9% and decrease it by 11.7% for dry land rice farms (Ajetomobi *et al*., 2010). In addition, a 5% reduction in precipitation will lead to increase in net-revenue for irrigated farms but decline for dry land rice agriculture.

However, Tanzania's economy is heavily dependent on agriculture, which is highly vulnerable to climate change (Mbilinyi *et al*., 2010). With the projected decline of annual basin run-off from 10% to 6% in the Wami-Ruvu basin, climate variability reduces potential areas for irrigation in the basin, leading to the decline in rice production (Mbilinyi *et al*., 2010). In 2006, the country, and especially the agriculture sector, experienced a prolonged drought, which reduced the overall GDP by 1% (Watkiss *et al.*, 2011). Furthermore, in a year 2008, the country's productivity was expected to decline on average ranging from 10 to 25% and with exception of few regions in Tanzania, most areas will suffer yield losses of 10 and 20% by 2030 and 40% by 2050 under two emission scenarios, leading to micro- and macro-economic implications, income losses and food insecurity (FAO, 2008; Mbilinyi *et al*., 2010).

These climatic variables (temperature and rainfall) determine crop productivity, which in turn affect food system (Mngale, 2009). When food security diminishes, peoples' livelihoods get impaired. This causes poverty and hunger, with negative impacts to smallholder farmers, many of whom are actually semi-subsistence consumers of food

(FAO, 2008). Therefore, results showed harmful effects for dry land rice farms' net revenue but beneficial effects for irrigated farms net revenue (Ajetomobi *et al*., 2010). Thus, adaptation and copping measures should be developed to combat the impact of climatic change.

2.5 Costs and Benefits of Adaptation Strategies

Understanding the cost associated with climate change adaptation interventions in agriculture is important for mobilizing institutional support and providing timely resources to improve resilience and adaptive capacities (Sova *et al*., 2012). However, the suitable adaptation measures differ from one location to another and farming system to another. For example, for nomadic and sedentary pastoral communities in Himalayan belt, the climate adaptation means changes in the policies of the range land management, alteration of the rotation, selection of the breeds and construction of ponds for rainwater harvesting (Krishna, 2011). These adaptation options increase costs.

Adaptation cost of climate change is the costs of planning, preparing for, facilitating, and implementing adaptation measures including transition costs (UNFCCC, 2009). According to Krishna (2011), the cost of adaptation measures in agriculture are divided into different categories; (1) Cost of behavioral adaptation including changes in dietary choices and cultural celebrations where by the farmer changes the production and consumption behavior to adapt to the climate change: (2) Changes in farming management practices including income diversification, soil moisture monitoring, crop diversification, improvement in soil and water management are not cost free to the farmer, hence they comprise costs of managerial adaptation (ISDR, 2008 as cited by Krishna, 2011). (3) A subset of adaptation cost that encompasses compliance to policy options; many that fall within this category require government and individual responses.

They include planning regulations and infrastructural development policies such as agricultural support and insurance policies. (4) Technological adaptation. These consist of development of irrigation infrastructure, water harvesting and storage reducing dependency on rainfall. However, these adaptation options are expected to produce benefits in short and long time dimension (Krishna, 2011).

Furthermore, some authors explain advantages of adaptation to the environment where by, benefits derived are assessed in terms of mitigating adverse distributional impacts of climate change. The UNFCCC (2009) defined adaptation benefits as the avoided damage costs or the accrued advantages following the adoption and implementation of adaptation measures. Thinking of adaptation benefits in the context of reduced vulnerability, benefits can be enumerated in several ways: increased productivity reduced food insecurity, greater capacity to maintain diversified assets, less stress on social relationships and reduced dread not all of which, reduce so readily into monetary equivalents (World Bank, 2010). Even if adaptation options have some benefits, still smallholder farmers in different production systems fail to adapt them due to several limitations they are facing environmentally and economically.

Thornton *et al.* (2009) observed that adaptation can be constrained by institutional, economic, political and social environment in which smallholder farmers operate (Thornton *et al.*, 2009 as cited by Krishna, 2011). Kurukulasuriya and Mendelsohn (2008) asserted that lack of knowledge, financial constraints, lack of information on the choice of adaptation options, labour constraints, shortage of land, poor potential for irrigation are barriers to adaptation facing most of the farmers but they, however, try to exists and cope in various ways over period of time so as to reduce climatic impacts (Ajao and Ogunniyi, 2011).

2.6 Review of Analytical Tools

2.6.1 Farmers perception on climate change impact

Various studies have been done on farmers' perception on climate change impacts. Kuponiyi *et al*. (2010) used descriptive statistics and multiple regression to assess farmers' perception of impact of climate change on food crop production in Ogbomoso Agricultural zone of Oyo State, Nigeria; Apata *et al*. (2009) used Logit model to analyse climate change perception and adaptation among arable food crop farmers in South Western Nigeria. Results revealed that, farmers relied on rainfed agriculture while abandon mono-cropping for mixed and mixed crop-livestock systems in dry land areas; Daninga (2011) used descriptive analysis approach on farmers perception concerning indicators affecting agriculture in Tanzania and revealed that, farmers are aware that, the impact of climate change has led to droughts and decline in crop production. Hassan *et al*. (2007) and Dhaka *et al*. (2010) used descriptive analysis in analyzing farmers' perception on climate change impact and adaptation in Ethiopia, South Africa and India. The study revealed that, the majority of the respondents had changed their agricultural management practices in response to changes in climate conditions. Hence, the study combined descriptives and Likert scale to assess farmers' perception on climate change impacts in different rice production systems.

2.6.2 Analysing the determinants of rice productivity and profitability

Ordinary least square is a useful estimation method for determining the relationship between dependent and independent variables. There are various functional forms for expressing production relationships such as: Polynomial, Linear, Cobb-Douglas, quadratic, semi log and square roots. However, the ordinary least square (OLS) was used due to its simplicity. The underlying OLS assumptions are as follows: (1) the variance of independent variables is the same all over the ranges; (2) the variance of error term values is approximately the same over all ranges of independent variables i; (3) the expected value of each disturbance or error term is equal to zero. However, when these assumptions are violated, this will weaken the validity of the results obtained from the regression (Fred *et al.*, 2012; Liberio, 2012).

Many scholars have attempted to use different methods and techniques when conducting research on crop productivity and profitability. The study done by Olujenyo (2008) on the determinants of agricultural production and profitability in Nigeria, used ordinary least square methods when estimating parameters of production function and found that only labour had a significant influence on output. Basorun *et al.* (2012) used ordinary least square method on factors influencing rice production in Igbemo, Nigeria and, Agom *et al.* (2009) on the production function analysis in Imo state, Nigeria observed that land, capital, labour, seeds and fertilizer had a positive effect on land. Khai *et al.* (2011), used Cobb-Douglas production function and Ordinary Least Square (OLS) when analysing technical efficiency of rice production and found that education and irrigation had a positive impact on technical efficiency. Fred *et al.* (2012) used OLS regression and gross margin to analyse the resource use efficiency in rice production and found out that labour and chemicals were utilized while land, fertilizer and seed were under-utilized. In addition, gross margin was employed by Fred *et al.* (2012) to assess the profitability of rice production in Ghana. Akinola *et al.* (2012) used gross margin for economic analysis on adoption of mulching technology in yam production in Nigeria. Therefore, in this study OLS regression analysis was used to analyse predictors of rice production and profitability in different rice production systems in wami-Ruvu basin, Tanzania.

2.6.3 Economic impacts of climate change under different emission scenarios

Ricardian Model was named after David Ricardo (1772–1823) because of his original observation that land value would reflect its net productivity at a site under perfect competition. In other words, it examines the relationship between the value of land or net revenue and agro-climatic factors (Deressa, 2007). The model has several strengths: first, it is cost effective, since secondary data on cross-sectional sites can be relatively easy to collect on climatic, production and socio economic factors; second, it has ability to incorporate private adaptations as farmers adapt to climate change to maximize profit; third, it takes adaptation into account by measuring economic damages as reductions in net revenue or land value; fourth, it makes possible to account for the direct impact of climate on crop yields; fifth, it values the contribution that environmental factors make to farm income and measure the marginal contribution that each input makes to farm income induced by climatic factors (Ajetomobi *et al*., 2010; Deressa *et al.*, 2008; Mendelson *et al*., 2007).

Despite having some strengths it also has some weaknesses (i) as a cross section analysis it doesn’t account for dynamic transition costs which can occur as farms moves between two sites; (ii) it fails to include important variables that could also explain the variation in farm incomes; (iii) the assumption of constant price is wrong because the inclusion of price effects is problematic which will lead to biased results (Deressa, 2007;Thapa, 2010).

Various studies have been conducted to measure the effects of climate change impacts on net farm revenue Vaghefi *et al*. (2011) used crop model ORYZA 2000 to estimate the potential impact of climate change on rice production in Malaysia. The model predicts that rice yields will decline by 0.69 ton/ha with increase in temperature by 2^{o}C under the scenarios of increased CO_2 concentration and reduction by 0.36 ton/ha at the current CO_2

level. Ricardian model is useful to examine the impact climate will play in the future. Thapa (2010) used Ricardian model to measure the impact of climate change in agriculture. Mbilinyi *et al*. (2010) used Global circulation model (GCM) on the projected climate change impact in agriculture under two emission scenarios (2030-2050). Fleischer *et al.* (2007) used Ricardian model to forecast average net profits per hectare according to AOGCM scenarios in Israel. Ajetomobi (2010) simulated the impact of future climate change scenarios on rice Agriculture in Nigeria under two climate models like CCC and PCM to examine the consequence of climate change scenarios in 2050-2100 using the Ricardian Model. This study employed t-test in comparative assessment of the impact of climate change on net revenue from rice enterprise under different emission scenarios in different production systems.

2.6.4 Assessing the cost and benefits of adaptation

Cost-benefit analysis is an economic approach for measuring economic viability of the investment or project by comparing the benefits against the costs. It helps in identifying the streams of benefits and costs over time for every investment and bringing back to present values by the means of discounting at a selected interest rate. According to Stern (2007), the discounting rate proposed was 1.4%, while Cline (1992) proposed 1.5%. The higher the discount rates, the more the future impacts are discounted. In the case of infrastructure, also higher interest rates have the effect of postponing action on climate change, as future benefits are more heavily discounted. The time horizon is mainly determined by the life of the investment in the case of infrastructures such as irrigation (UNFCCC, 2009).

Furthermore, the cost-benefit analysis has the following advantages: (i) it help in decisions on programme options by weighing up costs and benefits of different interventions; (ii) it acts as a decision support tool for demonstrations and a powerful tool for economic investment, in risk reduction that maximizes benefit for every dollar of investment spent; (iii) it is useful in assessing larger scale infrastructure and public investments projects and its use at community or local level; (iv) it helps in decision making as it provides important information to decision makers (UNFCCC, 2009).

Notwithstanding its usefulness the model has the following disadvantages: (i) Costs and benefits of adaptation have to be presented on a range of values and not single values; (ii) it ignores the distribution of the costs and benefits of adaptation options and fails to account for those costs and benefits that cannot be reflected in monetary terms; (iii) data limitations cause substantial challenges, specifically, if there is uncertainty over data gathered or no resource to collect primary data (UNFCCC, 2009).

Therefore, researchers use different methods in assessing economic viability of the project in different places. World Bank (2010) used cost-benefit analysis in assessing economics of adaptation to climate change in Ethiopia Germana (1993) used cost-benefit analysis methods to analyse the economics of irrigation project under small scale in Kenya. Hatibu *et al*. (2004) employed benefit-cost ratio, net present value and internal rate of return when assessing profitability of rainwater harvesting systems for agricultural production in selected semi-arid areas of Tanzania and found that rainwater harvesting was the viable adaptation option to under take Herath *et al*. (2011) used benefit-cost ratio to estimate cost and benefit to evaluate the profitability of rice production without including adaptation costs to climate change and found that benefit–cost ratio during the dry and rainy season were greater than one. Cost-benefit analysis was used in the study to analyse the cost and benefits of adaptation options in rice production systems.

Nevertheless, there are several reported studies on climate change impacts and adaptation in agriculture and crop subsector in particular. These include a study on the economics of climate change for the agriculture sector in Tanzania (Mbilinyi *et al*., 2010); a study on climate change and crop farmers' adaptation measures in the South-East Rainforest Zone, Nigeria (Onyeneke *et al*., 2010). In Tanzania, little is known regarding farmers' perception, economic impacts of climate change under different future emission scenarios, micro-level economic quantification of climate change impacts on such rice production systems, costs and benefits of adaptation options in different rice production systems. Therefore, this study aimed at covering the knowledge gaps regarding the economics of climate change adaptation in different smallholder rice production systems (rainfed, rainwater harvesting and irrigated) using Likert scale, ordinary least square regression and cost-benefit analysis.

CHAPTER THREE

3.0 METHODOLOGY

3.1 The Conceptual Framework

Farmers in different smallholder rice production systems are aware of the issues regarding climate change and will often ascribe changes in farm productivity to changes in rainfall patterns. These systems including irrigation, rainwater harvesting and upland rainfed rice systems. Rainfed upland rice is grown on naturally-drained soils where the water table always remains below the rice roots and the moisture supply depends entirely on rainfall; irrigated rice is grown on banded "paddies" (flooded parcel of arable land), either under rainfed or irrigated conditions; rainwater harvesting system includes constructing water retail bunds, harvest rain water and store the water at the foot of mainly rice crop (Somado 2008; URT, 2010). The nature of climate variation depends on how people perceive about climate change and variability (Fig.1).

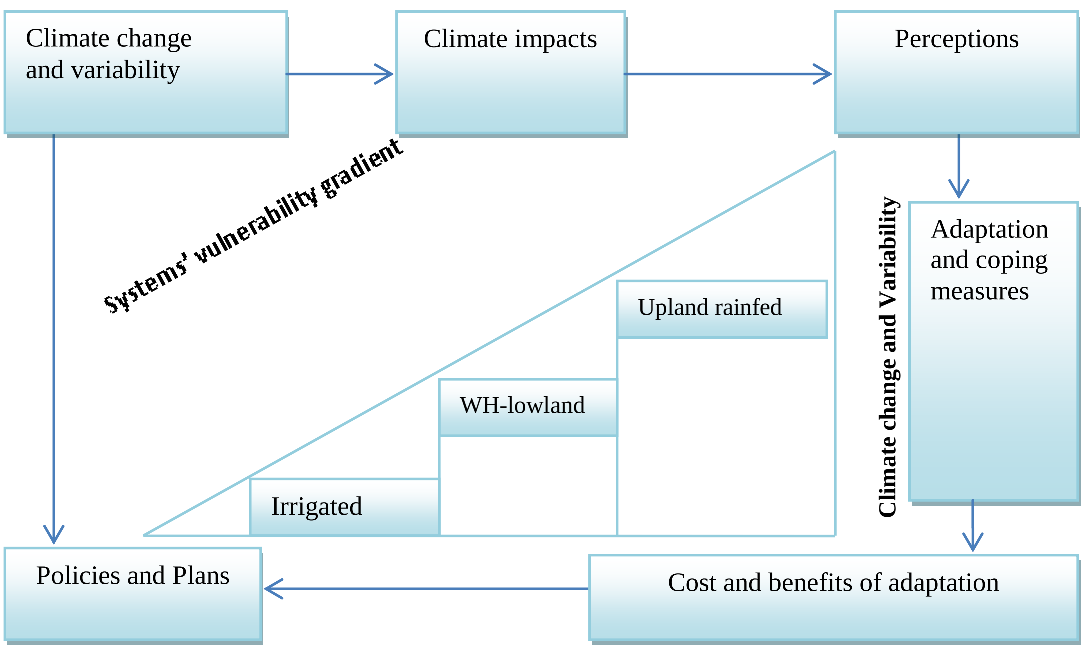

Figure 1: Conceptual Framework

The impact of climate change depends on the system vulnerability gradients and magnitude from rainfed to irrigated rice production systems. The impacts felt by farmers can be perceived as negative if climate variations result into low rainfall, occurrence of floods, low crop yields, increasing natural forest and eruption of pests and diseases. These perceived impacts determine what adaptation options (short- or long-term adaptations) farmers should take in an attempt to counteract the effects resulting from climate change and variability. Adaptation options include mulching, planting of drought resistance crops, practicing off-farm activities, afforestation, irrigation and changing in planting dates.

Furthermore, the decision whether to adopt or not to adopt a new technology or strategy depends on the cost and benefit derived from adaptation options. Benefits derived from adaptation include increased crop yield, income generation while adaptation costs involves costs of investment, maintenance and operation costs. Better adaptations will mitigate the problem of climate change, which in turn will decrease the intensity of factors of climate change in the atmosphere and lead to sustainable livelihood to the community and society in general. Therefore, a better understanding of farmers' perceptions to climate change, ongoing adaptation measures and the decision-making process is important to inform policy makers aimed at promoting successful adaptation of the agricultural sector and reduce the effects brought by climate change.

3.2 Description of the Study Area

3.2.1 Location

This study was conducted in Morogoro rural and Mvomero Districts in Morogoro Region, Tanzania. The specific locations were Kiroka (Morogoro rural District), Mkindo and Mgongola (Mvomero District). These locations were selected because they were in different agro-ecological zones and use irrigation, rainwater harvesting and rainfed rice production systems. Morogoro is the third largest region in Tanzania, occupying a total land area of about 72 939, which is approximately 8.2% of the total area of Tanzania mainland and has a population of 1 759 809 people. The region lies between latitude 5^{o} 58" and 10^{o} 0" to the south of the equator and longitude 35^{o} 25" and 35^{o} 30" to the east (URT, 1997). It has a wide climatic variation with the temperature ranging from 18 to 28^{o}C and the annual average rainfall ranges from 500 to 1800 mm (Daninga, 2011). It is bordered to the North by Arusha and Tanga Region, to the east by the Coast Region, to the south by the Ruvuma and to the west by Iringa and Dodoma Region.

Morogoro rural District is explicitly situated between latitude 5^{o} 8’ and 7^{o} 35’ to the south of the equator and longitude 37^{o} 33’ and 38^{o} 33’ to the east. The district can be divided into three geographical zones namely: (1) mountainous/highlands, (2) semi-Mountainous/lowland and savanna. (3) Kiroka is located on the eastern side of the Uluguru Mountains in Morogoro rural District and it is about 30 km from Morogoro municipality. The topography of this area is hilly with few patches of flats along the valley bottoms. The altitude ranges from 300 m to over 1800 m. Mvomero is one of the five districts of Morogoro Region that lies within 37-38’ longitude east of Greenwich and 5-7^{o} latitude south of the equator. The longitude ranges from 380-520 above sea levels.

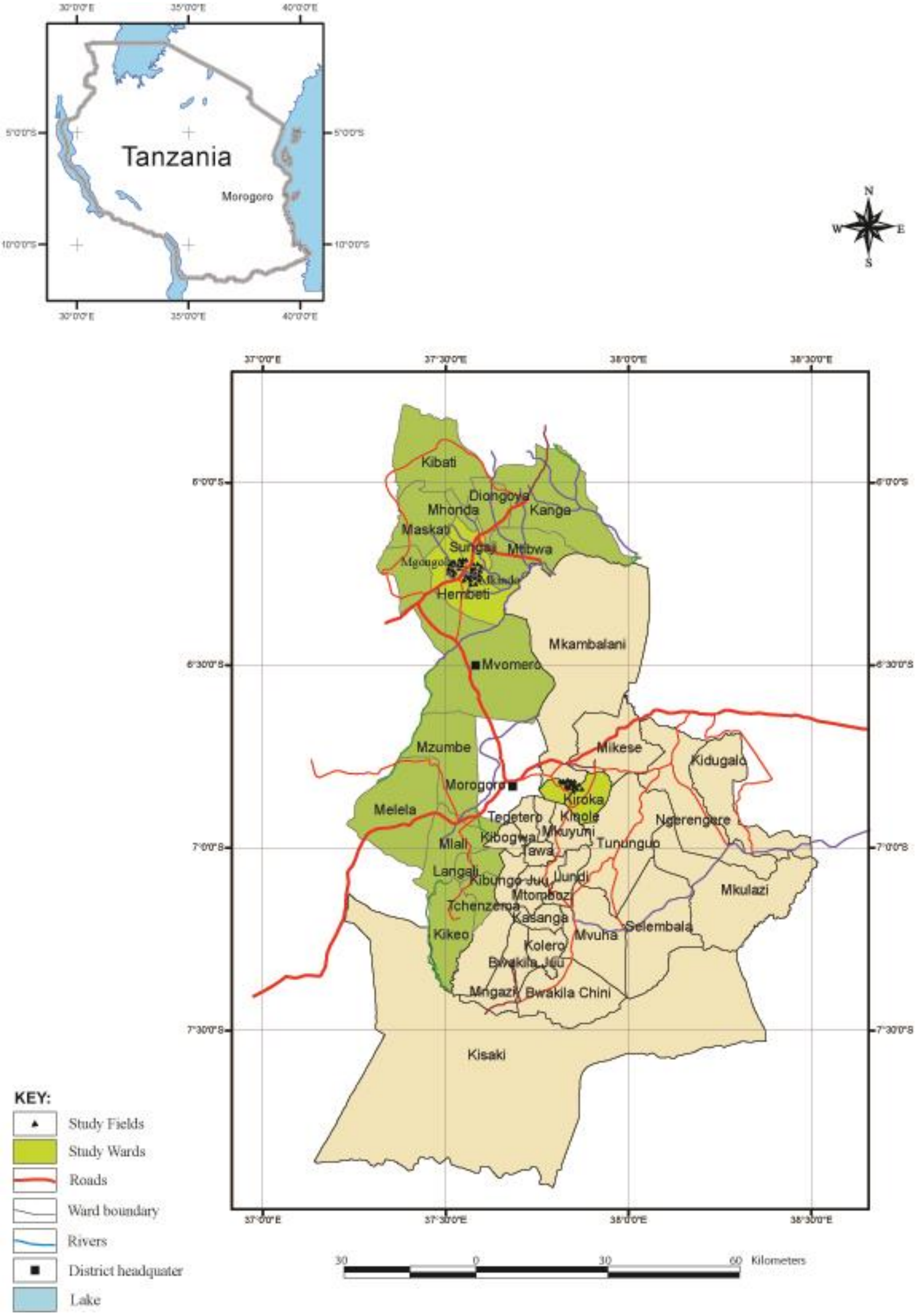

Figure 2: The location of the study villages

3.2.2 Climate and Soil

Morogoro rural District has unimodal rainfall except in mountainous. Short rains start in October and end in January while long rains last from mid-February to May with average of 600 mm- 2000 mm per annum. The average annual temperature is 29^{o}C. The temperature may become lower and sometimes reaches 15^{o}C in May up to July in Uluguru Mountains. Kiroka is generally tropical humid at lower altitudes and sub-tropical at higher altitudes. Total annual rainfall amount ranges from 1300 mm to 2900 mm. The area experiences very short dry seasons (less than two months in a year). The type of soil available in the area is sandy loam to sand clay loams in some areas it includes clay and heavy clay soils.

Mvomero District experiences bi-modal rainfall pattern with a long wet season from March to May and a short wet season from October to December. The former constitute *Masika* rains while the latter constitute *Vuli* rains. Dry season usually is from January to February and the hot season occurs from August to October, while the period from January to July is a cold season. Annual average temperature in the district ranges from 20-30^{o}C. The Northern area has a humid to sub-humid climate and annual ranging from 1500 to 2000 mm, while the southern part is much drier with annual rainfall between 600 and 1200 mm. The soil available in the area includes sandy and clay loam.

3.2.3 Agro-ecological zones

Geographically, Morogoro District is divided into three agro-ecological zones: highland and mountain zone, low mountain zone/Miombo woodland and Savannah and river basin /lowland zone. The highland and mountain zone receives more than 2000 mm rainfall per annum and have an average altitude between 1200 m-2000 m above the sea level and, covers about 25% of the total area of the district. This zone is the source of main rivers in the district such as Ruvu River.

The low mountain zone rainfall ranges from 1000 to 2000 mm per annum. The area has an altitude between 600 m to 1200 m above sea level and covers about 20% of the total area; while the low land zone covers about 55% of the whole area and altitude ranging from 400 m to 600 m above sea level with rainfall between 600 mm to 1200 mm per annum.

3.2.4 Economic activities

The major economic activities in Morogoro rural District are agricultural crop production and livestock keeping. The main food crops and cash crops grown in the district include banana, rainfed upland rice, fruits, coffee, beans, spices, vegetables, maize, cassava, sorghum, simsim. The lowland areas have fertile soil deposited from highlands by floods during heavy rainfall and the area is suitable for rice production. Other land uses include livestock keeping, including pigs, goat, cattle, ducks and chicken and fishing; wildlife conservation and forest reserves. The majority of Mvomero and Morogoro rural Districts economic activities are based on agricultural crop production and pastoralist livestock keeping in the southern part. More than 85% of the population engaged in agriculture produce maize, beans, cassava, sorghum, rice, fruits, coffee, and cotton. The animal husbandry includes cattle, goat, sheep, pigs, chicken and ducks.

3.2.5. Adaptation strategies

Kiroka located in a highland area was characterized as a rainfed production system as the sample farmers practiced upland rainfed rice production. A number of adaptations were practiced in Kiroka areas including agroforestry, planting drought-resistant crops, crop diversification, irrigation farming, usage of chemical fertilizer, changing in planting dates and off-farm activities.

Mkindo and Mgongola were located in Mvomero District. Mkindo was characterized as an irrigated production system as the sample farmers practiced irrigated rice production. Adaptation strategies included mulching, water productivity, planting of drought-resistant crops, early maturing crops, crop diversification, irrigation farming and usage of chemical fertilizer, changing in planting dates and off farm activities. Farmers at Mgongola were involved in rainwater harvesting based lowland rice production system. The main adaptation strategies reported by farmers in Mgongola were planting drought-resistant crops, crop diversification, early maturing crops, irrigation farming, usage of chemical fertilizer, changing in planting dates, water productivity and off farm activities.

3.3 Research Design

This study used a cross sectional approach by collecting data at one episode of time. Cross sectional design is useful because it is cost-effective, less time consuming and much information is obtained in a relatively short period of time and allows data to be collected at one point in time from different individuals or groups of respondents (Bailey, 1998).

3.4 Study Population

The study population was all farmers engaged in small-scale rice production systems in the selected locations. They were targeted because people were located in different agro-ecological zones and practice different production systems in Wami-Ruvu basin and were adversely affected by changes in climate in the crop production in their respective farms.

3.5 Data Types and Sources

3.5.1 Primary data

Primary data were obtained using a structured questionnaires and focus group discussion with key informants were held. Primary data included farmers' perception on climate change effects, adaptation options, input and output prices.

3.5.2 Secondary data

The major sources of secondary data included meteorological stations, Sokoine National Agricultural Library (SNAL), Government institutions such as Tanzania Meteorological Agency (TMA), village offices, various reports from publications including journal articles and reports were accessed. This is due to the fact that additional information from different perspectives was needed to enrich the study**.** These secondary data included the number of farmers using the scheme, investment cost, potential areas for irrigation, down scaled climate data and trends for the last 30 years recorded by different meteorological stations.

3.6 Sampling

Purposive sampling technique was used to obtain the study districts and villages. The main criteria for selection were the different agro-ecological zones and smallholder rice farmers. Morogoro rural and Mvomero Districts were purposively selected for the study. A total of three villages were purposively selected, that is, one village from Morogoro rural District and two villages from Mvomero District. In each village, sampling frame was used to select random samples of 50 smallholder farmers from the village household register. For the sampled household, the head or his representative was interviewed. Therefore, the study covered 150 respondents in total.

3.7 Data Collection

3.7.1. Questionnaire design

A structured household questionnaire with both closed and open-ended questions was used to obtain information on stated objectives and was designed to collect both qualitative and quantitative data from farmers. The questionnaires were pre-tested on 15 households to check their reliability and validity before the main survey (actual data collection). This helped to avoid ambiguity of some of the questionnaire items. The Questionnaire was divided into the following sections: Section A: General information about farmers' household; Section B: Farmers' perception on climate change impact; Section C: Effect of climate change on net revenue; Section D: Cost and Benefit of climate change adaptation; Section E: Farm productive and livestock assets; Section F: Off-farm activities; Section G: Assets-based wealth.

(a) Questionnaire administration

Before conducting research three enumerators with experience were employed and trained on how to ask questions and data recording, importance and objective of the research. After recruitment and provision of training to enumerators, the administration of questionnaire took 4 weeks, between December 2012 and January 2013. Face to face, interviews were conducted with household heads or in some cases the representative household members. Interviews were conducted in Swahili despite the fact that questionnaires were in English. In addition to that, close supervision of enumerators was undertaken by the researcher during the process of data collection to make sure data collected was of high quality.

3.7.2 Focus group discussion and key informant interviews

For qualitative data collection, focus group discussions and key informant interviews were used. Focus group discussions were done in the three villages. The group participants and key informants were chosen with the intent of balancing social aspects such as gender, age and geographical dispersion in the target areas. During the discussion, a checklist with guiding questions was used. The information gathered included farmers perception on climate change impacts, adaptation strategies used in the community by farmers, challenges faced when adapting, costs and benefits of adaptation, production practices used by rice producers and climatic trends for the past few years. Focus group discussion was useful as it allowed freedom of expression and maximum participation in respect to knowledge, experience, opinions and feelings.

Key informant interviews were used to gather great depth of knowledge and additional information from knowledgeable and informed people on the subject matter under study in the study area. They included agricultural and livestock extension officers, members from the nearest meteorological station and the village chairperson. The information collected included how the climate change affected agriculture, adaptation measures with respect to climate change in their areas, investment and maintenance costs for the irrigation schemes and, the climate data for the past 30 years.

3.8 Data Analysis

Primary data were organized, coded, processed and analyzed using qualitative and quantitative methods. MS Excel, Statistical Package for social sciences (SPSS) version 12 and STATA were used to analyze data. Descriptive statistics such as means, frequencies and percentages were derived using SPSS. The analyses were carried out to achieve the study objectives as described below.

3.8.1 Descriptive analysis

Descriptive statistics including means, standard deviation, frequencies and percentage were used to analyse farm data (yield) and economic and socio-demographic profile of respondents.

3.8.2 Quantitative analysis

(a) Assessment of farmers perception on climate change impacts

Likert scale was used to assess and present findings of respondents' perceptions on the climate change impacts in different rice production systems. For each perception measuring statement respondents were asked to state whether they agree, strongly agree, disagree, strong disagree or were neutral (Undecided). In analysing the responses, agree and strong agree responses were combined into one category to indicate strongly agree while disagree and strong disagree were combined to indicate strongly disagree and neutral were treated as don't know (undecided).

(b) Analysis of the determinants of rice productivity and profitability

In production theory, a production function is described in terms of maximum output that can be produced from a specified set of inputs, given the existing technology available to the farm (Battese *et al*., 1992). When the farm produces at the best production frontier, it is considered efficient. The most common assumption is that the goal of the producers is profit maximization; however, it is believed that the objectives and goals of the producer are inter twined with farmers' psychological make-up (Debertin, 1993). Therefore, this objective assumes that producers aim at maximizing output subject to existing constraints and it was analysed by using OLS model.

OLS regression model was useful in estimating the determinants of rice productivity and profitability. Multiple linear regression model applies to the data taken on a dependent variable Y and a set of explanatory variables X_1, X_2, …, X_k with i sets of data. In matrix form, the formula was presented in Equation 1 as follows:

$$Y = \beta X + U \qquad (1)$$

Where, Y represents the matrix of output (kg) and β represent the matrix of the beta coefficients, which explain how change in independent variable influenced change in the dependent variable. X is a matrix with i rows and $k+1$ column and u is the matrix of error term. Thus, the formula can be expanded to fit the prediction between independent and dependent variable as shown in Equation 2:

$$Y_1 = ß_0 + ß_1X_1 + ß_2X_2 + ß_3X_3 + ß_4X_4 + ß_5X_5 + ß_6X_6 + ß_7X_7 + ß_8X_8 + ß_9X_9 + ß_{10}X_{10} + ß_{11}X_{11} + ß_{12}X_{12} + ß_{13}X_{13} + ß_{14}X_{14} + ß_{15}X_{15} + ß_{16}X_{16} + ß_{17}X_{17} + ß_{18}X_{18} + ß_{19}X_{19} + ß_{20}X_{20} + ß_{21}X_{21} + ß_{22}X_{22} + ß_{23}X_{23} + ß_{24}X_{24} + u \qquad (2)$$

Where; Y_1 = Output, $ß_0$ = Intercept; $X_1 \ldots X_{24}$= independent variables; u = Error term

Profitability (Y_2) determined as gross margin is defined as gross revenue less total variable cost per hectare (Olujenyo, 2008). The variable costs included labour cost, labour squared, seeds, seeds squared, herbicides, fertilizers, fertilizer squared. The same independent variables included in the production model were also fitted in the profitability model. Mathematical expression is shown in Equation 3 as follows:

$$Y_2 = ß_0 + ß_1X_1 + ß_2X_2 + ß_3X_3 + ß_4X_4 + ß_5X_5 + ß_6X_6 + ß_7X_7 + ß_8X_8 + ß_9X_9 + ß_{10}X_{10} + ß_{11}X_{11} + ß_{12}X_{12} + ß_{13}X_{13} + ß_{14}X_{14} + ß_{15}X_{15} + ß_{16}X_{16} + ß_{17}X_{17} + ß_{18}X_{18} + ß_{19}X_{19} + ß_{20}X_{20} + ß_{21}X_{21} + ß_{22}X_{22} + ß_{23}X_{23} + ß_{24}X_{24} + u \qquad (3)$$

Explanation of variables and prior expectations

Labour (X1): Labour was expected to have a positive relationship with profit and productivity. Labour availability will enable a farmer to undertake farming operations effectively and timely. Labour persons days were calculated to obtain cost of hired labour as follows: Labour persons days = [(number of family labour engaged in production x effective days x number of hours) /8 working hours].

Similarly, **labour (X2)** were squared to see its linearity with the dependent variable. According to the study done by Olujenyo (2008) in Nigeria, labour has a significant influence on output. Therefore, the coefficient was expected to have a positive effect on both production and profitability, as family labour engagement tends to improve production by reducing cost for hiring labour.

Seeds (X3): Seed was expected to have a positive relationship with production and profitability. The amount of seeds was measured in kilogram per hectare. Seed is the major input used in production function (Fred *et al.*, 2012). Similarly amount of seeds were squared (**X4**) to determine the nature of incremental increase in output and profit. Therefore, the coefficient was expected to have a positive sign on profit and production.

Fertilizer (X5): Fertilizer was expected to have a positive relationship with production and it was in kilogram per hectare. Fertilizer enhances the productivity of land and can not be excluded from production (Fred *et al*., 2012). Moreover, to determine the effects of further application of fertilizer on the production and returns to land, amount of fertilizer used per acre was squared (**X6**). Therefore, the coefficients of fertilizer in the production and profitability models were expected to be positive.

Herbicides (X7): The variable was measured in litre per hectare and it was expected to have a positive relationship with production and profit. Farmers control pest by using herbicides, which is expected to increase rice production. Therefore, the coefficient was expected to have a positive sign in production and profit.

Seasonal rainfall (X8): Seasonal rainfall was expected to have a positive relationship with production and was measured in milimetres. As rainfall increases production also increases. *Masika* rainfall was taken as a variable for all the production systems due to the availability of enough rainfall /moisture and the sign for the respective coefficient was expected to be positive in the production and profit model.

Seed Variety (X9): The dummy variable was included in the model to show the influence of seeds variety on dependent variables and it was measured in kilogram per hectare. The dummy variables were constructed as ‘1’ for those who used improved seeds and ‘0’ for those using local seeds. The coefficient of this variable was expected to be positive in production and profitability because improved seeds have a positive impact on both crop production and profitability. Herath and Kewasaki (2011) reported that, new rice varieties provided high yield, temperature resistance and consumed less water.

Soil water holding capacity (X10): The dummy variable was included in the model to show the positive influence of soil water holding capacity on dependent variables (profit and production). The dummy variables were ‘1’ for high soil water holding capacity and ’0’ for low soil water holding capacity. The relationship was expected to be positive because high soil water holding capacity has a positive impact on crop production as it improved the soil moisture for plant growth, increase production hence profit. Thus, the coefficient was expected to be positive in the two models.

Age category (X11): The age related dummy variables were coded ‘1’ for active age with less than or equal to 40 years of age and ‘0’ those older than 40 years. Age was expected to have a positive relationship with productivity and profit, since older farmers may be more experienced in production activities. Fleischer (2007) argues that age reflects managerial and experience of the farmer as it increases production and farm profit. Therefore, age category as a dummy variable was included in the model to show its influence on the dependent variable. Thus, the coefficient was expected to be positive in the production and profitability model.

Gender of the household (X12): The dummy variables for gender were coded ‘1’ for female household and ‘0’ for male household. Gender of the household was included in the model to show its influence on production and profit. In most rural smallholder farmers, specifically women have more farming experience and various information on different management practices, as they tend to do most of the agricultural work (IFPRI, 2007). This is one dimension the other is that women have limitation of accessing productive resources such as land, they may also be excluded in extension and training as men may attend these trainings. In addition, male members of the household were expected to participate more in farming activities and in long working hours compared to women. The coefficient was expected to have a positive sign on productivity and profitability.

Access to extension services (X13): The dummy variable for extension service was included in the model to show the influence of extension services on the dependent variables. The dummy variable was coded with the value of ‘1’ for those who had access and ‘0’ for those who did not have access to extension services during the production period. Extension services were expected to have a positive relationship with productivity and profitability. It makes farmers aware of the production activities and information on adoption of different technologies. Free extension services significantly increase the likelihood of farmers to participate effectively in agriculture production (IFPRI, 2007). Therefore, the coefficient was expected to have a positive effect on both production and profitability.

Access to credit (X14): The dummy variable for credit was included in the model to show the influence of credits on the dependent variables (productivity and profitability). The variable was '1' for those who had access and '0' for those who did not have access to credits. Credit was expected to have a positive relationship with productivity and profitability. Credit is a useful input in any production activity as it helps farmers to purchase the necessary agricultural inputs for production. Most of the farmers who have access to credits are expected to improve their production and farm income (Thapa, 2010). Therefore, the coefficient was expected to have a positive sign on both production and profit function.

Off-farm engagement (X15): The dummy variable for off-farm engagement was included in the model to show the influence of off-farm engagement on dependent variables (profit and productivity). The variable was coded '1' with main activity of a farmer being off-farm and '0' for otherwise. Farmers with access to technology are also more likely to diversify into non-farming activities, although households with large investments in farm equipment and machinery may find such diversification to be costly (IFPRI, 2007). Thus, the coefficient for the two models was expected to be positive.

Food security (X16): The dummy variable for food security was included in the model to show positive the influence of food security on dependent variables. The variable was coded ‘1’ for food self-sufficient and ‘0’ for otherwise. Food security is a measure of how often a household could satisfy its food needs that is it shows production sufficient for a year. Thus, the coefficient was expected to be positive for the two models.

Farm size (X17): The size of the farm was positively related to production. The variable farm size was measured in hectares. The respondents with large farm size tend to realize increased production and vice versa for those respondents with smaller farm sizes. Farm size was squared (**X18**) to see its linearity with dependent variables. Operators of large farm sizes are likely to use improved technologies thus increasing production and profit (Hassan and Nhemachena, 2008). Hence, the variable was expected to have a positive sign in the two models.

Household size (X19): Household size expressed as the number of the people living in each household. Size of the household was expected positively related to production. Therefore, as the household size increases further / squared (**X20**) then labour force may increase in the family, hence increase production and profit. Thus, the coefficient was expected to have a positive sign.

Education (X21): Education had a positive relationship with production and profit. It was constructed from the number of years a farmer spent in school. Education availability allows farmers to participate better in production and able to adapt new innovations effectively and efficiently (Gbetibouo, 2009). Education level of the household was squared (**X22**) to see its linearity with the dependent variable. As number of years spent in school increase further, the respondents’ exposure to education will increase the farmers’ ability to utilize information in order to improve production and profit. Therefore, the coefficient was expected to have a positive sign on the two models.

Relative diversity of farm tools (X23): The variable was expected to have a positive contribution with production and profitability. The variable was measured as the ratio between the number of farm tools possessed and number of common tools in that system as follows: Relative diversity of farm tools = Number of farm tools possessed/Number of common tools in that system. The sign for the coefficient was expected to be positive for the two models.

Assets-based wealth (**X24**): Assets- based wealth was measured in numeric index and the variable was expected to have a positive relationship with production and profit. Increase in assets-based wealth increases production and profit. Therefore, the sign of the coefficients was expected to be positive for production and profitability model.

Moreover, in the OLS model, the data were pooled because the sample size of 50 observations for each system was not sufficient in explaining the determinants of rice production and profitability.

(c) Economic impacts of climate change on rice production for different emission scenarios

Impact of future climate change scenarios on net farm revenue were simulated / predicted using the results from the estimated coefficients for net revenue function. In the simulations, the only variables subjected to change were the climate variables (temperature and rainfall), other factors remained the same. The data set included baseline scenario (1970-2010) and mid-century climate change (2040-2070) under A2 and B1 emission scenarios. The climate parameters used were the average annual monthly temperature and rainfall during the growing season. The data set was for two climate emission scenarios (A2 and B1) were used to forecasts percentage change in net farm revenues. The forecasts were calculated for each farmer separately and then aggregate net farm revenue was calculated and compared to the aggregate profit in the base year using t-test.

The unpaired, or "independent samples" *t*-test" method was used between the treatment group (estimated net farm revenues from future climatic scenarios revenues) and control group (estimated net farm revenues from the baseline).

(d) Estimation of the costs and benefit of adaptation strategies in different rice production systems

A Discounted Cash Flow (DCF) technique was used to analyse the economic viability of adaptation options in three different production systems. The assumptions made in the analysis include: (i) the time horizon of 30 years was chosen because climate change is a long-term phenomenon, therefore forecasting for the future years is necessary (ii) Stern's discount rate of 1.4% (Stern, 2006) was used for adaptation investment with social implication on future generation under a changing climate. Stern discount rate was adopted being unusually low compared to commercial interest rate. The relevance of Stern's discounting rate is based on the fact that it attaches more weight on the future effects of climate change (Dietz, 2008) – hence favoring adaptation action now. The Sterns' discount rate is given by Ramsey's equation (Ramsey, 1928).

$$S = \rho + \mu g \qquad (4)$$

Where:

'S" is the social discount rate, "ρ" is the rate of pure time preference, "μ" is the elasticity of the marginal utility of consumption and "g" is the rate of growth of per capita consumption. Stern (2006) suggested that ρ is 0.1%, μ is 1% and g is 1.3%, therefore he found that, as shown in Equation 5;

S = 0.1 + (1*1.3) = 1.4 %...(5)

The mathematical equations underlying the computation of NPV, BCR and the criteria for accepting an investment project in each case are given in subsequent sub-sections.

Benefit – Cost ratio

The Benefit–Cost Ratio (BCR) is calculated as the net present value of benefits divided by net present value of costs. Also, it can be expressed as the ratio of all discounted (present) incremental benefit over discounted (present) cost of the project. It is the benefit generated by the project per unit cost of the project. The formula is expressed as follows in Equation 6:

$$B/C = \sum_{t=0}^{n} \frac{B_i}{(1+i)^t} \Big/ \sum_{t=0}^{n} \frac{C_i}{(1+i)^t} \qquad (6)$$

B = benefit at time t, *C* = cost at time t, *i*= interest rate at time t, *NPV* = net present value at time t and *t* = time horizon.

Selection criteria

BCR >1 means present value of benefits are greater than present value of costs.

BCR<1 means present value of costs exceed present value of benefit.

BCR=1 means present value of benefits are equal to present value of costs.

Therefore, projects or adaptation options with BCR greater than or equal to 1 are viable and economically acceptable for implementation, unlike the project or an adaptation with BCR less than 1 which is not economically viable and not good for implementation.

Net Present Value

Net present Value is expressed as discounted (present value) benefit minus discounted (present value) cost. Cash outflow comprised of fixed cost and variable costs.

These include investment cost and input costs for producing output (crops) while cash inflow comprised of the revenue obtained from crop sales. Therefore, mathematical expression of Net Present Value was as follows in Equation 7;

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t} \qquad (7)$$

Where; *B* = benefit at time t; *C* = cost at time t; *i*= interest rate at time t; *NPV* = net present value at time t and; *t* = time horizon.

Selection criteria:

NPV greater than zero represents viable adaptation option/project while NPV less than 0 shows that project were not viable or adaptation options were not viable.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Demographic and Social-Economic Characteristics of the Respondents

The socio-economic profile of the respondents examined were age, marital status, household size, education of the respondent, main activities of the respondents, perception on climate as follows:

4.1.1 Age of the respondents

The distribution of the respondents according to age was as presented in (Table 1). The age of the respondent indicated that experience had an influence on agricultural production and adaptation options. A large proportion of respondents were 32-51 years old, followed by over 51 years old and few respondents were in the age below 32 years old. This implied that rainfed area had large group (58%) of active people aged between 32-51 years followed by irrigated (56%) and rainwater harvesting area (44%). Therefore, results of this study revealed that, many of the households' heads were in the age group of active people and could take actions on adaptation measures on the climate change.

4.1.2 Education level

The distribution of respondents by education level indicated that most of the respondents in irrigated area had primary education (78%) and beyond secondary education (4%) compared to non-irrigated areas (Mgongola and Kiroka). Rainfed area had high level of illiteracy (28%) compared to other villages. In addition, rainfed and rainwater harvesting areas had equal number of respondents with secondary education (6%) compared with respondents from irrigated (4%) Based on these findings, one could infer that farmers with high level of education marginally had more knowledge and information on good agricultural practices, coping and adaptation strategies and, those farmers with tertiary education were able to synthesize information much better than those who had less formal education or illiterate. This indicated that farmers' education and skills were important factors in production activities; adaptation of strategies (options) against adverse effects of climate change.

4.1.3 Household size

Irrigated area had higher percentage of the household size, 5-7 members, (48%) compared to rainfed area (42%) and rainwater harvesting area (38%) locations (Table 1). Results from this study indicated that large household size might have positive impact in the improvement of the productivity especially if members fully participate in farming activities. These findings indicated that households with large farm size were more likely to engage in agricultural production, take advantage of high production in agriculture and are more likely to adapt to climate change.

4.1.4 Main activities of the head of the household

Majority of the respondents in rainwater harvesting areas (72%) were engaged in crop production and, other activities (28%) such as causal labour and livestock keeping. Most of the respondents in rainfed areas (44%) engaged in crop and livestock production compared to irrigated (16%) and rainwater harvesting (12%). The majority of the people in irrigated area (18%) earned their living from crop production and business followed by rainwater harvesting (16%) and rainfed category (10%). This suggested that, crop production was the major activity in the study area followed by livestock keeping while off farming activities and engagement of work for wages were taken as coping strategies to supplement income and against climate change impact in the study area.

Table 1: Distribution of respondents by social and economic characteristics

Variables	Kiroka (Rainfed) Frequency	%	Mgongola (RWH) Frequency	%	Mkindo (Irrigated) Frequency	%
Sex						
Male	25	50	32	64	35	70
Female	25	50	18	36	15	30
Total	50	100	50	100	50	100
Age						
< 32	9	18	12	24	12	24
32 – 51	29	58	22	44	28	56
Above 51	12	24	16	32	10	20
Total	50	100	50	100	50	100
Education level						
No formal education	14	28	11	22	7	14
Primary	33	66	36	72	39	78
Secondary	3	6	3	6	2	4
Beyond Secondary	0	0	0	0	2	4
Total	50	100	50	100	50	100
Household Size						
< 2	6	12	12	24	7	14
3 – 4	18	36	17	34	14	28
5 – 7	21	42	17	34	24	48
8 – 10	3	6	4	8	4	8
11 and above	2	4	0	0	1	2
Total	50	100	50	100	50	100
Household Activities						
Crop production	21	42	36	72	33	66
Crop and Livestock	22	44	6	12	8	16
Crop and Business	5	10	8	16	9	18
Others (Livestock and causal labor)	2	4	14	28	0	0
Total	50	100	50	100	50	100

4.2 Technical services and input used

4.2.1 Extension services

Extension service is an important factor in production activities and when choosing adaptation options to use at the farm. Table 2 reveals that high proportion (82%) of the respondents in rainwater harvesting areas claimed that, although they were aware of the availability of the extension personnel, they had no access to extension services compared to those in rainfed areas (48%) and irrigated areas (8%). This is due to the assumptions made by some of the farmers they knew everything and that there was no need for soliciting extension services. The majority (92%) of the sample population in irrigated areas had access to extension services followed by rainfed (52%) and lastly by rainwater harvesting (18%) area population. This indicated that those who had access to extension services improved their production through using good agricultural management practices and acquired information on sound adaptation measures which could be used reduce the impact of climate change. The results indicated that extension services provide information which increases the likelihood to adapt to climate change.

4.2.2 Access to loans

Most of the farmers in rainfed area accessed loans (40%) than those in irrigated (32%) and rainwater harvesting (14%) (Table 2).The rainwater harvesting area had the largest proportion of sample population (86%) with no access to finance compared to irrigated (68%) and rainfed area (60%). Institutions such as CRDB bank provide financial services to farmers especially those involved in irrigation activities. This is due to the fact that this type of activity tends to provide profit to farmers and provides a good return after harvesting compared to those who depend solely on rainfed crop production activities. Access to finance enabled farmers to purchase the necessary inputs, such as, fertilizers, improved seeds and farm implements. Also farmers with access to finance services were in better position to use the facilities to cope with the climate change impacts. The findings indicated that access to credit had a positive influence on farmers' adaptation of strategies and that lack of finance, and other inputs, hindered resource availability and made farmers fail to afford costs related to adaptation.

4.2.3 Inputs

Majority of the respondents used inputs (Table 2). In irrigated areas 88% of the farmers used improved seed varieties and the rest of the respondents (12%) used traditional seeds. In case of rainwater harvesting, 22% of the sample population used improved seeds and 78% local seeds. In rainfed area 16% of the respondents used improved seeds while majority of the respondents (84%) used traditional seeds. Household that used improved seed varieties such as Salo TXD 306 and 220 were able to get high yields compared to those who used traditional seeds such as *Supa Mbeya, Masantura, Rangimbili* and *Tule na Bwana*. For example, in Mkindo, Salo TXD 306 was mostly used in irrigation as was high yielding within a short time (matured within 120 days) and under good management could produce 3 tons of rice per acre. This variety is drought and disease resistant and is semi-aromatic. *Mbawambili* variety is drought-tolerant but low-yielding (in rainwater harvesting and rainfed areas) and takes more than 6 months to mature. Therefore, farmers who used improved seeds and had information on good agricultural practices were in a better position to reduce the impacts of climate change vulnerability and opt for adaptation measures.

Table 2: Technical services and type of seeds

	Kiroka (Rainfed)		Mgongola(RWH)		Mkindo (Irrigated)	
Variables	Frequency	%	Frequency	%	Frequency	%
Access to extension services						
Yes	26	52	9	18	46	92
No	24	48	41	82	4	8
Total	50	100	50	100	50	100
Access to finance						
Yes	20	40	7	14	15	32
No	30	60	43	86	35	68
Total	50	100	50	100	50	100
Type of seeds used						
Improved	8	16	11	22	44	88
Local	42	84	39	78	6	12
Total	50	100	50	100	50	100

4.3 Gender Perspective on Economic Characteristics and Climate Change

4.3.1 Gender and access to extension services

Gender responsibilities and participation is important in any economic activity. It shows the role which males and females play. Table 3 shows the engagement of males and females in different activities. Females had slightly more access to extension services (56%) than males (52%). The reason could be that females were more engaged in production and thus eager to get more information on production, climate change and its effect to the environment. Furthermore, male respondents in the studied villages did not have access to extension services (48%) compared to female respondents (44%). The reason could be that most men thought they had adequate information on these issues. Therefore, this concludes that female had slightly more access to information obtained through extension services and could use it improve production and; through awareness and adoption of strategies reduce adverse impacts of climate change in their areas.

4.3.2 Gender and access to credit

Females had more access to credit (40%) compared to males (22%) (Table 3). This could be due to the fact that most of the women were members of micro finance institutions including savings and credit cooperatives (SACCOS) compared to men. Also those women engaged in irrigation production had more likelihood of accessing credit because they could easily pay back the loan through higher returns.

Table 3: Gender perspective on technical, credit and climate

Activity	Male Percentage	Female Percentage
Access to extension service		
Accessed	52	56
Not accessed	48	43
Total	100	100
Access to credit		
Accessed	22	40
Not accessed	78	60
Total	100	100
Threat to climate change		
Health	3	7
Agriculture	76	64
Both Health and Agriculture	21	27
Fuel wood availability	0	2
Total	100	100
Adaptation strategies		
Grow drought resistance crops	10.9	6.9
Early mature crops	5.4	1.7
Crop diversification	8.7	10.3
Switch to off farm activities	2.2	5.2
Mulching	1.1	1.7
Irrigation	10.9	12.1
Chemical fertilizer	17.4	10.3
Water productivity	1.1	1.7
Change planting dates	5.4	3.4
Afforestation	0	5.2
No adaptation	37	41.4
Total	100	100

4.3.3 Gender and climate change perceptions

Climate extremes, such as, high temperatures and low rainfall are threats to production. The findings from this study revealed that female respondents perceived that climate change had more impact on health and fuel wood availability. The male respondents perceived that climate change was a serious threat on agriculture (76%) as it resulted into decline in rice production, increase in diseases and food prices (Table 3). The results indicated that females were more aware than males on climate change impacts in the studied areas especially on health, agriculture and fuel wood availability. Females had more access to the extension services and information from other sources such as radio, newspapers.

4.3.4 Gender and adaptation strategies

Female respondents were of the opinion that irrigation (12.1%), crop diversification (10.3%), use of chemical fertilizers (10.3%), off- farm activities (5.2%), change in planting dates (3.4%), mulching (1.7%) were the major adaptation options in rainfed and irrigated areas (Table 3). Female respondents also asserted that planting of trees / afforestation (5.2%) was also the best adaptation strategy as it shielded crops against strong winds, while male respondents did not mention afforestation as an adaptation option. Also 41.4% of female respondents thought that there were no adaptation options compared to 37 % of male respondents.

4.3.5 Gender aspects regarding costs and benefits

Table 4 shows that a high percentage of male respondents (62%) owned irrigated land; 56% owned rain water harvesting and (38%) rainfed land. Females owned 30% of land in rainfed area, 18% in rainwater harvesting and 16% in irrigated areas. Equal proportion of land (14%) in rainwater harvesting and irrigated area is owned by both males and females compared to rainfed (18%).

Despite the fact that males and females in the studied area owned land, a few of the respondents did not own land (14%) in rainfed areas, (12%) in rainwater harvesting areas and (8%) in irrigated areas. Most of the land owned was used for production residential and/or commercial activities. Even though a large percentage of males owned land, they incurred production expenses such as purchase of inputs, harvesting, transportation and fixed costs.

It was observed that 18% of the male respondents in rainfed owned production assets, 54% in rainwater harvesting area and 48% in irrigated area owned production assets. Despite the fact that males owned most of the production assets, females also owned production assets and participated in farming activities.

Table 4: Gender and production

	Rainfed				RWH				Irrigated			
Activities	**%Husband**	**%Wife**	**%Both**	**% Not owned**	**%Husband**	**%Wife**	**% Both**	**% Not owned**	**%Husband**	**%Wife**	**% Both**	**% Not owned**
Land ownership	38	30	18	14	56	18	14	12	62	16	14	8
Production assets	18	16	66	0	54	20	26	0	48	10	38	0
Farming activities	4	14	82	0	28	8	76	0	12	2	86	0
Cost of Production	24	18	58	0	60	16	24	0	72	14	14	0
Accrued benefit	4	12	84	0	30	12	58	0	14	6	80	0

*n=150

Gender role was an important factor in production. A large proportion (30%) of respondents in rainwater harvesting areas owned accrued benefits compared to 14% in irrigated and 4% in rainfed areas. An equal proportion of female respondents in rain fed and rainwater harvesting (12%) owned accrued benefits compared to 6% in irrigated areas.

The conclusion was that there was gender balance among all the villages. A large proportion of male smallholder farmers in rainwater harvesting areas owned production assets and participated in farming activities compared to other studied areas. Females participated more in farming activities compared to males in rainfed areas, smallholder farmers in rainfed areas incurred more costs of production and owned the accrued benefit compared with other areas.

4.4 The Perception of Farmers about Climate Change Impact

4.4.1 Threat from climate change

The perceptions regarding threats from climate change impacts differed among farmers (fig. 3). The study found that climate change was perceived to have more impact on agriculture than on other sectors, as agriculture depended much on rainfall compared to other sectors. A few respondents (about 2%) perceived climate change impacts in the health sector and fuel wood availability. While (10%) of the respondents in rainfed system perceived that there were no threats from climate change in any of the livelihood sectors. This was due to lack of knowledge and awareness on the impacts caused by the climate in those sectors.

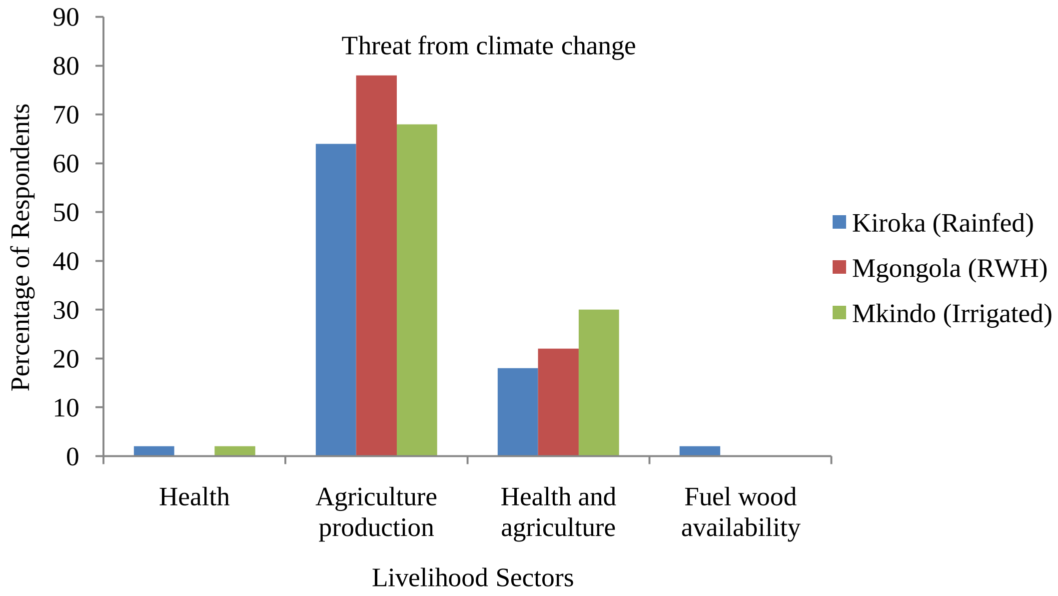

Figure 3: Farmers perception on threat from climate change

4.4.2 Perceived impacts of climate change on rice production

The majority of the respondents (98%) across the rice production systems perceived climate change to have impacted negatively on rice production (Fig. 4). Climate change impacts all the production systems with differing magnitude of impacts on yields that can not be explicitly conceived in mere perception of farmers. Under a changing climate, with no adaptation, rainfed areas and RWH experienced low yields of 0.72 tons per hectare, which was below the average national rice production in comparison with other systems. For example, RWH and irrigated systems had production level of 1.24 and 4.51 tons per hectare, respectively, under a changing climate. Therefore, farmers were aware of the adverse effects of climate change on rice production.

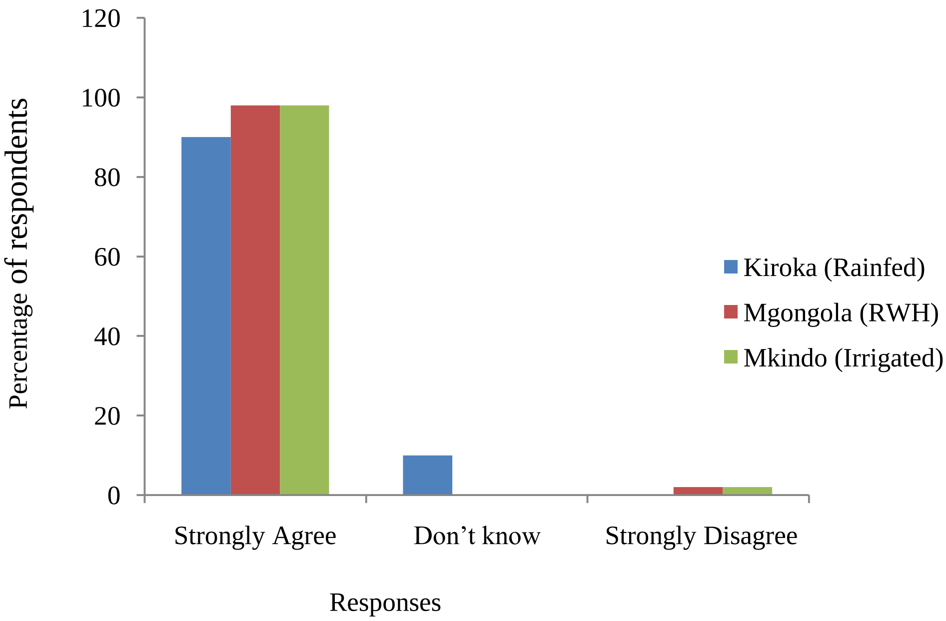

Figure 4: Perception of climate change impact on rice production

4.4.3 Rainfall-related production risks

Results from the FGDs conducted in Rainfed, RWH and irrigated areas indicated that there were changes in rainfall patterns for the past thirty years. For example in the past 30 years (1980’s) *Masika* rain season regularly started from March to June; the dry season started from July to August; and *Vuli* from September or mid-October. In Kiroka where rainfed rice production is practiced, for the past 30 years *Masika* regularly started from February to June; the dry season from June to July; while *Vuli* started from August to September. Due to heavy rainfall in year 1999, irrigated areas experienced floods which had big impacts on their livelihoods (Daninga, 2011).

Furthermore, respondents reported that in recent years the *Vuli* and *Masika* rains were not predictable in Irrigated and RWH areas. *Masika* usually lasted from February to July while *Vuli*, with relatively low amount of rainfall, lasted from September to December. These seasons’ patterns led to change in the crop pattern and for example, the main crops grown currently were rice and maize. In Kiroka where rainfed rice production is practiced, currently *Masika* lasted from February to April; the dry season from May to September; while *Vuli* lasted from October to December and the main crops grown were banana, maize, sorghum, cassava and rice. Therefore, the changing pattern of rainfall regime resulted into a number of production risks that farmers had to bear over time.

4.4.4 Flooding

Results in Table 5 show that about and over three quarters (74% and 88%) of the respondent farmers in RWH and irrigated areas concurred with the argument that due to the change in rainfall pattern, the incidences of floods had increased in their areas. The incidences of floods were relatively less perceived by farmers in a rain-fed farming system.

Table 5: Perceptions on flooding risk

Responses	Kiroka (Rainfed)		Mgongola (RWH)		Mkindo (Irrigated)	
	n	%	n	%	n	%
Strongly Agree	33	66	37	74	44	88
Don’t know	5	10	0	0	0	0
Strongly Disagree	12	24	13	26	6	12

The lowland irrigated and RWH crop land landscapes are prone to flooding with high intensive rains. For example, in year 1999, floods occurred in Mgongola and led to the destruction of houses and farms. In rain-fed uplands, the hilly land scapes facilitated drainage of excessive rain currents down the slopes, hence reduced the threat of flooding.

4.4.5 Crop failure

The results in Table 6 indicate that majority of respondents (88%-100%) across the rice production systems perceived that rainfall related risk due to climate change and variability caused crop failures.

Table 6: Perception on crop failures risk

Responses	Kiroka (Rainfed)		Mgongola (RWH)		Mkindo (Irrigated)	
	n	%	n	%	n	%
Strongly Agree	44	88	50	100	45	90
Don't know	5	10	0	0	1	2
Strongly Disagree	1	2	0	0	4	8

These observations corresponded with the findings from the study reported by IFPRI (2007) that, farmers perceived that drought, heavy rainfall and floods were the major causes of crop failure. This implied that rainfall fluctuation also affected crop production much in the study area.

4.4.6 Drought risk

Drought aggravated by climate change and variability has led to impacts in crop production. These impacts include reduced and failed crop yields, increased crop pest infestation and diseases. Results in Fig. 5 show that most of the respondent farmers (> 90%) agreed that drought had adversely impact their rice production. According to Daninga (2011) the high frequency of drought was a result of numerous economic activities. This culminated into the destruction of the environment and adversely affected rainfall formation cycle hence minimizing chances of having rainfall in the area. For example, it was observed that due to increased population pressure forests had been encroached by farmers in search of agricultural land and firewood collection.

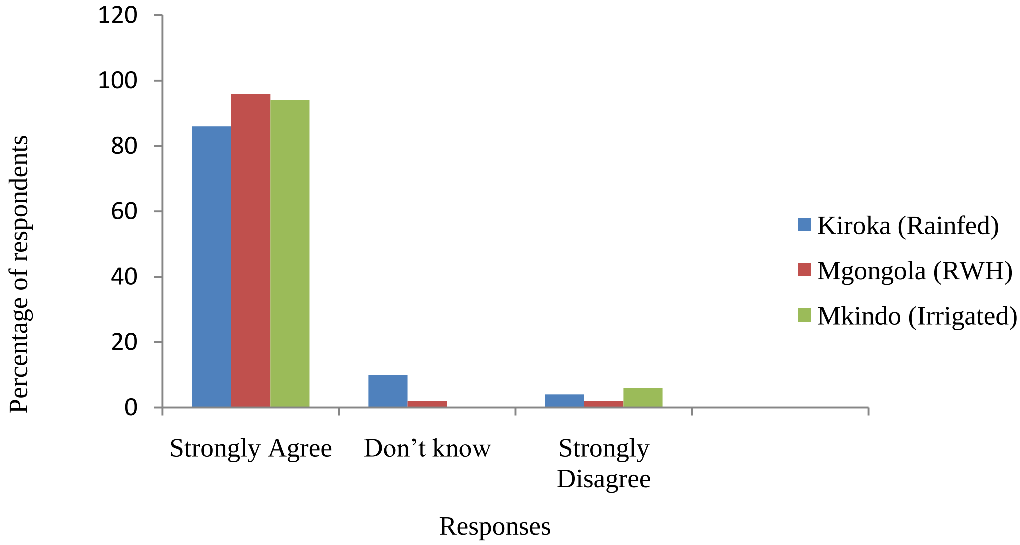

Figure 5: Farmers perception on drought risk

4.4.7 Climate change and rural urban migration

Respondents were asked whether climate change led to rural urban migration or not. Table 7 indicates that over a half of the sampled farmers in the three production systems agreed that climate change effect led to increased rural-urban migration. However, the rural-urban migration problem was not widely (only 54% compared to 74% and 80%) perceived by farmers in the irrigated areas as compared to farmers in other rice systems. The reason behind was that, irrigation provided an opportunity of risk-roofing farming compared to other systems. Most of the farmers in irrigated area were observed to have adapted well some coping technologies such as the use of improved seeds and fertilizers.

Table 7: Rural urban migration due to climate change

Responses	Kiroka (Rainfed)		Mgongola (RWH)		Mkindo (Irrigated)	
	n	%	n	%	n	%
Strongly Agree	40	80	37	74	26	52
Don’t know	6	12	1	2	4	8
Strongly Disagree	4	8	12	24	20	40

Therefore, due to ecological and economic hardship resulting from the impact of climate change, respondents in RWH and rainfed systems were compelled to immigrate to urban and peri-urban areas to look for the alternative sources of livelihood.

4.4.8 Impact of climate change on food price

Food expenses were widely perceived and reported to increase due to climate change impacts in all rice production systems (Fig. 6). Increased food costs could be accounted for by the high demand caused by the low crop production. Theoretically, the quantity of a product produced is inversely related to the price. The scarcity caused by low production, in part due to climate change, would lead to hiking of food prices.

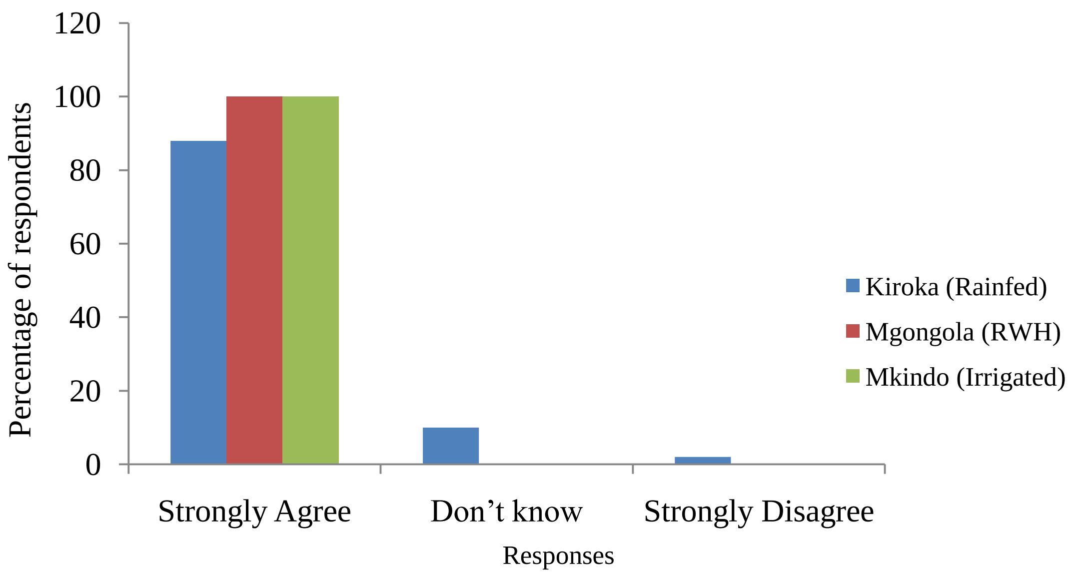

Figure 6: Farmers perception on food price

Moreover, results from FGDs indicated that the average price of a bag of rice (90 kg) in year 2009 was Tshs. 50 000 and by the year 2011 had reached an average price of Tshs. 110/bag. This was an indication that food expenses were not constant because of erratic rains in the area (Daninga, 2011).

4.5 Awareness of Climate Change, Adaptation Measures and Hindrances to Adaptation

4.5.1 Farmers' perception on climate change and adjustment to reduce the impacts

The information on establishment of the level of awareness of climate change and adaptation measures taken to reduce climatic risks indicated that the majority of farmers across the rice production systems were aware of the climate change adaptation measures (Table 8).

Table 8: Awareness on climate change and adjustment to reduce its impact

Village name	Awareness		Actions to reduce the impacts	
	n	%	n	%
Kiroka (Rainfed)	43	86	21	42
Mgongola (RWH)	49	98	24	48
Mkindo (Irrigated)	48	96	38	76

Results from the focus group discussions revealed that farmers were aware of climate change, its impacts and reported different adaptation and coping measures (mulching, irrigation, rainwater harvesting). These measures include some that were actually implemented by farmers and some that could be potentially implemented.

4.5.2 Climate change adaptation strategies

Production risks associated with climate change and variability influenced smallholder farmers to take necessary measures so as to avoid and reduce the negative impacts.

The use of chemical fertilizer was a widely used adaptive strategy in the irrigated system in comparison with other rice systems (Fig.7). Despite its potential in increasing productivity the use of fertilizer was still limited particularly in rainfed and RWH systems. An irrigation possibility reduces the production risk due to secured access to agricultural water, hence prompting the use of costly inputs such as fertilizer among smallholders that are inherently risk-averse. Other important adaptation used in the studied rice systems included irrigated farming, crop diversification, planting of drought resistant varieties, off-farm activities, planting early maturing varieties, mulching and afforestation.

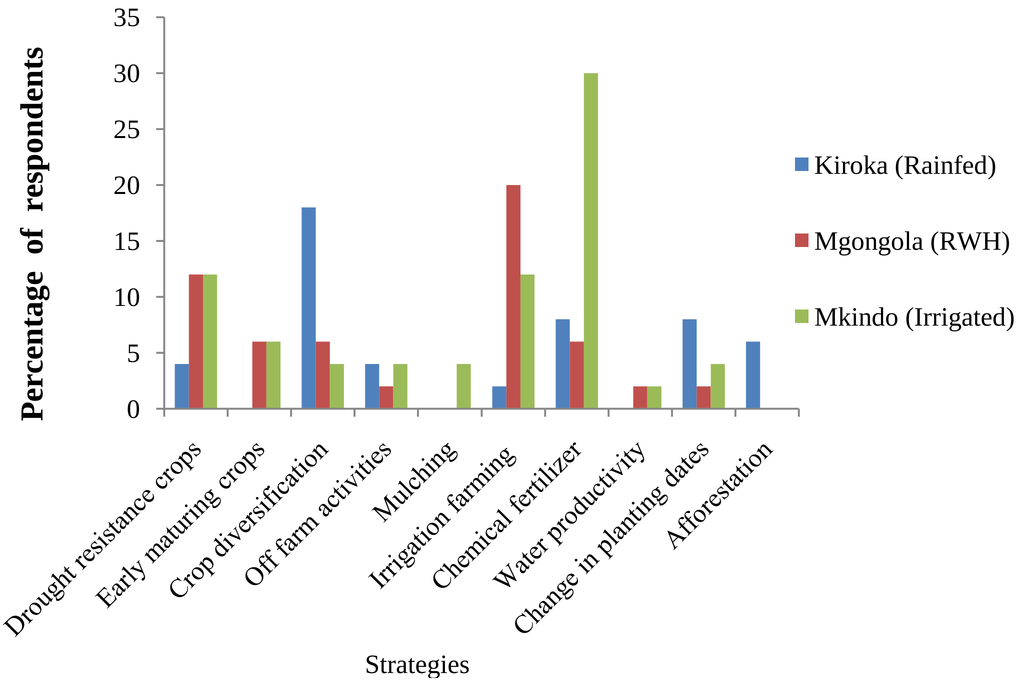

Figure 7: Adaptation strategies

These observations were similar to those made by Herath and Kawasaki (2011) who confirmed that green management of soil fertility was an alternative sustainable way of adaptation as increased use of chemical fertilizer to attain higher yields led to higher costs and lower profits. Therefore, smallholder farmers should be given knowledge and education on other important climate-proofing adaptation strategies such as system of rice intensification (SRI), use of adapted improved seeds and fertilizers such as upland rainfed rice (*Nerica*), so as to reduce the impacts of climate change and improve productivity.

4.5.3 Hindrances to adaptation

Several factors might hinder farmers from attaining or practicing effective adaptation strategies. Results in Fig.8 indicate that lack of knowledge on adaptation methods was the most critical factor acting as a barrier to adaptation in rainfed (66%), RWH (32%) and irrigated areas (36%). This could be due to poor or lack of access to agricultural education and extension services among farmers. A sizeable proportion of farmers (14%-36%) lacked capital for acquisition of modern technologies (tractors) and inputs across the rice production systems. Moreover, 30% of respondents in RWH reported lack of access to water for irrigation that would have mitigated production risk. There are possibilities of upgrading RWH through investment in water storage such as mini-dams in order to promote irrigation in a RWH-based system.

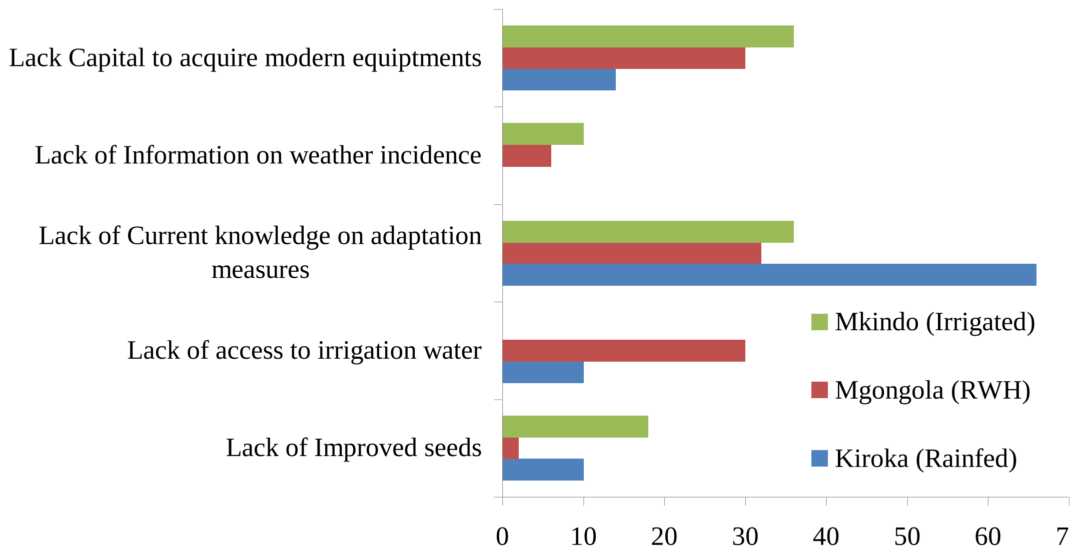

Figure 8: Hindrances to Adaptation

4.6 Determinants of Productivity and Profitability on Rice Returns to Land

4.6.1. Determinants of productivity

Labour is a necessary input factor for any rice production. Descriptive results (Table 9 and 10) show that mean family labour was 174 man-days per hectare. This indicated that smallholder farmers depended heavily on family labour in their rice farming activities to make it productive and profitable (Fred *et al.*, 2012). The household size ranged from 4.5 to 26. The mean age of farmers was 42 years indicating that most of the households were in the active age group for engaging in farming. Household heads had a mean of 5 years of formal education, an indication that most of the farmers attained primary education. The average farm size was 0.52 ha. This implied that the study mostly covered small farms where on average farmers cultivated less than one hectare. The average fertilizer application on the farm was 72 kg/ha for those few who applied it. Herbicides were used to control weeds at the average amount of 0.62 litres/ha. The average amount of seeds for rice production used by farmers was 465.92 kg/ha.

The ordinary least square regression results linking rice output (production) to farm exogenous variables had an F-value of 8.69. This indicated that the model was able to significantly ($P<0.01$) account for the joint variation of independent variables with the dependent variables. The R^2 value of the variables included in the estimated regression equation accounted for 55% of the variations in the production model. This indicated that regression model was good at explaining the relationship between dependent variables and independent variables.

Moreover, the independent variables, such as labour, amount of seeds squared, fertilizer, seasonal rainfall, seed variety, access to extension services, relative diversity of farm tools, food security were statistically significant (at levels ranging from $P<0.1$ to $P<0.01$). Labour had a significant influence on rice production ($P<0.05$). A unit increase in labour -person day resulted into an increase in the amount of output. The relationship between labour and production was positive and statistically significant. This implied that a unit change in labour person -day resulted in a significant ($P< 0.05$) improvement of rice production as the expected value of the coefficient. This might have been because farming activities were labour intensive leading to the improvements of rice production (Kolawole, 2006).

Table 9: Regression estimates (OLS) of predictors of rice production function

Variables	Mean	Std. Dev.	Coeff.	t-ratio
Labour (person-days/ha)	174.84	111.49	7.039	1.99**
Seeds (kg/ha)	465.93	594.26	-2.078	-2.79***
Fertilizer (kg/ha)	72.12	211.31	6.061	2.37**
Herbicides (l/ha)	0.62	0.70	-70.370	-0.74
Seasonal rainfall (mm)	337.63	213.02	60.466	5.13***
Labour squared	42 916	783 76	-0.036	-2.25**
Seed squared	567 882	2024 288	0.002	2.27**
Fertilizer squared	44 734.	510 476	-0.006	-2.31**
Variety (1=improved)	0.47	0.50	255.527	1.99**
Soil water holding capacity (1=high)	0.40	0.49	2.754	0.03
Farm size (hectares)	0.53	0.29	-162.118	-0.74
Farm size squared	0.37	0.47	39.017	0.82
Years in school (years)	5.19	3.14	44.225	0.94
Years in school squared	36.71	29.43	-6.416	-1.31
Age category (1= active age: <=40 yrs)	0.56	13.35	-185.174	-1.68*
Gender of household head (1=female)	0.61	0.49	-181.311	-1.58
Household size (number)	4.58	2.23	-10.856	-0.14
Household size squared	25.91	23.55	3.970	0.55
Access to extension (1=has access)	0.54	0.50	246.044	2.00**
Access to credit (1=has access)	0.28	0.45	-23.589	-0.20
Off-farm engagement (1=as main activity)	0.39	0.49	-51.240	-0.48
Relative diversity of farm tools (ratio)	0.23	0.08	53.232	0.08
Food security (1=food self-sufficient)	0.33	0.58	191.898	1.98**
Assets based wealth (numeric index)	0.20	0.23	632.932	2.71***
Constant			-3926.055	-4.61
Model diagnostics	*R-sq.*		*63%*	
	Adj. R-sq.		*55%*	
	Sign. (F-stat.)		*8.69****	

*, ** and *** denote significant at P<0.1, 0.05 and 0.01 levels, respectively

The amount of seed squared was statistically significant (P<0.05) and had a positive influence on rice production. The relationship between amount of seed squared and production were positive indicated that a unit increase in the amount of seeds by 1 kg will further increase output by 0.002 kg/ha. Under optimal conditions if improved seeds were used at higher rate in the farms there was a higher probability of increasing crop output (IFPRI, 2007).

On the other hand, the relationship between amount of seeds and production was negative (P<0.01) and implied that, an increase in amount of seeds by 1 kg led to significant reduction of output by 2.078 kg/ha. This might have been because most of the farmers used local seeds because they could not afford to purchase improved seeds that were relatively expensive and lacked knowledge on the appropriate variety of seed to sow (Oyebanjo *et al.,* 2005). Therefore, the signs of the variable coefficient were different (not positive) as they were expected.

Furthermore, the use of improved seed varieties had a positive relationship with production and statistically significant at (P<0.05) implied a unit increase in amount of seed variety increased rice production by 255.527 kg/ha. A study carried by Maddison (2007) on perception of adaptation to climate change in Africa showed that, the use of varieties such as early maturing crops, helped farmers to adapt to climate change impacts. Therefore, as expected, the coefficients for improved seed varieties were positive.

The relationship between fertilizer use and rice production was positive and statistically significant (P<0.05). This indicated a positive relationship between amount of fertilizer use and rice production, and implied that a unit increase in amount of fertilizer use resulted into an increase of rice production (output) by 6.061 kg/ha. Moreover, the coefficients of fertilizer squared were negative implying a negative relationship between the amount of fertilizer use and rice production. A unit increase in amount of fertilizer by 1 kg reduced rice output by 0.006 kg/ha. If more fertilizer were added to a fixed land resource, the maximum level of output might have been reached, and beyond which outputs declined. Use of inputs at an optimal rate is important to ensure long-term sustainable productivity and profitability.

Seasonal rainfall had positive relationship with rice production and statistically significant ($P<0.01$), implied a unit increase in amount of rainfall (by 1 mm) resulted into an increase of rice production by 60.47 kg/ha. Therefore, access to water enhances rice production (output) as crops receive adequate moisture needed for plant growth and the sign for the coefficient were positive as it was expected.

Contrary to the expected signs, age category had a negative relationship with rice production. This implied that older smallholder farmers engaged in production tended to realize more output than younger ones. As the respondent becomes older, she loses working energy thus contributing less production (Ajuye, 2010).

Access to extension services was statistically significant ($P<0.05$) and positively related with rice production. This implied that acquiring information through extension services and other contacts had considerable influence on increased production. Access to extension service resulted into an increase of rice production by 246 kg/ha to farmers. Apata (2009) reported that better access to extension services and attendance of training workshops to farmers had strong influence on adaptation of new technologies.

Food security was statistically significant and had a positive relationship with rice production ($P<0.01$). Increase in being food self-sufficient increased production by 1.91. Asset-based wealth was statistically significant at ($P<0.01$) and positively related with rice production. This implied that a unit increase in asset- based wealth increased rice production by 6333 kg/ha. Assets owned by households included radios, houses, bicycles and farming implements, for example, ox-ploughs, tractors, hoes and livestock (Ajuye, 2010). These assets are often used to determine the welfare status of the households, that is, a household with more domestic assets, farming implements and livestock is considered better off compared to a household with less. With current and future climate change, a household could also sell some assets that would enable it to adopt a coping technology such as a water pump to facilitate irrigation of crops that would eventually be sold to improve the household's livelihood and reduce vulnerability to climate change. Therefore, ownership of assets such as farming implements were important inputs in agriculture and influence the household's productivity.

However, relative diversity of farm tools, farm size, farm size squared, household size squared, soil water holding capacity were insignificant ($P<0.01$, $P<0.05$ and $P< 0.1$), implying they had no significant contribution to rice production. Farm size had no influence on rice production due to poor farm management applied in the production area. Also increase in the number of the household size had no significant influence on production due to an increase in the number of dependents in the family and who could not participate fully in the production process. Moreover, the capacity of soil not to hold water had no contribution to production as it hindered crop growth.

4.6.2 Determinants of profitability

The ordinary least square regression results linking profit to farm exogenous variables had an F-value of 3.52. This indicated that the model was able to significantly ($P<0.01$) account for the joint variation of independent variables with the dependent variables. The R^2 value of the variables included in the estimated regression equation accounted for 29% of the variations in the production model. This indicated that regression model was good at explaining the relationship between dependent variables and independent variables. From the regression results, seasonal rainfall, years in school, food security and asset-based wealth were positive and statistically significant ($P<0.01$; $P<0.05$; $P< 0.1$), implying a positive relationship between independent variables and profit.

Table 10: Regression estimates (OLS) of predictors of rice returns to land

Predictor variables	Descriptive		Overall	
	Mean	Std Dev.	Coeff.	t-ratio
Labour (person-days/ha)	174.84	111.49	-163.805	-0.02
Seeds (kg/ha)	465.93	594.26	-2 800	-1.92*
Fertilizer (kg/ha)	72.12	211.31	-150.752	-0.03
Herbicides (l/ha)	0.62	0.70	-408 168	-2.18**
Seasonal rainfall (mm)	337.63	213.02	85 021	3.69***
Labour squared	42 916	78 376	-23.146	-0.73
Seed squared	567 882	2 024 289	1.323	0.98
Fertilizer squared	44 735	510 476	0.568	0.11
Variety (1=improved)	0.47	0.50	317 488	1.26
Soil water holding capacity (1=high)	0.40	0.49	2 678.900	0.01
Farm size (hectares)	0.53	0.29	-272 015.072	-0.63
Farm size squared	0.37	0.47	-35 484.350	-0.38
Years in school (years)	5.19	3.14	188 418.142	2.05**
Years in school squared	36.71	29.43	-21 658.374	-2.26**
Age category (1= active age: <=40 yrs)	0.56	13.35	-264 262.637	-1.23
Gender of household head (1=female)	0.61	0.49	-31 678.979	-0.14
Household size (number)	4.58	2.23	-141 651.587	-0.93
Household size squared	25.91	23.55	21 162.945	1.50
Access to extension (1=has access)	0.54	0.50	236 444.000	0.98
Access to credit (1=has access)	0.28	0.45	145 810.352	0.62
Off-farm engagement (1=as main activity)	0.39	0.49	-97 343.090	-0.47
Relative diversity of farm tools (ratio)	0.23	0.08	-319 530.311	-0.25
Food security (1=food self-sufficient)	0.33	0.58	400 450.185	2.12**
Assets based wealth (numeric index)	0.20	0.23	1 432 352.584	3.14**
Constant			-5 008 251.9	-3.01

Model diagnostics	*R-sq.*	*40%*
	Adj. R-sq.	*29%*
	Sign. (F-stat.)	*3.52****

*, ** and *** significant at P< 0.1, 0.05 and 0.01 levels, respectively.

Seeds were expected to influence the profit but were negatively related to profit. This implied there was a negative relationship between seeds and profit. A unit increase in the amount of seed by 1 kg reduces profit by Tshs 2800. Maddison (2007) observed that, non-availability of the desired seed varieties and higher prices of quality seeds were the factors hindering rice cultivation and reduce profit.

Seasonal rainfall had a positive significant contribution on profit (P<0.1). An increase in amount of rainfall by 1 mm increased profit by Tshs 85 021. The findings were similar to those reported by Kurukulasuriya and Mendelson (2007) who observed that water flows increased the net farm returns in irrigated farms. Access to irrigation or an increase in amount of rainfall increase probability of farmers in making profit by growing large quantities of rice (Ajuye, 2010). A number of studies have reported improved yields and subsequent farm returns in rain-fed systems as result of increased rainfall (Mutabazi, 2007; Hassan *et al*., 2007; Ajetomobi *et al.,* 2010; Ahmed *et al*., 2011).

Education was statistically significant and positively related with with profit (P<0.05). This indicated that there was a direct relationship between education and profit. The more educated the household head was, the higher the profit the farm household realized. These observations were in line with those made by Deressa (2007) who reported that education level increased net revenue per hectare. However, the coefficient of years in school squared had negative coefficients implying that there was a negative relationship between education and profit. Thapa (2010) reported that more educated people prefer working on off-farm activities, probably due to the low wages and returns from the agricultural sector. Food security was positive and had a statistically significant influence on profit (P<0.05). An increase in amount of food consumed per year increased profit. The results were similar to those reported by Mngale (2009) who repoted that respondents who are food secure had land size of 3-6 acres and were food secure for 1-6 months. So the land size is an important component contributing to production and food security. The Tanzania

National Food Security Policy (URT, 2008) proposes that improved food security leads to improved human capital and higher wages in the labour market, with income being generated to purchase other crops when there is food insufficiency.

Asset-based wealth was significantly positive related with profit ($P<0.05$) suggesting that a unit change in assets-based wealth increased profit by Tshs 1 432 352. Household assets increase chances of production. Wealthier farmers for example who possessed assets such as tractors, ox-ploughs, livestock were more likely to grow crops such as rice as they could afford to buy inputs, including renting or buying plots, which enhanced production hence profit (Ajuye, 2010).

Herbicides had a negative relationship with profit. A unit increase in amount of herbicides by 1 litre decrease profit by Tshs. 408 168. The results revealed that there was no significant use of pesticides as there were no significant outbreaks of disease in rice during the survey period.

However, seed squared, fertilizer squared, variety, soil water holding capacity, household size squared, access to extension services, labour, access to credit and relative diversity of farm tools were positive, but insignificant ($P<0.01$, $P<0.05$, $P<0.1$), meaning that they had no contribution to profit in the study area. The negative coefficient of fertilizer squared was contrary to the expected sign. This implied that the price of fertilizer per kg might have been due to wrong application, leading to excessive administration of the fertilizer consequently leading to extra cost incurred by farmers (Kolawole, 2006). Moreover, labour was insignificant probably be due to the fact that rice production was labour intensive. Most of the operations were executed manually, which resulted into increase in the cost of labour. Hired labourers were frequently used by farmers in an attempt to meet their production targets (Kolawole, 2006). Productivity of labourers might be influenced by age as older farmers were reported to be less productive than younger farmers (Nwosu *et al*., 2012).

4.7 Economic Impacts of Climate Change on Rice Enterprise under Different Emission Scenarios

The regression based prediction of future economic impacts of climate change tested two climate parameters, namely temperature and rainfall. However, eventually temperature was dropped from the estimation as it lacked significant variance across the study locations (Table 11). The approach used in this study was similar to that of Thapa (2010) who omitted the quarterly temperatures due to the problems of collinearity in their research on climate change impact on Nepalese agriculture. Also in the research carried out by Ajetomobi (2010) in Nigeria on the economic impact of climate change in irrigated rice production indicated that temperatures were insignificant due to high correlation with each other.

Based on the study by Ajetomobi *et al*. (2010) on climate change and net revenues, the simulation model was used for different climatic emission scenarios to determine how net farm revenues per hectare from rice production would be affected by future climate change emission scenarios (B1 and A2) from the year 2040-2070.

This study estimated the impact of projected future climate change scenarios (B1 and A2) on rice production system using the results from the estimated coefficients for net revenue function, under the assumption that the variable subjected to change was climate while all other factors remained constant. The estimation reflected variation in net farm revenues per hectare for each individual farm.

Table 11: Baseline and future climate change scenarios

Climate	Kiroka Masika	Kiroka Vuli	Mgongola/Mkindo Masika	Mgongola/Mkindo Vuli
Temperature(^{o}C)				
Baseline	26	26	26	26
B1 Scenario (change)	0	+1	+1	0
A2 scenario (change)	+1	+2	+2	+2
Rainfall (mm)				
Baseline	451	193	524	324
B1 Scenario (% change)	26	23	13	-1
A2 scenario (% change)	20	26	-8	16

The results in Table 12 indicate the marginal effects of rainfall on the net farm revenues across the rainfed, RWH and irrigation rice production systems. The projected future climate change scenarios indicated that an increase in rainfall by 20 mm would have a positive impact on the rain-fed rice production system as it increased average net revenue to by 25 to 32% in Scenario B1 and A2, respectively.

Table 12: Projected net revenue (TShs '000) from baseline and future climate scenario

	Baseline	Scenario B1		Scenario A2	
	Mean	Mean	t-ratio	Mean	t-ratio
Kiroka (Rainfed)	31 745	41 778	2.22	39 737	2.12
Mgongola (RWH)	37 563	43 259	1.64	39 263	1.98
Mkindo (Irrigated)	17 132	20 618	1.99**	17 728	0.02** ***

* Values calculated as the mean of the samples;** and *** denotes significant at P<0.05 and P<0.1, respectively.

Either an increase or decrease of rainfall from projected future climate change in RWH would increase the average net revenue to 5% and 15% under scenarios B1 and A2, respectively. These changes were statistically significant (P<0.05 and P<0.1) in irrigated areas. This implied that change in rainfall had great contribution to the average net revenue, as there were a lot of variations in rainfall and net revenue from the baseline and the emission scenarios B1 and A2. These results were in line with the findings by

Nhemachena (2010) who reported that net revenues might rise or fall with higher level of rainfall and precipitation above 450 mm. Seasonal average wetter conditions might also become harmful to agricultural production Deressa (2007) also found that the reduction in net revenue per hectare during the summer season was due to the already high level of rainfall. Further increase in precipitation resulted in flooding and damage to field crops and re-initiated growth as crops had reduced water requirements during the harvest season.

Results in Table 13 indicate that an increase in rainfall by 20 mm might cause an increase in net revenue per hectare by 25 to 32% in rainfed area. Also an increase of rainfall in RWH area might cause an increase in net revenue by 5 to 15% and from 14 to 20% in irrigated area, respectively; although these changes were not very different due to small variation in rainfall in irrigated area.

Temperature is a crucial factor in crop production as it facilitates seed germination, increased plant growth rate and decreased growth duration, leading to a shorter grain filling period (Vaghefi *et al.,* 2011). Since we were not able to incorporate temperature into the equation, while it has an impact on net revenue, we assumed that 1^{o}C change in temperature was likely to occur in rainfed areas and RWH areas. This projection was according to that made by Ahmed *et al*. (2011) when he conducted the research on climate volatility and poverty vulnerability in Tanzania.

Table 13: Combined effects of temperature and rainfall on net revenue (Tshs '000)

Items	Kiroka (Rainfed) Net revenue	Mgongola (RWH) Net revenue	Mkindo (Irrigated) Net revenue
Baseline	31 745	41 778	39 737
Temperature (^{o}C)			
B1Scenario (% change)	+31	+15	+20
A2 Scenario (% change)	+25	+4	+3
Rainfall (mm)			
B1 Scenario (% change)	+32	+15	+20
A2 Scenario (% change)	+25	+5	-14

The net revenue per hectare was expected to increase by 31% in a rainfed area, 15 % in a RWH area and 20% in an irrigated area under the B1 scenario (Table 14). Under A2 scenario, rice revenue might increase by 25%, 4% and 3% for scenario A2 in rainfed, RWH and irrigation areas, respectively. This was supported by the observations made by Eid *et al*. (2007) that a rise in temperature by 1^{o}C had a pronounced positive effect on net revenue as it caused increased pressure of USD 150.96ha. In addition, observations made by Felkner (2009) on the impact of climate change on rice farming revenue revealed that there was a positive relationship between crop yields and net farm revenues and it was also considered that changing the rice varieties could maintain yields and revenues under future climatic conditions (2050-2090), if well cultivated in rainy and dry seasons (Herath *et al*., 2011).

The study on the economic impact of climate change on African agricultural production systems revealed that, the Parallel Climate Model (PCM) scenarios that forecast mild climate changes, predicted some increase in net revenue by year 2100 (Fleisher, 2007; Nhemachena *et al*., 2010). However, a study conducted on climate volatility and poverty vulnerability in Tanzania by Ahmed *et al*. (2011) indicated that scenarios with the largest decrease in climate variability especially precipitation volatility were projected to decrease poverty vulnerability through reduction of its impact on agricultural production, hence increase net revenue. Therefore, observations made in this study led to the conclusion that there was a significant increase in average net revenue per hectare to smallholder farmers in irrigated compared to those in rainwater harvesting and rainfed areas. This implied that future climate change would make more contribution in irrigation system than in RWH and rainfed systems through increased net farm income to smallholder farmers. Therefore, irrigation should be a good intervention and adaptation for mitigation of the impacts of climate change.

4.8 Costs and Benefits of Different Rice Production Systems

In the process of production, farmers incur costs which were classified into variable and fixed costs. Variable costs are the costs which vary with the level of output such as the costs of fertilizers, planting, harvesting, while fixed costs are the costs which do not vary with the level of output, for example, depreciation, maintenance costs and land renting. Total revenue was calculated as price of output (yield in kg) and yields (output) per hectare. Depreciation of bunds was discounted for three years while irrigation was discounted for thirty years at the discount rate of 1.4%. Table 14 shows that in the production process, irrigated production system was associated with the highest variable costs amounting to Tshs. 2263 489/ha. However, the rainfed production system had the least fixed costs of Tshs. 37 500/ha compared to other production systems.

Table 14: Costs and benefits of rice production systems

Items	Kiroka (Rainfed)	Mgongola (RWH)	Mkindo (Irrigated)
Yield (tons/ ha)	0.72	1.24	4.51
Price (Tshs/ton)	857 143	952 381	952 381
Total revenues (Tshs/ha)	616 350	1 184 250	4 295 000
Variable costs (Tshs/ha)	503 600	813 855	2 263 489
Fixed costs (Tshs/ha)	37 500	203 125	1 247 673
Total cost (Tshs/ha)	541 100	1 016 980	3 511 163
Net Profit (Tshs/ha)	75 250	167 270	783 837
Net present value (Tshs/ha)	1 199 253	2 665 769	12 491 951
Family labour (person-days/ha)	925	134	120
Returns to labour (Tshs/person-day)	81	1251	6555
Benefit/cost ratio	1.14	1.16	1.22

The cost differential suggested high investment in irrigated and RWH systems as opposed to the rainfed system. Apparently, the level of farm investment increased with the extent of secured access to agricultural water. Furthermore, the results in Table 15 indicate that the net present values were positive; hence, all the rice production systems were economically viable. The benefit- cost ratios were also positive indicating that benefits were greater than costs. Irrigated rice system was the most viable system as it had the highest net present value, that is, Tshs. 12 491 951/ha; rendering it the most viable and profitable adaptation. It should be noted that irrigation has to be carried where it is technically feasible. Irrigation also had highest returns to labour amounting to Tshs 6 555/person-day followed by Tshs 1 251/person-day in rainwater harvesting and the lowest returns to labour in rainfed (Tshs 81/person-day) (Appendix 1).

The findings revealed that all the three production systems were economically viable (Appendix 2, 3 and 4). Irrigation has the highest benefit–cost ratio of 1.22, 1.16 in rainwater harvesting and 1.14 in rainfed. Moreover, when assessing the impact of climate change on rice production, Herath and Kawasaki (2011) found that, the benefit-cost ratio during the dry and rainy season was greater than one, and the irrigation based dry season production had the highest benefit-cost ratio of 2.41.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Farmers were aware of the impact of climate change in all the studied areas. They revealed that the impact might have been due to climate variability, such as observed high ambient temperatures and low rainfall. Climate extremes entailing droughts and floods were thought to have impact on human health, plant and livestock productivity. The effect on human health was associated with outbreaks of diseases, such as malaria, cholera and typhoid.

Drought led to low crop yield especially in the depended rainfed system as reduced yields was perceived to cause an increase in the food prices due to low supply and higher consumer demand.

Farmers used a range of strategies to cope and adapt to climate effects. The strategies used for adaptation included afforestation, change in planting dates, switching to irrigation farming, practicing mulching, crop diversification and engagement in non-farming activities. Farmers that did not have any coping strategy were impacted more by climate change variation. The adverse effects were faced by the majority of farmers in the rainfed system of Kiroka.

Despite being willing to use the coping and adaptation strategies, most of the smallholder farmers faced challenges when trying to adopt the adaptation strategies. The challenges included lack of capital, adaptation knowledge and water for irrigation.

It was observed that variables such as labour, fertilizer, seasonal rainfall, seeds, access to extension, years in school, assets-based wealth and food security were significantly important in rice production.

The results from the two emission scenarios indicated that the net revenue per hectare was expected to increase in all of the production systems under scenario B1 and A2 in the mid-century (2040-2070).

The discounted project variability measures, including net present value, were positive in all the three production systems. This implied that the adaptation options (rainwater harvesting and irrigation) were viable and the benefits were greater than the cost. The irrigation system had higher net present values compared with rainfed and rainwater harvesting systems. Thus, farmers ought to opt for irrigation as an adaptation strategy as it yields greater benefits than other two production systems.

5.2 Recommendations

Therefore, in order to cope with the climate change impacts, it is recommended that farmers can use the following adaptation measures: afforestation, adjustment of planting dates, maximization of water use, application of chemical fertilizers, switching to irrigation farming, practicing mulching, crop diversification, planting earlying maturing crops and crop varieties and engagement in non-farming activities. There should be forged a close linkage between farmers and policy makers, in order to build up the current coping strategies into sustainable adaptation strategies which will be streamlined into national agricultural, economic and climate change adaptation policies.

The government should make efforts to ensure that credit support facilities are made available to farmers so as to increase their ability and flexibility to change production strategies in response to climate change. Also extension services to poor farmers in rural areas in form of training and particularly information on adaptation strategies such as the use of fertilizers, improved seed varieties and other packages should be availed so as to boost production.

Promotion of mechanization through appropriate technologies would improve productivity. Also use of proper irrigation technologies suited to the area and which is affordable to the farmers in rural farmers would help to increase food security, income and hence improve farmers' livelihood.

Climate change under moderate case emission scenario would have tangible incremental increase in farm net returns particularly in rainfed rice system and therefore, promotion of improved upland rainfed rice varieties such as *Nerica* would be beneficial to smallholder farmers. Baseline net farm benefits are substantive for irrigated and rainwater harvesting based rice enterprise with positive increment with future climate change; thus, capital investment in irrigation and upgrading of rainwater systems with water storage structures is recommended.

5.3 Areas for Further Research

There should be more research on the economics of climate change and adaptation in different parts of the country in order to compare their effects on crop and livestock revenues in different agro- ecological zones. Also, research is needed on the economic contribution of new rice varieties, such as N*erica*, to the revenue in other areas of

Tanzania. In order to facilitate policy makers in the development of interventions for improved agricultural productivity.

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APPENDICES

Appendix 1: Costs and benefits of rice production systems

	Kiroka (Rainfed)	Mgongola (RWH)	Mkindo (Irrigated)
Production and revenue			
Farm size (ha)	0.41	0.74	0.44
Yield (ton/ha)	0.72	1.24	4.51
Price (Tshs/ton)	857 143	952 381	952 381
Revenue (Tshs/ton)	616 350	1 184 250	4 295 000
Variable costs (Tshs/ha)			
Ploughing	10 500	78 125	302 642
Planting	5 625	125 000	149 242
Seeds	125 000	125 000	195 003
Weeding	187 500	125 000	354 861
Fertilizer	62 500	202 109	455 617
Spraying	31 250	44 662	136 816
Harvesting	75 000	77 958	402 564
Storage	600	3 585	22 500
Transportation	5 625	32 416	244 244
Total variable costs	503 600	813 855	2 263 489
Fixed and intermediate costs			
Rent	37 500	78 125	941 176
Water fee	NA	NA	56,250
Excavated bunds	NA	125,000	163 874
Maintenance	NA	NA	1 326
Depreciation	NA	NA	85 047
Total fixed and intermediate costs	37 500	203 125	1 247 673
TOTAL COST (Tshs/ha)	541 100	1 016 980	3 511 163
Family labour (person-days/ha)	925	134	120
Net profit per ha (returns to land)	75 250	167 270	783 837
Net profit per person-day (returns to labour)	81	1 251	6 555
NPV (returns to land)	1 416 383	3 148 418	14 753 676
B/C ratio	1.14	1.16	1.22

Source: Field survey in Wami-Ruvu basin (2012)

Appendix 2: Cash flow Kiroka (Rainfed)

	YEARS										
		Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**
Production & revenue											
Farm size (ha)	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Yield (ton/ha)	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Price (Tsh/ton)	857,143	857,143	857,143	857,143	857,143	857,143	857,143	857,143	857,143	857,143	857,143
Revenue (Tsh/ton)	616,350	616,350	616,350	616,350	616,350	616,350	616,350	616,350	616,350	616,350	616,350
Variable costs (Tsh/ha)											
Ploughing	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
Planting	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625
Seeds	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Weeding	187,500	187,500	187,500	187,500	187,500	187,500	187,500	187,500	187,500	187,500	187,500
Fertilizer	62,500	62,500	62,500	62,500	62,500	62,500	62,500	62,500	62,500	62,500	62,500
Spraying	31,250	31,250	31,250	31,250	31,250	31,250	31,250	31,250	31,250	31,250	31,250
Harvesting	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000
Storage	600	600	600	600	600	600	600	600	600	600	600
Transportation	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625
Total variable costs	503,600	503,600	503,600	503,600	503,600	503,600	503,600	503,600	503,600	503,600	503,600
Fixed & intermediate costs											
Rent	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500
Water fee											
Excavated bunds											
Maintainance											
Depreciation											
Total fixed & intermediate costs	37,500										
Total costs	541,100	541,100	541,100	541,100	541,100	541,100	541,100	541,100	541,100	541,100	541,100
Family labour (person-days/ha)	925	925	925	925	925	925	925	925	925	925	925
Net profit per ha (returns to land)	75,250	75,250	75,250	75,250	75,250	75,250	75,250	75,250	75,250	75,250	75,250
Net profit per person-day (returns to labour)	81	81	81	81	81	81	81	81	81	81	81
NPV (returns to land)	1,416,383										
B/C ratio	1.14										

	YEARS										
	Year 10	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**	**Year 19**	**Year 20**
Production & revenue											
Farm size (ha)	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Yield (ton/ha)	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Price (Tsh/ton)	857,143	857,143	857,143	857,143	857,143	857,143	857,143	857,143	857,143	857,143	857,143
Revenue (Tsh/ton)	616,350	616,350	616,350	616,350	616,350	616,350	616,350	616,350	616,350	616,350	616,350
Variable costs (Tsh/ha)											
Ploughing	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
Planting	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625
Seeds	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Weeding	187,500	187,500	187,500	187,500	187,500	187,500	187,500	187,500	187,500	187,500	187,500
Fertilizer	62,500	62,500	62,500	62,500	62,500	62,500	62,500	62,500	62,500	62,500	62,500
Spraying	31,250	31,250	31,250	31,250	31,250	31,250	31,250	31,250	31,250	31,250	31,250
Harvesting	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000
Storage	600	600	600	600	600	600	600	600	600	600	600
Transportation	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625	5,625
Total variable costs	503,600	503,600	503,600	503,600	503,600	503,600	503,600	503,600	503,600	503,600	503,600
Fixed & intermediate costs											
Rent	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500
Water fee											
Excavated bunds											
Maintainance											
Depreciation											
Total fixed & intermediate costs											
Total costs	541,100	541,100	541,100	541,100	541,100	541,100	541,100	541,100	541,100	541,100	541,100
Family labour (person-days/ha)	925	925	925	925	925	925	925	925	925	925	925
Net profit per ha (returns to land)	75,250	75,250	75,250	75,250	75,250	75,250	75,250	75,250	75,250	75,250	75,250
Net profit per person-day (returns to labour)	81	81	81	81	81	81	81	81	81	81	81
NPV (returns to land)	1416383										
B/C ratio	1.14										

Appendix 3: Cash flow Mgongola (Rainwater harvesting)

	YEARS										
		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Production & revenue											
Farm size (ha)	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Yield (ton/ha)	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24
Price (Tsh/ton)	952381	952381	952381	952381	952381	952381	952381	952381	952381	952381	952381
Revenue (Tsh/ton)	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250
Variable costs (Tsh/ha)											
Ploughing	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125
Planting	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Seeds	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Weeding	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Fertilizer	202,109	202,109	202,109	202,109	202,109	202,109	202,109	202,109	202,109	202,109	202,109
Spraying	44,662	44,662	44,662	44,662	44,662	44,662	44,662	44,662	44,662	44,662	44,662
Harvesting	77,958	77,958	77,958	77,958	77,958	77,958	77,958	77,958	77,958	77,958	77,958
Storage	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585
Transportation	32,416	32,416	32,416	32,416	32,416	32,416	32,416	32,416	32,416	32,416	32,416
Total variable costs	813,855	813,855	813,855	813,855	813,855	813,855	813,855	813,855	813,855	813,855	813,855
Fixed & intermediate costs											
Rent	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125
Water fee											
Excavated bunds	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Maintainance											
Depreciation											
Total fixed & intermediate costs	203,125	203,125	203,125	203,125	203,125	203,125	203,125	203,125	203,125	203,125	203,125
Total costs	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980
Family labour (person-days/ha)	134	134	134	134	134	134	134	134	134	134	134
Net profit per ha (returns to land)	167,270	167,270	167,270	167,270	167,270	167,270	167,270	167,270	167,270	167,270	167,270
Net profit per person-day (returns to labour)	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251
NPV (returns to land)	3,148,418										
B/C ratio	1.16										

	YEARS										
	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Production & revenue											
Farm size (ha)	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Yield (ton/ha)	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24
Price (Tsh/ton)	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381
Revenue (Tsh/ton)	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250	1,184,250
Variable costs (Tsh/ha)											
Ploughing	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125
Planting	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Seeds	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Weeding	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Fertilizer	202,109	202,109	202,109	202,109	202,109	202,109	202,109	202,109	202,109	202,109	202,109
Spraying	44,662	44,662	44,662	44,662	44,662	44,662	44,662	44,662	44,662	44,662	44,662
Harvesting	77,958	77,958	77,958	77,958	77,958	77,958	77,958	77,958	77,958	77,958	77,958
Storage	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585
Transportation	32,416	32,416	32,416	32,416	32,416	32,416	32,416	32,416	32,416	32,416	32,416
Total variable costs	813,855	813,855	813,855	813,855	813,855	813,855	813,855	813,855	813,855	813,855	813,855
Fixed & intermediate costs											
Rent	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125	78,125
Water fee											
Excavated bunds	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Maintainance											
Depreciation											
Total fixed & intermediate costs	203,125	203,125	203,125	203,125	203,125	203,125	203,125	203,125	203,125	203,125	203,125
Total costs	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980	1,016,980
Family labour (person-days/ha)	134	134	134	134	134	134	134	134	134	134	134
Net profit per ha (returns to land)	167,270	167,270	167,270	167,270	167,270	167,270	167,270	167,270	167,270	167,270	167,270
Net profit per person-day (returns to labour)	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251
NPV (returns to land)	3148418										

B/C ratio	1.16										

Appendix 4: Cash flow Mkindo (Irrigated)

	YEARS										
		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Production & revenue											
Farm size (ha)	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
Yield (ton/ha)	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51
Price (Tsh/ton)	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381
Revenue (Tsh/ton)	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000
Variable costs (Tsh/ha)											
Ploughing	302,642	302,642	302,642	302,642	302,642	302,642	302,642	302,642	302,642	302,642	302,642
Planting	149,242	149,242	149,242	149,242	149,242	149,242	149,242	149,242	149,242	149,242	149,242
Seeds	195,003	195,003	195,003	195,003	195,003	195,003	195,003	195,003	195,003	195,003	195,003
Weeding	354,861	354,861	354,861	354,861	354,861	354,861	354,861	354,861	354,861	354,861	354,861
Fertilizer	455,617	455,617	455,617	455,617	455,617	455,617	455,617	455,617	455,617	455,617	455,617
Spraying	136,816	136,816	136,816	136,816	136,816	136,816	136,816	136,816	136,816	136,816	136,816
Harvesting	402,564	402,564	402,564	402,564	402,564	402,564	402,564	402,564	402,564	402,564	402,564
Storage	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500
Transportation	244,244	244,244	244,244	244,244	244,244	244,244	244,244	244,244	244,244	244,244	244,244
Total variable costs	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489
Fixed & intermediate costs											
Rent	941,176	941,176	941,176	941,176	941,176	941,176	941,176	941,176	941,176	941,176	941,176
Water fee	56,250	56,250	56,250	56,250	56,250	56,250	56,250	56,250	56,250	56,250	56,250
Excavated bunds	163,874	163,874	163,874	163,874	163,874	163,874	163,874	163,874	163,874	163,874	163,874
Maintainance	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326
Depreciation	85,047	85,047	85,047	85,047	85,047	85,047	85,047	85,047	85,047	85,047	85,047
Total fixed & intermediate costs	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673
Total costs	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163
Family labour (person-days/ha)	120	120	120	120	120	120	120	120	120	120	120
Net profit per ha (returns to land)	783,837	783,837	783,837	783,837	783,837	783,837	783,837	783,837	783,837	783,837	783,837
Net profit per person-day (returns to labour)	6,555	6,555	6,555	6,555	6,555	6,555	6,555	6,555	6,555	6,555	6,555
NPV (returns to land)	7,939,819										
B/C ratio	1.22										

	YEARS										
	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Production & revenue											
Farm size (ha)	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
Yield (ton/ha)	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51
Price (Tsh/ton)	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381	952,381
Revenue (Tsh/ton)	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000	4,295,000
Variable costs (Tsh/ha)											
Ploughing	302,642	302,642	302,642	302,642	302,642	302,642	302,642	302,642	302,642	302,642	302,642
Planting	149,242	149,242	149,242	149,242	149,242	149,242	149,242	149,242	149,242	149,242	149,242
Seeds	195,003	195,003	195,003	195,003	195,003	195,003	195,003	195,003	195,003	195,003	195,003
Weeding	354,861	354,861	354,861	354,861	354,861	354,861	354,861	354,861	354,861	354,861	354,861
Fertilizer	455,617	455,617	455,617	455,617	455,617	455,617	455,617	455,617	455,617	455,617	455,617
Spraying	136,816	136,816	136,816	136,816	136,816	136,816	136,816	136,816	136,816	136,816	136,816
Harvesting	402,564	402,564	402,564	402,564	402,564	402,564	402,564	402,564	402,564	402,564	402,564
Storage	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500	22,500
Transportation	244,244	244,244	244,244	244,244	244,244	244,244	244,244	244,244	244,244	244,244	244,244
Total variable costs	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489	2,263,489
Fixed & intermediate costs											
Rent	941,176	941,176	941,176	941,176	941,176	941,176	941,176	941,176	941,176	941,176	941,176
Water fee	56,250	56,250	56,250	56,250	56,250	56,250	56,250	56,250	56,250	56,250	56,250
Excavated bunds	163,874	163,874	163,874	163,874	163,874	163,874	163,874	163,874	163,874	163,874	163,874
Maintainance	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326	1,326
Depreciation	85,047	85,047	85,047	85,047	85,047	85,047	85,047	85,047	85,047	85,047	85,047
Total fixed & intermediate costs	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673	1,247,673
Total costs	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163	3,511,163
Family labour (person-days/ha)	120	120	120	120	120	120	120	120	120	120	120
Net profit per ha (returns to land)	783,837	783,837	783,837	783,837	783,837	783,837	783,837	783,837	783,837	783,837	783,837
Net profit per person-day (returns to labour)	6,555	6,555	6,555	6,555	6,555	6,555	6,555	6,555	6,555	6,555	6,555
NPV (returns to land)	14,753,676										
B/C ratio	1.22										

Appendix 5: Respondents questionnaire

Economics of climate change adaptation in smallholder rice production systems in Wami-Ruvu basin

Section A. General Information

1. I) Questionnaire Number……………………………………..
   II).Division………………III).Ward…………………………..
   IV) Village name………………………v) Harmlet…………………………..
2. Please indicate the location of the farm; 1= Upland ( ) 2= Lowland ( ) 3= Midland ( ).
3. Fill the following household roster

Serial Number	Name of the hh head	Current residence 1. Always at home 2. Temporarily away	Sex 1. Male 2. Female	Age of the hh in years	Education level 1.Illiterate 2.Primary 3.Secondary 4.Beyond secondary 5.Other (specify)	Years in school	Working on the farm 1.Does not participate 2.Rarely participate 3.Always participate	Main activities of the household 1. Crop production 2. Livestock production 3. Both crop and livestock production 4.Fishing 5.Casual labor 6.Salaried job 7.Artisan 8.own business 9. student 10.Others (mention)

4.Household size……………………person.
5.Were you born in this village? 1= Yes( )2= No( ).
6.In case you were not born in this village ,fill in the following table

Migrated from 1=Neighbouring rural area, 2=district 3=Regional/ city)	Year of migration	Reason for migration

Reasons for migration 1=marriage 2=accompanied parents 3=farming in rainfed served areas 4=farming in irrigated served areas 5=farming in rainwater served areas 6=employment transfer 7=searching for wage work 8=other specify…

7. Do you have access to extension services or technical advice in your area? 1= Yes ( ) 2= No ( ).
8. Do you have access to finance to run your farming activities? 1= Yes ( )2= No ( ).

Section B: Farmers Perception On Climate Change Impact

9. Are you aware that climate change is taking place? 1= Yes ( ) 2= No ( ).

10. The threat of climate change is more on 1. Health 2. Agriculture Production 3. Both health and agriculture production 4. Fuel wood availability 5. Biodiversity quality and sustainability (   ).

11 Kindly use the option below to answer the following questions according to your level of agreement or disagreement

1. Strong Agree 2. Agree 3.Don't Know 4. Strong Disagree 5.Disagree.

11. Climate change has a very big impact on paddy production……
12. Variations in climate has caused an increase in incidences of floods during the raining season---------
13. Shifts in rainfall seasonality have caused crop failures and low yield. --------------
14. Some crop varieties have no longer been productive due to persisted droughts in the area. ------------
15. Climate change has led to crop infestation and diseases due to droughts ---------------
16. Climate change has led to rural-urban migration. ----------------
17. Excessive rainfall contributes to destruction of buildings and infrastructures………….
18. Flood does not contribute to soil erosion…………..
19. Water becomes scarce and dried due to droughts and low rainfall………….
20. Dry spell of crops is the results of drought…………………………….
21. Climate variability has impact on rainfed production………………..
22. Decrease in rainfall reduce water stored in bands……………………….
23. Climate change has led to the deforestation……………………..
24. The cost of food crops are increasing because of climate change. ----------------

Section C: Effect of climate change on Net revenue.

25. What type of production system are you using? 1= Rainfed (   ) 2= Rainwater harvesting ( ) 3= irrigation ( )
26. Do you have a farm experience? 1=Yes ( ) 2.No ( )
27. For how long have you been involving in crop cultivation?1= Less than 5 years( ) 2= 5 to 10 years ( )3= More than 10 years ( )
28. Tick the type of soil texture in your farm 1= sandy ( ) 2=clay loam ( ) 3=sandy clay ( ) 4=Heavy clay ( )5=loam ( ) 6=clay ( )
29. What is the soil color 1= reddish ( ) 2= brown ( ) 3= Black ( ) 4=Gray ( )

30. Is it suitable for production? 1.Highly suitable( ) 2= Suitable( ) 3=Not suitable ( )
31. If yes, what is the extent of water holding capacity 1= High ( ) 2= Low ( )3= Moderate ( )
32. Do you have a reliable supply of seeds for the crops you grow? 1=Yes ( ) 2= No ( ). If not what makes it difficult for you to obtain the type of seeds you want?...............
33. What type of seeds are you using? 1= Improved ( ) 2= Moderate ( ) 3=Poor ( ) please name the seed………………………………
34. What is the source of labor for the farm activities 1.family ( ) 2. Exchange () 3. hired labour( )4.Both family and hired ( )
35. Tick in the appropriate answer , are they working on 1= Full time ( ) 2= Part time 3= Both ( )

Section D: Cost and Benefit of Climate Change Adaptation

36. Have you made any adjustments to reduce the impact of climate variability? 1. Yes ( ) 2. No ( )
37. What adjustments have you made in response to changing in rainfall? list…………………………………………………………………………………
38. What other adjustments have you made in response to changing in temperature? Please list…………………………………………………………………………………
39. What measures do you practice to conserve the soil in your area? List…......……….
40. Who usually incurs the cost of production ?1= Husband ( ) 2=Wife () 3= Husband and Wife ( ) 4.children ( ) 5.family ( )

41. fill the following table for the season 2010/11

Plot No.	**Size (Acreage)**	**Land Tenure**	**Owner ship**	**GPS Points**			**Other main Crops grown**	**Adaptation measures**	
				Latitude	Longitude	Altitude		Agriculture Water management	Other measures
1.									
2.									

Plot No.	**Yield per plot**		**Seasonality**	**Amount sold (kg)**		**Market price**		**Amount consumed (kg)**		**Amount Current stored (kg)**	
	Rice	Other crops	1. Good 2. Normal 3. Bad	Rice	Other crop	Rice	Other crops	Rice	Other Crops	Rice	Other crops
1.											
2.											

Land tenure: 1. Owned –inherited ( ) 2.Owned-bought ( ) 3.Owned-gifted ( ) 4.Not owned-borrowed ( ) 5.Not owned –rented in ( )**. Ownership;** 1= Husband ( ) 2= Wife ( ) 3= Husband and wife ( ) 4. Children ( ) 5.Family ( ).**Operation;** 1= Husband 2= Wife 3= Husband and wife ( ) 4.Children ( ) 5.Family ( ).

Agriculture Water Management Adaptation Measures: 1.Water harvesting ( ) 2.Irrigation ( )**: Other adaptation measures: 1**. Soil water conservation ( ): **Water Harvesting;** 1.Majaruba system, with canal ( ) 2.Traditional furrow ( ) 3.Majaruba, without canal ( ) **Irrigation; 1.**Furrowing (gravity) ( ) 2. Flooding ( ) 3.Drip ( ) 4.Sprinkler ( ) 5. Contour ( ) 6. Pump ( ) **Soil water conservation:** 1.Rainfed ( ) 2. Tillage ( ) 3.Bunds ( ) 4.Ripping (deep tillage) ( )

Direct cost and Family labour inputs: Family labour=people (A.E)*Effective days *Effective hours
A.E=Adult Equivalent (1=A person of 15 and above years of age; A child of 10-14 years of age will be equated to 0.5 of an adult equivalent

Plot No	Activity									
1		Operation	Family labour	Cost for hired labour	No. of people	No. of days	No. of hours	Amount	Unit price	Total cost
	Bands construction									
	Land renting									
	Land preparation									
	Ploughing									
	Planting									
	Cultivating									
	Weeding									
	Input									
	Harvesting									
	Fertilization									
	Storage									
	Storage bags									
	Spraying									
	Water fees									
	Transport									
2										
	Bands construction									
	Land renting									
	Land preparation									
	Ploughing									
	Planting									
	Cultivating									
	Weeding									
	Input									
	Harvesting									
	Fertilization									
	Storage									
	Storage bags									
	Spraying									
	Water fees									
	Transport									

42. Total Farm size …………………… (hectares)

BAS (Below average season)			AVS (Average season)			ABS (Above average season)		
Adapt.	yield	Price	Adapt.	Yield	price	Adapt.	Yield	Price

43.Who owns the accrued benefit ?1 = Husband ( ) 2= Female ( ) 3= Husband and wife () 4.Children ( ) 5.family ( )

44.What is the reason for production trends ………………………………………………

45. Is this production sufficient for your household for a year? I= Sufficient ( ) ii Not Sufficient ( ) iii Surpluses ( ) iv I don't know ( )

46. Are you able to feed yourself from own produced food throughout the year until the next harvest? 1=Yes ( ) 2= No ( ). If no how many months in a year are your household able to adequately feed itself from own produced food? Name them……………..
47. Compare the period before and after involvement in irrigation, is your household 1= More secure food ( ) 2= No change ( ) 3= Less food secure ( )
48. Has your agricultural income 1= Increased ( ) 2= Remained the same ( ) 3= Declined ( ) after commencement of irrigation scheme?
49. For either answer, provided above give an explanation…………………………
50. Did you experience any problems in producing paddy last year? 1. Lack of irrigation water ( ) 2. Capital constraints ( ) 3.Animal damage ( ) 4. Theft of produce ( ) 5. Other specify…………………………………

Section E: Farm Productive and Livestock Assets

51. For how long have you been raising livestock? 1= Less than 5 years ( )2= 5 to 10 years () 3= More than 10 years ()

52.Why do you keep livestock?1= For commercial ( )2= For domestic purpose ( )3= Both above()

53.Please indicate the type and number of non- working livestock the household owns.

Type of live stock	Owner ship 1.Husband 2.Wife 3.Husband and wife 4.Children 5.Family	Number of animal		Value of animal (Average price)		Type of prod uce	Amount produce d	Amount sold	Selling price per unit	Amount Consume d
		Young	Adult	Young	Adult					
Cattle										
Sheep										
Goats										
Pigs										
Poultry										
Ducks										
Other										

Section F: Off-Farm Activities

54. What is the main source of income; 1. Sales crop ( ) 2. Sales livestock ( ) 3.Off-farm activities ( ) 4. Others specify……………

55.How much money does your household earn from the following income sources on a monthly basis?

Source of income	Monthly income in TSH.
Business	
Wages and salary	
pensions	
Income from renting land	
Remittances from family/friends(monetized &in-kind terms)	
Salary from employment	
Artisan works	
Other(specify)	

Section G: Assets Based Wealth

56.What is your form of financial asset 1.Savings ( ) 2.Money from credits ( ) 3. Support ( )

57. Please provide information on the following key productive assets

Type of assets	Ownership: 1= Husband 2= Female 3= Husband and wife 4. Children 5. Family	Number owned	Working status: 1=most of them working properly 2=working moderately 3=working improperly 4=not working	Total value
Land				
Panga /knife				
Ox-plough, weeder, riper				
Wheel barrow				
Oxen				
Tractor				
Sprayer				
Watering can				
Irrigation pump/Treadle pump				
Pick-up/lorry				
Warehouse/storage structure				
Hand hoe				
Slasher				
Rake				
Other(specify)				

b) Consumable assets and amenities for measuring long-term wealth (to be used to develop wealth index based filmer and pritchet)

What is the roofing material of the main house? 1.Mud/cowdung 2.Leaves/Grass 3.Timber/wood 4. Corrugated iron sheets 5.Other specify…………………………….	What is the wall material of the main house? 1. Mud/cow dung/raw bricks 2. Stones 3. Burnt bricks 4. Cement blocks 5. Wood/bamboo 6. Iron/material sheets 7. Other (specify)…. ……………………. ( )	How many sleeping rooms does this main house contain………...is there any other dwelling apart from this main house which is used for sleeping? 1. Yes 2. No ( )
What is floor material of the main house? 1. Earth 2.Cement 3.Other (specify)…………… ( )	What kind of toilet is mostly used? 1. No any toilet 2. Pan/bucket 3. Pit latrine covered 4. Pit latrine uncovered 5. Own flush toilet 6. Shared flush toilet 7. Other (specify)………………… ( )	What is the main source of energy for cooking? 1. Firewood 2. Charcoal 3. Paraffin 4. Gas 5. Electricity 6. Crop residues 7. Animal dung 8. Other (specify)… ( )
What is the main source of energy for lighting? 1. Paraffin 2. Gas 3. Electricity 4. Generator 5. Candles 6. Battery 7. Firewood 8. Other (specify)………………... ( )	What is the major source of water for drinking? 1. Piped in dwelling 2. Piped outside dwelling 3. Public tap 4. Bore-hole 5. Protected well/spring 6. Unprotected well/spring 7. Rain water 8. Vendor/tanker truck 9. River/lake /stream 10. Other (specify)………………….( )	Does the household own any of the following items? 1. lorry/pick up/ luxurious car 2. Motorbike 3. Television 4. Bicycle 5. Radio 6. Bed 7. Iron 8. Mobile phone 9. Landline 10. Sofa 11. Spongy mattress 12. wrist/wall watch

Appendix 6: Focus group discussion

1. What do you understand by the term climate variability.
2. What are indicators of climate change.
3. What are the causes of climate change and variability.
4. How many seasons do you have in this area.
5. Have the rain seasons changed for the past 20-30 years.
6. Which months were the masika rains begin and ends in the year before 1990.
7. Which months were the Vuli rains begin and ends in the year before 1990.
8. What are crops grown or produced twice a year.
9. What is the impact of climate variability in the crop production.
10. What are the impact of climate variability to the community.
11. What are adaptation strategies do you practice to reduce the effects of drought and lack of rainfall in your area.
12. What are the cost involved in carrying those adaptation strategies in your farm.
13. What are the benefits involved when carrying adaptation strategies in your farm.
14. What are the constraints in carrying out adaptation strategies.