

**FARMERS' PERCEPTIONS, ATTITUDES AND ADAPTATION TO
RAINFALL VARIABILITY RISKS IN DRYLAND AREAS OF TANZANIA**



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**FOR REFERENCE
ONLY**



**A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY OF SOKOINE UNIVERSITY
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ABSTRACT

The thrust of this study was to examine farmers' perceptions and attitudes towards risks, and local adaptation strategies against agricultural risks caused by rainfall variability. Specific objectives were to: (i) analyse the characteristics of agricultural risks caused by rainfall variability, (ii) analyse farmers' perceptions and attitudes to risks, and heterogeneity in risk perceptions, (iii) assess farmers' adaptation strategies against risks, and (iv) analyse economic viability of rainwater harvesting as a strategy for adapting to risks. The data for this study were collected through household, key informants' and local scheme managers' interviews. The questionnaire was administered to a sample of 200 farming households in three villages located in the upland, midland and lowland areas of the Makanya River Watershed in Northern Tanzania between October and November 2004. Data were analysed using descriptive and quantitative methods. Implying the possibility of climate change, long-term maize yields exhibited a declining trend the same way as recorded rainfall. Farmers perceived flood to be resourceful as they could locally manage it to improve availability of soil moisture in the cropland. The relatively poor farmers demonstrated to be more exposed and vulnerable to market-related risks compared to non-poor farmers. Micro-level aspects which reduce exposure and sensitivity while increasing adaptive capacity to risks were found to be high literacy level, smaller household size, improved welfare capability in terms of consumption level and increased stock of cattle. Farmers were found to be risk takers contrary to what is thought under peasantry theory which categorises them as risk averse. The risk taking behaviour was significantly explained by the extent of livelihood diversification and attitude towards

market orientation. Rainwater harvesting was among the most important strategies used by farmers to adapt to agricultural risks caused by rainfall variability. The policy-relevant recommendations are: First, addressing the agricultural risks caused by rainfall variability them should be central to policies and interventions aiming at reducing poverty and vulnerability in dryland areas. Second, by design, the programmes and projects aimed at reducing vulnerability to risks should to take into account the existing heterogeneity among farmers in terms of their perceptions and attitudes to risks. Third, public responses to disasters should shift from the current short-lived reactive disaster mitigation to proactive management investments which increase local adaptive capacity. Lastly, rainwater harvesting should be promoted through investments and technology transfer.


DECLARATION

I, **KHAMALDIN DAUD SULEYMAN MUTABAZI**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is the result of my original work and has neither been submitted nor being concurrently submitted for a degree award in any other university.



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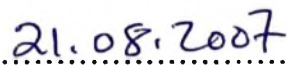
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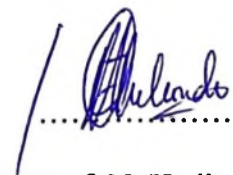
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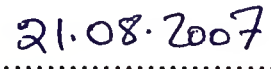
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DEDICATION

This dissertation is dedicated to my beloved parents who paved the way for my academic career through objective upbringing, and my wife and children who mean a lot in my life. Foremost, I thank almighty 'ALLAH (S.W)' who bestowed me the necessary energy and patience to deliver this thoughtful piece of work.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percent
<	Less than
>	Greater than
A-average	Above average
B-average	Below average
BCR	Benefit Cost Ratio
CRA	Composite Risk Assessment
CV	Coefficient of variation
DRS	Drought Relief Saving
e.g.	for example
FEWSNET	Famine Early Warning Systems Network
FSIT	Food Security Information Team
GDP	Gross National Product
GM	Gross margins
GPS	Geographical Position System
ha	Hectare
ISDR	International Strategy for Disaster Reduction
IWF	Indigenous Weather Forecasting
kg	Kilogram
LSMS	Living Standard Measurement Study
m.s.l	Mean sea level

Max.	Maximum
MDGs	Millennium Development Goals
Min.	Minimum
MLE	Maximum Likelihood Estimation
mm	Millimeter
MRW	Makanya River Watershed
n	Number
NPV	Net Present Value
NPV	Net Present Value
OLS	Ordinary Least Squares
P	Probability
PRA	Participatory Rural Appraisal
r	Discount rate
R	Correlation coefficient
RWH	Rainwater harvesting
SEU	Subjective Expected Utility
SSA	sub-Saharan Africa
SUA	Sokoine University of Agriculture
TAS	Tanzanian shilling
UNCCD	United Nations Convention to Combat Desertification
Vs.	Versus
WPLL	Western Pare Lowlands

CHAPTER ONE

1.0 INTRODUCTION

1.1. Characteristics of drylands and their implications on agriculture

Drylands are defined in terms of the ratio of mean annual precipitation (rainfall and snowfall) to mean annual potential evapo-transpiration with this ratio ranging from 0.05–0.65 (White and Nackoney, 2003). Potential evapo-transpiration is the amount of moisture that if it were available, would be removed from a given land area by evaporation and transpiration. This definition of drylands has been adopted by the United Nations Convention to Combat Desertification (UNCCD). Drylands are characterized by low, erratic and highly inconsistent rainfall levels. In terms of area, they cover just over 45% of the earth's land surface excluding cold climate regions. Drylands are mainly found in the tropics, north and south of the equator where over a billion people in 110 countries try to make a living (Turnbull, 2002). Twenty percent of African countries have more than 90% of their productive lands in vulnerable drylands (Turnbull, 2002). An estimated 38% of the population in sub-Saharan Africa (SSA), which is roughly 260 million people, lives in drought prone drylands UNDP (1997), cited by Rockstrom (2000). More than 50% of Tanzania mainland can be described as semi-arid dryland receiving less than 570 mm of rainfall in nine out of ten years (Hatibu, 2000).

The main characteristic of drylands which adversely affects agriculture is the negative balance between rainfall and potential evapo-transpiration per year. On average the annual rainfall ranges from 400 to 800 mm which falls during a short rain season,

compared to 4 - 7 mm per day of average potential evapo-transpiration (Hatibu *et al.*, 2006). Such rate of evapo-transpiration is equivalent to a loss of 360-630 mm of rainfall during the production rain seasons which last for about three months. The dryness is exacerbated by high temperatures during the rain season as well as the long dry period between wet seasons. Furthermore, the rains are exorbitantly variable and fall with high intensity leading to high rates of runoff. Ngana (1990) reported the coefficients of variation of seasonal rainfall ranges of between 60 to 190%. The combined effect of the high rates of evaporation and runoffs lead to shortage and high variability of soil moisture which limits plant growth (Hatibu *et al.*, 2006).

Seasonality is another feature which undermines agriculture in dryland areas. In drylands farmers are generally used to experience seasons that are either “below average” (B-average) or “above average” (A-average) (Hatibu *et al.*, 2006). B-average seasons have rainfall amount that is below the long-term mean and/or unevenly distributed within the season, while A-average seasons have rainfall above the long-term mean and more evenly distributed. If the seasonal rainfall is above average but unevenly distributed within a growing season to meet crop water requirement during critical growing stages, the season is still “B-average” because the yield is still affected as in the case of “B-average” season. Virtually, the B-average seasons can be characterized by either seasonal drought or a series of dry spells. Furthermore, the concept of seasonality can be subjectively assessed by asking farmers to rate the season whether it was bad (B-average) or good (A-average). This is much more revealing than relying on rainfall records from a particular weather station which could be unrealistic because of spatial variability and inequity in sharing common

rainwater such as runoff under macro-catchment rainwater harvesting (RWH). RWH for agriculture refers to concentration of rainwater from direct rain (*in-situ*) or surface runoff from external catchment with or without storage into the cropland to provide for soil moisture required by the plant (Hatibu *et al.*, 2006; Senkondo *et al.*, 2004). All such types of RWH are meant to upgrade the productivity of rainfed agriculture.

Rainfed agriculture is a system of production where the rainwater falling directly on a given field is the main source of water for growing crops, trees or pasture, without which no yields are possible. In SSA region, rainfed agriculture accounted for 53.2 million hectares of the area under cereal production compared to only 2.0 million hectares under irrigation. Though cereal yield under irrigated farming is much higher (1.71 ton/ha) than cereal yield under rainfed (0.83 ton/ha), the overall production from rainfed agriculture is 93% of the total production (Rosegrant, 2002). However, because of its dependence on direct rainfall, rainfed agriculture is adversely affected by spatial and temporal variability of rainfall.

1.2. Rainfall variability and associated risks in the drylands of Tanzania

In the dryland areas of Tanzania, the problem of rainfall variability manifests in three dimensions of amount, duration, and on-set and end-dates which make planning on farm riskier. The amount dimension has two extreme situations of too little (drought and dry spell) and too high rainfall (floods). Duration refers to expected spacing of the rainfall throughout a growing season. On-set and end-dates dimension is when the rainfall normally starts and ends in a particular growing season. Concisely, these

dimensions of rainfall variability can be explained in four phenomena namely seasonal drought, dry spells, erroneous on-set and end dates, and floods.

Four types of droughts have been suggested in literature. These include meteorological, agricultural, hydrological and socio-economic droughts. Meteorological drought refers to deficiency of precipitation from expected or "normal" amount over an extended period. Agricultural drought may be characterized by a deficiency in water availability for plant growth. Hydrological drought is associated with the effects of periods of rainfall shortages on water supply systems such as reservoirs and rivers. Socioeconomic drought occurs when the demand for an economic good exceeds supply because of a weather-related shortfall in water supply (Sinha, 2005; ISDR, 2002). The four typologies of drought are no exception in dryland areas of Tanzania and SSA in general.

Rainfall variability is the critical risk factor faced by farming households in the drylands. In their study conducted in dryland areas of Tanzania, Mahoo *et al.* (1999) found that rainfall was unreliable from season to season and dry spells were vivid. In one of their study sites called *Kisangara* which is close to our study area in the lowland, the month of November would receive at least 18 mm of rainfall during the short rain season and the length of the longest dry spell with 30% probability of occurrence is 15 days. At the same place, during the long rain season, the dry spells of more than 14 days at 30% chance were experienced in the rest of the months except April. In all these situations, there is high possibility of crop damage by water stress caused by intermittent dry spells during the season. In this respect, rainfall variability

poses a tremendous production risk in the dryland farming systems (Venalainen and Mhita, 1998; Ngana, 1990; Beltrando, 1990).

Risks are generally defined in a threefold definition as: (a) the chance of a bad or negative outcome; (b) the variability of outcomes, i.e. converse of stability; and (c) uncertainty of outcomes (Hardaker, 2000). These definitions of risks were used to characterize different forms of agricultural risks caused by rainfall variability. With regard to the chance of a bad outcome, smallholder farmers face a greater likelihood of reduced crop yield and farm income or total crop failure and loss of farm income. In the context of variability, smallholder farmers face higher fluctuation of the yield and farm income. In the case of uncertainty of outcomes, farmers face difficulties in making farm investment decisions and planning, since they cannot foresee when it will certainly rain, its duration and its end. The problem is that there is inadequate assessment and understanding of the characteristics of these risks in terms of their magnitude, distribution and variability amongst smallholder farmers. Consequently, the likely poverty impacts and vulnerability caused by these risks to farming households in rural drylands are not well understood. In this respect, the poverty reduction policies and interventions to reduce agricultural risks caused by rainfall variability in the poverty stricken rural drylands are inadequately informed. The linkage between poverty and risk in developing countries has recently gained importance in the literature on development economics (Christiaensen *et al.*, 2003; Mosley and Verschoor, 2003). This study will contribute to knowledge by assessing the characteristics of the risks caused by rainfall variability in terms of magnitudes

and variability in relation to socio-economic and biophysical conditions of smallholder farmers in the rural dryland areas of Tanzania.

1.3. Farmers' perception of and attitude towards risks

Risk perception is defined as a way of conceiving risk while attitude is defined as a complex mental state involving beliefs, feelings, values and dispositions with regard to risks (Hillson and Murray-Webster, 2004). Compared to perception which could be an instant mental judgment on risk, attitude to risks is shaped by long-run experiences and processes by the subject. Therefore, the course of actions taken by an individual decision-maker depends on their perceptions and attitude to risk with regard to expected outcomes of given sources of risks. The linkage between perceptions and attitudes to risk and being trapped in poverty is reported in other studies conducted in rural India and some African countries (Christiaensen *et al.*, 2003; Mosley and Verschoor, 2003). If poor people are risk-averse to the extent that they are unwilling to invest in the acquisition of assets and often engage in low-risk low-return activities they remain locked into perpetual poverty. Furthermore, Ellis (2000) argues that the perceptions and attitude of smallholder farmers to risks in terms of risk aversion inhibit the adoption and diffusion of innovations that could increase output and incomes. Reducing the susceptibility to agricultural risks caused by rainfall variability is certainly a development issue which requires possession of thorough knowledge on the perception and attitude of individual farmers to risks. The perception and attitude to risks shape the way farmers react to risks. Whereas smallholder farmers in dryland areas operate and make decisions amidst risks caused by rainfall variability, we have little understanding of their perceptions and attitude to these risks. What farmers as

decision-makers do in practice is a manifestation of what is in their mindsets envisaging perceptions and attitudes to different things. Therefore, before we can influence what farmers do we must first understand and influence the way they perceive and believe in different things. It is for this reason this study was designed to analyze farmers' perceptions and attitudes to agricultural risks caused by rainfall variability.

The state of perception and attitude has a bearing on emanating adaptive strategies of individual farmers. Local adaptive strategies developed and tested over time by farmers themselves are worth exploring since they form a stepping ground for development interventions. Due to dynamism of risks and contexts, such adaptive strategies are not constantly understood, because they never remain static over time and space for the same individual and among individuals. In this regard, the thrust of this research was to delve the strategies for adapting to the risks caused by rainfall variability among farmers in the study villages.

1.4. Problem statement and justification

Agricultural risks especially those caused by rainfall variability are more pressing in the dryland areas to the extent of undermining poverty and vulnerability reduction efforts. In SSA, dryland areas are homes of the poorest and vulnerable farming households implying the stark reality that the war on poverty would be won or lost in these endemically poverty-stricken areas. In terms of empirical knowledge, we have limited understanding of farmers' perception and attitude to risks caused by rainfall variability. Furthermore, beyond such risk behaviour of farmers, we are as well

inadequately informed on the dynamic portfolio of local adaptive strategies and the viability of prime ones such as RWH in making them resilient to the odds of risks. In this regard, the research sought to fill knowledge gaps with respect to:

- Characteristics of agricultural risks faced by smallholder farmers as a result of rainfall variability
- Farmers' perception and attitude towards risks,
- Strategies used by the farmers to adapt to risks, and
- Economic viability of RWH as one of such strategies.

The characteristics of agricultural risks caused by rainfall variability such as drought-related crop failure in SSA and Tanzania in particular have been documented (FEWSNET, 2003; FSIT, 2003; Leichenko and O' Brien, 2002). Nevertheless, the analyses in these studies were done at national and regional levels, hence failing to express the micro-level characteristics of such risks clearly. This study seeks to fill this gap and contribute to increased understanding of how individual farmers perceive the severity of different sources of risks, and the extent of instability of yield and farm returns.

When it comes to farmers' perceptions and attitude to risks is very critical in any attempt to improve the risk adaptation strategies but research based knowledge on the same is scanty. A few studies have been done (for example, Senkondo, 2000; Smith *et al.*, 2000) but there is still a huge knowledge gap on issues related to farmers' perceptions and attitude to risks. In terms of risk perception, the knowledge gap

includes lack of enough understanding on how farmers in varied biophysical and socio-economic circumstances perceive different risks they are exposed to and divergences underlying individual perceptions. It is amenable to systematically delve on how smallholder farmers conceive a portfolio of risks related to resource access and tenure security, agricultural production or the supply side including rainfall and those not related to rainfall, market or demand side, and social and institutional aspects. Attitudes of farmers to risks are not extensively studied under different contexts and circumstances of smallholder farmers as basic units of the decision making process.

Adaptation to risks is next to perception and attitude processes after the farmer has experienced or anticipated the threshold of risk damage and become determined to react. Considerably, in the climate change and variability policies, emphasis has been on mitigation side entailing measures to curb global warming. Recently, adaptation which involves long-run adjustment and sustenance of coping strategies, is increasingly receiving attention (De Loe and Kreutzwiser, 2000). However, empirical information on how the vulnerable households and communities are adapting to climate variability risks is still limited. Much of the focus of the past social research on how farmers react to risks they are exposed to, has been on *ex-post* short-run household coping strategies (Eriksen *et al.*, 2005; Dercon *et al.*, 2004; De Weerd, 2002) rather than long-run adaptation strategies. Furthermore, in most of these studies, the portfolio of adaptive strategies is excessively analyzed at household level with little or lack of community-level insights. Adaptive strategies are understood better if they are coherently analyzed from the broad community perspective down to

the household as a subset of the aggregate community. In bridging this knowledge, this study analyzed the portfolio of adaptive strategies of farmers at both household and community level.

Studies have shown that although shortage of rainfall is an important factor, the critical problem in drylands is often inter- and intra-seasonal variability (Barron *et al.*, 2003; Mahoo *et al.*, 1999; Ngana, 1990). In dryland areas, too much rain (flood) and too little rain (drought) do occur in the same area in the same season. In this regard, the major problem is lack of efficient means to manage the rainwater resources rather than lack of rainfall as such. RWH practices can convert the seemingly defective flush flood as well as optimize direct rain and runoff to provide for the needed soil moisture for plant growth.

Exclusively, past empirical work on RWH for agriculture (e.g. Oweis and Hachum, 2006; Hatibu *et al.*, 2006; Fox *et al.*, 2005; Senkondo *et al.*, 2004; Barron *et al.*, 2003; Rockstrom, 2003; Rockstrom *et al.*, 2002) concentrated more on analyzing the magnitude of farm outputs (yield and returns) rather than on how robust different RWH systems stabilize these outputs under different seasonality contexts. Currently, an understanding of the efficacy of RWH as adaptive strategy against risks caused by rainfall variability under different settings of seasonality is non-existent. This study intends to contribute in bridging this gap by analyzing the efficacy and consistence of different levels of RWH in giving higher and stable farm outputs particularly in bad years.

1.5. Objectives and hypotheses

The general objective was to examine farmers' perceptions, attitudes and adaptation to risks in order to contribute to our understanding of their behaviour and reactions to rainfall variability risks. The specific objectives formulated to deliver this objective were:

- (a) To analyze the characteristics of agricultural risks caused by rainfall variability,
- (b) To analyze farmers' perceptions and attitudes to risk and heterogeneity in risk perceptions,
- (c) To assess farmers' adaptation strategies against risks caused by rainfall variability,
- (d) To analyze economic viability of RWH as a strategy for adapting to risks caused rainfall variability.

The broad testable hypotheses with respect to these specific objectives were:

- (a) Characteristics of agricultural risks faced by farmers differ according to biophysical and socio-economic characteristics,
- (b) Perceptions and attitudes of farmers to different types of risks differ and are influenced by biophysical and micro-level socio-economic characteristics,
- (c) Adaptation strategies of individual farmers and farming communities against common risks are not similar because of differences in biophysical and socio-economic conditions,
- (d) Rainwater harvesting system with external catchment is effective in mitigating rainfall variability risks and economically viable

1.6. Conceptual framework

Adaptation has worked its way, as an organizing concept, into the research on vulnerability to climatic and other forms of disturbing stress. A number of frameworks have been proposed for examining the causal structure of the vulnerability and reactions of people to environmental and social forces (Luers, 2005; Polsky and Esterling, 2001; Adger, 2001; McCarthy, *et al.*, 2001). Current assessment of adaptation often takes place within the assessment of vulnerability, since the two are now seen as inextricably linked (Luers, 2005; Grothman and Patt, 2005; O'Brien *et al.*, 2004; Alwang *et al.*, 2001).

Although there is considerable diversity in existing theories, vulnerability is generally defined as the susceptibility to damage. The consolidated path towards adaptation starts with exposure of a system (people or place) to hazards or shocks, sensitivity of the system relative to a threshold of damage, susceptibility of the system to damage, and adaptation entailing adjustments in a system's behaviour and characteristics that enhance its ability to cope with external stress. These concepts have emerged from the risk-hazards and food security literature, and over the last decade have been expanded and integrated into the discourse of the global environmental change research community (Luers, 2005). Conceptually, this study framed in linear continuum of adaptation path entailing Exposure --> Sensitivity --> Vulnerability (ESV) presented in Fig. 1.

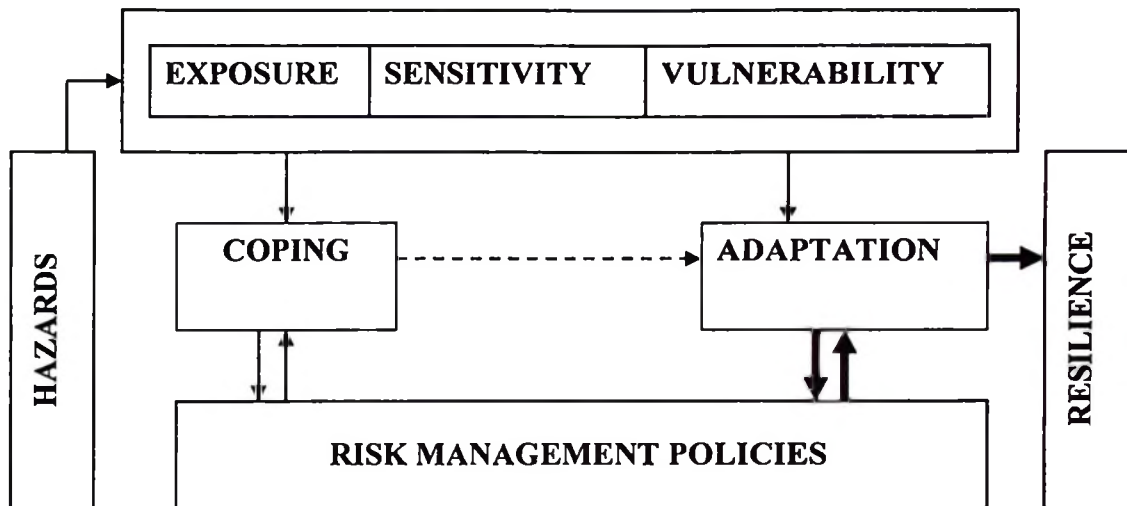


Figure 1: Conceptual framework of the study

ESV framework provided a realm in which key research aspects were conceptualized and analyzed. Exposure comes into being when the household or a system is subjected to perturbations or stress from risky hazards, e.g. occurrence of critical dry spell. Exposure entails also characteristics of the disturbing event such as magnitude, variability and frequencies of occurrence. Sensitivity is defined as the degree to which the household or a system will respond to a disturbing stress. Sensitivity explains personalized attributes of perception and attitude of the subjects to risks they are exposed to. Vulnerability refers to the likelihood that a system might suffer damage as a result of exposure to stress. Adaptations are actions that lead to decrease in vulnerability of the household or a system to risks. As opposed to adaptation, coping strategies are basically *ex-post* short-lived measures of the system to survive the stress. Exposure is an exogenous factor to sensitivity and vulnerability which are all together interrelated. ESV elements trigger coping and adaptation strategies in the system. Some coping strategies might evolve into long-term adaptation strategies. Effective coping and adaptation to risks fosters a system or household's resilience.

Social resilience is the ability of the household or community to adapt in face of external sources of risks. Policies for risk management for reducing vulnerability and fostering social resilience would attempt to strengthen coping and adaptation strategies. Indeed, the long-term objective and priority of risk management policies is increase adaptive capacity of society at risk. A portfolio of coping and adaptation strategies would be dynamic and informative to policies through a feedback loop. In brief, ESV framework represents a path towards risk resilience and policy responses.

1.7. Organization of the thesis

The remainder of the thesis is organized into five chapters. Chapter 2 gives a review of extent of risks associated with rainfall variability, attitude and perception of farmers, farmers' adaptation strategies against risks and economic viability of RWH for mitigating risks associated with rainfall variability. Chapter 3 is about methodology, which is embodied with description of the study area, the data collection approaches, and methods applied for qualitative and quantitative data analysis. Chapter 4 presents empirical results and discussion of the underlying reflections tailored to objectives. Broad aspects falling under Chapter 4 are results and discussion of extent of agricultural risks associated with rainfall variability, farmers' perceptions and attitudes to risks and heterogeneity in risk perception, farmers' risk adaptation strategies towards risks and economic viability of RWH for adapting to risks caused by rainfall variability. The last chapter (Chapter 5) presents the summary, conclusions and policy recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Characteristics of risks caused by rainfall variability

Three typologies of characteristics reviewed in this section fall under the definition suggested by Hardaker (2000). These include conceptualization of risk as the chance of a bad or negative outcome; the variability of outcomes, i.e. converse of stability and uncertainty of outcomes. However, much of the review is devoted to the first two definitions, as the latter was not practically subjected to empirical analyses in this study. Bad or negative outcomes of risks caused by rainfall variability in the drylands include reduced crop yield and farm income, and total crop failure which translate into complete loss of crop income.

Evidence from literature has documented the risks caused by rainfall variability. Leichenko and O'Brien (2002) have estimated that the two severe droughts in the southern Africa region in 1992 and 1995 reduced the total cereal production by nearly half (12 555 000 vs. 22 848 000 metric tons) and one-third (19 192 000 vs. 27 838 000 metric tons) from respective preceding years. Ethiopian panel analysis estimated that household income growth was reduced by about a fifth because of rainfall shortage (Christieansen *et al.*, 2003).

The food shock of 2003/04 in Tanzania which was caused by a dry spell that occurred between mid-January and third week of March in 2003 reduced crop yield by about 50-90%, particularly in dryland areas. This dry spell left over two million people,

most of them in rural dryland areas, severely food insecure and had to depend on relief food (FEWSNET, 2003; FSIT, 2003). Furthermore, Mmbaga and Lyamchai (2001) estimated the average maize loss due to drought to about 50% up to total crop failure in bad years. In the cited examples, the analyses of risks caused by rainfall variability are over-generalized to the extent of being unable to ascertain the effects at the farm-level conditions of smallholder farmers resulting from these risks. While the above literature paints a bolded macro-picture of the magnitude and impacts of rainfall-related risks at national and regional levels, the micro-picture of the characteristics of these risks is entirely faint. Policies and strategies have never been consistent and robust enough to address these risks.

The Tanzanian disaster management policy contains more of reactive plans to manage risks such as drought. The policy focuses on the provision of *ad hoc* relief assistance, mainly food, to farmers who had suffered, or who were exposed to losses because of drought. In other countries like Australia, the package of drought measures extends to include aspects like subsidies for the purchases of fodder, low-interest loans and cash grants (Quiggin and Chambers, 2004). However, even such measures which are seemingly robust were still criticized for undermining incentives for appropriate preparedness to drought Freebairn (1983), cited by Quiggin and Chambers (2004).

Economists debate a range of market-based measures aimed at providing a more coherent and less costly response to climatic uncertainty. Crop insurance involving compensation for yield loss because of drought has been predominantly used in developed world such as the United States (US). In terms of drought management

policy and actions, Africa can learn a lot from Australia, a typical dryland country which has relatively excelled in drought management. The Australian National Drought Policy of 1992 is loaded with extensive insights on risk management in agriculture. In this policy, drought is considered as one of several sources of uncertainty affecting farm businesses and is part of the farmer's normal operating environment. Its effects can be reduced through risk management practices which consider all situations, including drought and commodity price downturns. The key policy implication is that farmers will have to assume greater responsibility for managing the risks arising from climatic variability. This will require the integration of financial and business management with production and resource management to ensure that financial and physical resources of farm businesses are used efficiently (Quiggin and Chambers, 2004).

The bottom line is that in order to make smallholder farmers in the dryland areas resilient to droughts and its associated risks, proactive farm-level investments and technologies which increase adaptive capacity are needed. In the dryland context, such investments and technologies should target to improve management of agricultural water. Investments should come from the government and its development allies such as donors and NGOs, and individual farmers.

2.2. Farmers' attitude and perceptions to risks

As noted earlier, what farmers are doing as decision-makers is a function of their mental processes entailing perceptions and attitudes. The knowledge on farmers' perceptions and attitudes towards risk is very critical in informing risk management

and development policies targeting agrarian communities in dryland areas. Perceptions and attitudes of farmers towards risks affect adoption of new technologies, and hence success of rural development programmes (Khanthavit *et al.*, 2001). In decision theory and practice, perceptions and attitudes are human elements keep on changing in response to changing contexts of risks and decision-makers' circumstances.

Farmers in the drylands have different pattern of risk perceptions because they thrive in varied context. Smith *et al.* (2000) studied heterogeneity in risk assessment by agro-pastoralists in arid lowlands of southern Ethiopia and northern Kenya. In their analytical framework, they decomposed risk into four components: risk exposure, subjective perception, *ex-ante* mitigation capacity, and *ex-post* coping capacity. The latter component can be extended to include long-term adaptation capacity. It is of interest to describe these components as this framework allows better understanding of observed risk perception heterogeneity. According to Smith *et al.* (2000), exposure is an objective component related to space and time but not idiosyncratic. Certain people at a specific place or time face different likelihood that a given risky hazard (e.g. drought, flood, conflict) will occur than others do at another place or time. Therefore, exposure is amenable to probabilistic measurement. In view of this, quantitative measures of risk typically rely exclusively on exposure data, for example, elucidation of the risk associated with drought through recorded rainfall data. Perception reflects individual's belief that he or she might experience a particular risky hazard and how severe its effects might be. Two individuals can have different subjective perceptions of their identical exposure to a given risk because of different

histories, preferences or information. Mitigation, coping and adaptation components relate to the capacity to reduce the adverse effects of risky hazards, either *ex-ante* (mitigation) or *ex-post* (coping and adaptation). Smith *et al.* (2000) developed CRA index aggregating the four components. The CRA index increases with exposure and perception but decreases with respondent's capacity to mitigate or cope with or adapt to risk.

Variations in risk exposure, perception, mitigation, and coping explain risk assessment heterogeneity to be observed among subjects of research in the field. Despite its robustness in delving risk assessment heterogeneity, this approach has never been applied further in different research environment. This prompted this study to CRA technique to understand the risk perception heterogeneity. The departure from the Ethiopian and Kenyan study conducted by Smith and others is that this study systematized the CRA approach by dividing the perception measuring axioms into those which are related to resource access, production, market and institutions. Aspects linked directly to agricultural water access are implied in resource access and production categories. The phenomenon of risk is far-reaching and reinforcing with market and institutional issues which are also worth analyzing.

In Tanzania, economic research on risk is patchy despite the fact that risk is an unavoidable aspect in smallholder agriculture, particularly in the precarious dryland environment. Apart from Senkondo (2000), the remaining section of research-backed literature has focused more on the influence of perceptions and attitudes as they impact on technology adoption than on intrinsic analysis of the same in the context of

risk. In the context of Tanzania, we lack extensive micro-level studies on behaviour of farmers in making decisions under risk which are pertinent as the circumstances of farmers and the contexts in which risks operate all keep changing over time and space.

2.3. Farmers' adaptation strategies against risks

With the challenge of reducing poverty and vulnerability, which are common in the drylands of Tanzania and SSA at large, researching on the ways the poor react to risks, is very pertinent. Increasing interest by researchers and development practitioners to combat poverty and vulnerability of farming households in dryland areas of SSA has attracted a handful of research on local responses to risks (Eriksen *et al.*, 2005; Dercon *et al.*, 2004; Tengo and Belfrage, 2003; Davis, 2003; Rockstrom, 2003; De Weerd, 2002; Dercon and De Weerd, 2002; Alwang *et al.*, 2001; Ersado, 2001; Ellis, 2000; Dercon, 2000). Overly, these studies most of which were conducted in the dryland tropics (for example, Eriksen *et al.*, 2005), focused more on *ex-post* coping strategies and rarely considered long-term local adaptive initiatives such as RWH. Even such attention concentrated on the identification of the coping and adaptive strategies among different socio-economic sections of the vulnerable households in the study areas. The added value of this study rests on going beyond just identification to undertaking in-depth analysis of the economic efficacy in terms of risk mitigation of the single most important adaptation strategy realized by the respondents.

Farmers in the dryland areas are not passive victims of the risks caused by rainfall variability but are rather active with a range of adaptation strategies to moderate negative externalities associated with these risks. Adaptation refers to a portfolio of strategies by which individual households change their productive activities and modify local rules and institutions to secure livelihood to moderate potential changes caused by risks they are exposed to (Grothman and Pratt, 2005; Berkes and Jolly, 2001).

It should be noted in advance that due to the multi-factorial nature of risk outcomes and farmers' behaviour to risk, a systems approach was used whereby risks related to rainfall variability were coherently analyzed with other types of risks. Christiansen *et al.* (2003) in their panel analysis of poverty impact of risk in Zimbabwe observed that the incidence of drought alone failed to explain the deterioration in household economic well-being.

The promising entry of enhancing the adaptive capacities of farmers in the drylands is to upgrade the farmer-based water and moisture system innovations. In the drylands where perennial water bodies for conventional irrigation are widely non-existent, the next best adaptation option is to devise farm-level innovations that optimize productivity of rainwater resources. Such rainwater resources include direct rain that can be captured instantly through *in-situ* practices and surface runoff generated from external catchment (Hatibu *et al.*, 2006).



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2.4. Economic viability of RWH for adapting to risks

In drylands of SSA, the pressing development challenge is that rainfed agriculture should be upgraded to improve food and income security amidst agricultural water constraint. It has been suggested that to feed almost 2 billion more people in the next 25 years, most of the food increase will have to come from irrigated agriculture involving withdrawal of blue water from rivers and lakes. Others, however, see irrigation expansion as a more limited option, since some quantity of water must remain in rivers to protect aquatic ecosystems. However, it is known that agriculture in Africa already accounts for 90% of all fresh water withdrawals from rivers (Falkenmark and Rockstrom, 2004; Rosegrant, 2002). Therefore, this leaves us with the fundamental question of how rainfed agriculture especially in the dryland tropics could be upgraded to meet the ever increasing food needs of the huge population in the dryland areas of Africa.

The promising breakthrough for upgrading rainfed agriculture in the drylands remains on how efficiently the forgotten green agricultural water is utilized through practices such as RWH. RWH for agriculture can be viable in areas with annual rainfall of as low as 300 mm (Ngigi, 2003). This means given the status of rainfall amount, which can be as high as 500-800 mm in most parts of dryland tropics, RWH is confidently a viable option.

Some studies have documented the potential of RWH in upgrading the performance of rainfed agriculture in dryland areas (Oweis and Hachum, 2006; Hatibu *et al.*, 2006; Fox *et al.*, 2005; Ngigi *et al.*, 2005; Goel and Kumar, 2005; Senkondo *et al.*, 2004;

Barron *et al.*, 2003; Rockstrom, 2003; Ngigi, 2003; Ngigi, *et al.*, 2005; Rockstrom, 2000). While these present the economics of water harvesting for agriculture, empirical analysis of the economic viability of RWH as a strategy for adapting to the risks caused by rainfall variability is not clearly explained. Exclusively, the past work concentrated more on analyzing the magnitude of farm outputs (yield and returns) given input factors such as land, labour, capital and water rather than how robust different RWH systems stabilize these outputs under different seasonality contexts. Production instability caused by rainfall variability is the major risk facing farmers in the dryland areas. That is why Koundouri *et al.* (2006) argue that intelligent policy formulation should consider not only the marginal contribution of input use to the mean of output, but also the marginal reduction in the variance of output. This study was intended to fill this knowledge gap by analyzing the efficacy and consistence (dominance analysis) of different levels of RWH in giving higher but stable farm outputs in bad and good seasons.

2.5. Approaches in risk attitude analysis

A range of approaches is utilized to analyze risk attitudes of decision-makers in various sectors including agriculture. These include: (a) direct elicitation of utility functions, (b) experimental procedures in which individuals are presented with hypothetical questionnaires regarding risky alternatives with or without real payments, and (c) inference from observation of economic behaviour using non-parametric (mathematical programming) and parametric (econometric) models. These approaches are found extensively in various literature some of which include Manski (2004), Anderson and Hardaker (2003), Senkondo (2000), Pennings and Smidts

(2000), and Rabin (2000). The third approach (c) might be extended to embrace the latent variable approach used to analyze attitude towards risk in this study. With the exception of the latent variable approach, other approaches are based on axioms of expected utility theory (EUT) in which the risk attitude is measured in terms of risk aversion coefficients.

The ability to generate probability distributions or risky events is the basic application ground in operationalizing the EUT in which either objective or subjective sources of probability distributions are used. Subjective source entails eliciting the probabilities from the decision-maker while objective refers to generating probabilities from historical observations. Subjective probability distributions are more relevant where the research intends to analyze risk from behavioural perspective of the decision-maker. In this respect, subjective probability is the decision-maker's degree of belief or expectation about the outcome of a future uncertain event. Contrary to objective probabilities established from historical events, subjective probabilities are attributed to decision-maker's state of belief about the likelihood of the occurrence of uncertain future events. Details on application of utility theory are found in a number of literature on risk including Manski (2004), Anderson and Hardaker (2003), Khanthavit *et al.* (2001), Senkondo (2000), Turan *et al.* (2003), Rabin (2000), Pennings and Smidts (2000), Hardaker (2000), Chichilnisky (2000), and Binswanger (1980).

Despite of its wider use in risk analysis, utility theory approach has never been free from criticisms. In economics, the utility theory builds on a basic assumption of

diminishing marginal utility of wealth which is used to characterize risk aversion. Diminishing marginal utility condition simply means we dislike vast uncertainty in lifetime wealth because the marginal value of a dollar when we are poor is higher than when we are rich. Economists pervasively explain widespread risk aversion by an assumption that people generally have diminishing marginal utility of wealth. The subjective expected utility (SEU) model which is backed by utility theory, is discredited because of its low predictive validity partly due to lack of adequate test designs and failure to recognize various psychological constructs of judgment and choice underlying decisions (Senkondo, 2000; Rabin, 2000; Shoemaker, 1982). Furthermore, Chichilnisky (2000) critiqued the expected utility approach for underestimating low-probability events, making it implausible to analyze catastrophic risks which might have low probability of occurrence with major irreversible consequences.

Above all, most of the utility models are too data hungry for regular applications. Despite their complexity, utility models might fail to capture risk behaviour and farming system dynamics. In addition, they also take a huge share of research time and attention at the expense of other pertinent research issues. Furthermore, in the context of rural economy where poverty is pervasive and the actual risky financial prospects in agriculture are meagre, as it is the case with the drylands of Tanzania, results from probability elicitation may not reflect actual behaviour of the subjects. In short, these were the technical limitations that discouraged the use of the SEU model in this study (for an elaborate critique of SEU model, see Hardaker and Lien, 2005;

Hardaker *et al.*, 2004). Therefore, this study employed the latent variable (LV) approach to measure risk attitudes.

In LV approach, the socio-economic or psychological variables are linked to economic analysis by working with 'soft' or 'latent' variables that cannot directly be observed by researchers and other change agencies. LV approach is synonymous to Likert scale framework widely used in attitudinal social studies. The strength of LV approach is well documented in a number of literature including Manski (2004), Pennings and Garcia (2001), Senkondo (2000) and Shoemaker (1982). Social researchers rarely ask respondents openly about their views or opinions in preference to structured interviews. Arguing on similar lines, De Weerd (2005) observed that to explain the farmer's behaviour, one needs to take cognizance of the farmer's views, a profile of his history and immediate environment and to ask him/her how he/she perceives and reacts to risk.

CHAPTER THREE

3.0 METHODOLOGY

3.1. The study area

The research was conducted in three villages in the Makanya River Watershed (MRW). The MRW is located in Same district North Eastern Tanzania (Fig. 2). The altitude of MRW ranges between 600 in the lowland to 2 424 m above m.s.l in the upland. The MRW has three dryland zones characterized by the rainfall regime and topography. These zones include the relatively high rainfall upland, midland with medium rainfall and low rainfall lowland. The three villages selected in these biophysically varied places are Tae, Mwembe and Makanya in upland, midland and lowland, respectively. Farmers in these three villages are hydrologically linked by the runoff produced uphill (Tae and Mwembe) and flowing into the drier lowland plains where runoff farming is prominent. The topo-sequential positions of the study villages in the MRW are as shown in Fig. 2.

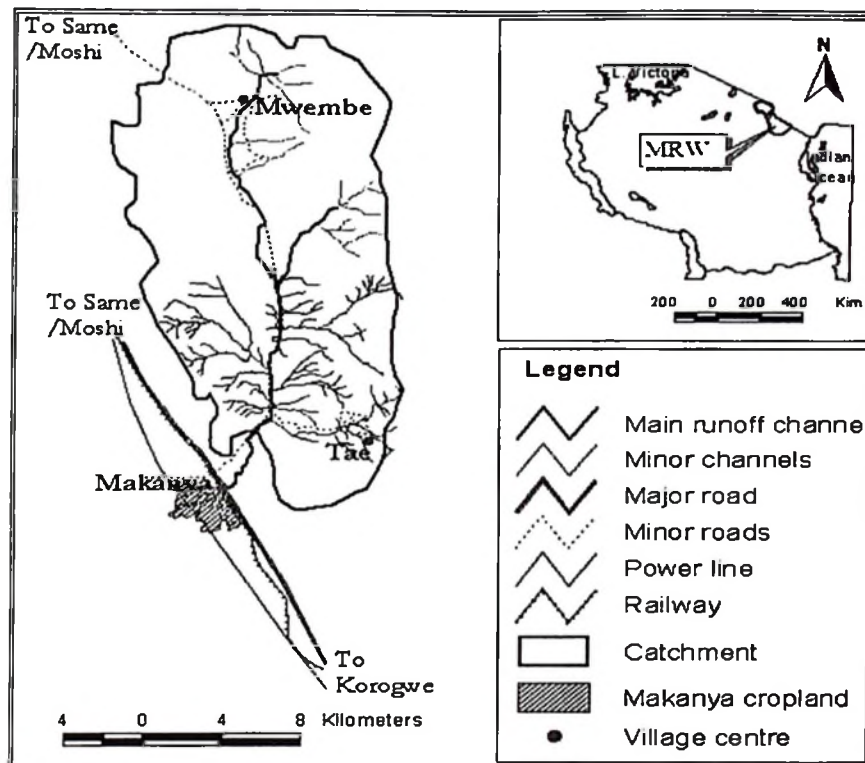


Figure 2: Map of Tanzania showing the MRW, and the study villages

The farming system in the MRW is based on bimodal rainfall regime. The short rain seasons extend across two consecutive years entailing months of October, November, December, January, and February. The long rain season spans within the same production year entailing months of March, April and May. The annual amount of rainfall ranges from around 400 mm in the lowland to 1 000 mm in the upland. Figures 3 and 4 presents the pattern of recorded seasonal rainfall from two rain gauge stations namely Hassan Estate and Suji Mission in the lowland and upland, respectively. The plotting was restricted to the period from 1997-2004 which coincides with the recall period used in the questionnaire to collect data on household crop production and income.

For the lowland, Fig. 4 shows that the two peaks of rainfall intensity were in the short rain season of 2003/04 and in the *El Nino* of 1997/98. Predominantly, the amount of rainfall during the long rain seasons was lower than that of short rain seasons.

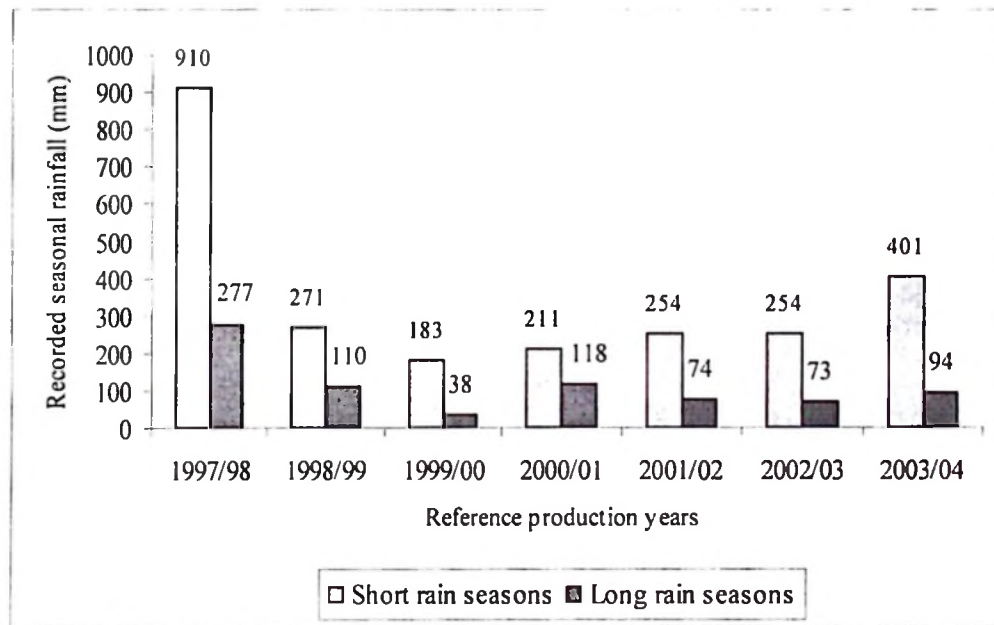


Figure 3: Recorded seasonal rainfall in the lowland (Hassan Estate station)

The peak rainfall in the upland was in the short rain seasons of 2003/04 and during the *El Nino* of 1997/98. The amount of rainfall was predominantly higher during the short rain seasons than during long rain seasons (Fig. 4). Comparison of results in Figs. 3 and 4 reveals that the amount of rainfall was higher in the upland than in the lowland.

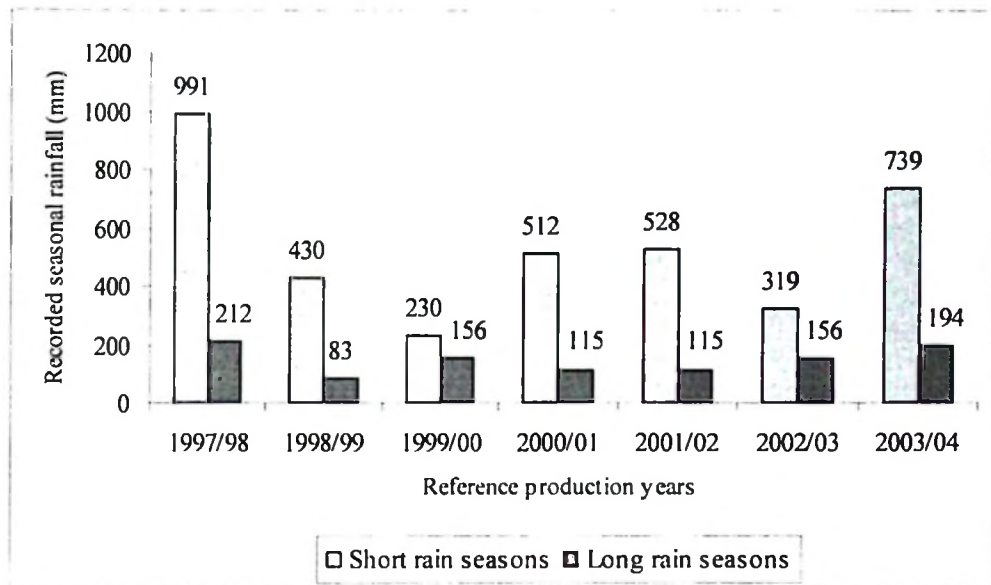


Figure 4: Recorded seasonal rainfall in the upland (Suji Mission station)

The selection of MRW as a single study site contrary to replicating the study in other areas had a justification behind it. MRW is a typical dryland landscape representing a socio-hydro-ecological setting in which the complex nexus of risk and adaptations could be comprehended. MRW is characterized by varied climatic and socio-economic patterns. Such diversity provides distinct production constraints and possibilities to farming households in different locations along the landscape. This would make the results from a systematic study conducted in MRW of wider application in the vast dryland areas in the tropics.

3.2. Data collection

3.2.1. Secondary information collection

Secondary information was sought to grasp insights on the global, regional, and national issues of relevance to aspects of interest to this research. Secondary information was sought through reviewing literature on a range of broad aspects of

the study. Major sources of secondary information included the National Agricultural Library (SNAL) at Sokoine University of Agriculture, the mini library at Soil and Water Management Research Group in the Department of Agricultural Engineering and Land Planning at Sokoine University of Agriculture, and the Internet.

3.2.2. Primary data collection

Collection of primary data using a questionnaire survey was preceded by key informants' interviews between October and November 2004. The questionnaire and the checklists used in the household survey, key informants' and community scheme managers' interviews are attached as Appendices 1, 2 and 3, respectively. Discussions with key informants' discussions were conducted to establish timeline of occurrence and impact of different risky hazards and community-wide adaptation strategies. Information gathered through key informants' interviews gave insights on the community-wide aspects of risks and adaptations, and public responses to disasters.

The household survey was conducted in three villages in the lowland, midland and upland areas. The overall sample size was 200 households that were randomly drawn from three study villages. The intention was to interview 80 farming households per village. Eighty (80) households per village and 240 households for three study villages were considered manageable given time and financial resources. However, due to untraceability and inconveniences caused by poor accessibility especially in midland and upland areas, not all sampled households were ultimately reached for interview. No troubles were made to replace the missed household heads as the sizes of reached samples were still statistically plausible. The structure of respondents by

locations is as shown in Table 1. It was hypothesized that household heads are more informed on matters related to the household compared to other members, thus their dominance in a survey (94%) reflects the credibility of the data collected. According to information obtained from respective village government offices, the study villages had approximately 1000 households. The interviewed sample was 8%, 7% and 6% of populations in the lowland, midland and upland villages, respectively.

Table 1: Position and gender of respondents by locations

Position/gender	Lowland village (n=77)		Midland village (n=65)		Upland village (n=58)		Overall (n=200)	
	n	%	n	%	n	%	n	%
Position								
Head	70	90	62	95	57	98	189	94
Spouse	5	7	2	3	-	-	7	3
Child	2	3	-	-	1	2	3	2
Blood relative	-	-	1	2	-	-	1	1
Gender								
Male	60	78	50	77	53	91	163	82
Female	17	23	15	23	5	9	37	18

3.3. Methods for data analysis

It is important to document important aspects related to measures taken to improve reliability of recall data and preliminary treatments of the data before rigorous analyses were undertaken. These aspects included measures taken to improve reliability of recall data, adjustment of household size for composition and scale economies, development of the acreage correction factor, and characterization of poverty. These aspects were central in the analytical framework and interpretation of results of this study.

3.3.1. Measures taken to improve reliability of recall data

In this study, farmers were asked to recall events that took place 6 years preceding the survey. Also, village level time series data of maize yields were deduced from respondents' recalls. A question about an event that occurred decades ago tends to yield a less reliable response than a query about similar event which took place last week or last year. In view of this, it is imperative to clearly show how practically these data were obtained from respondents as to express how reliable they are.

Risk analysis which is the centerpiece of this study is basically about dynamics. Inevitably, in order to learn about the dynamics underlying the production process, a number data points are needed. Improved reliability is achieved by drastically minimizing deviation of the recall response from the actual datum or the closest proxy of the same. Associative and sequential probing was the guiding principle applied to collate maize output, production costs and price of data for past 7 years inclusive of this study's survey year. The recall process was facilitated through articulation of major events which had occurred in a particular year. Tactically but conveniently, a respondent was for example asked what was your income last year, year before, during *El Nino* or the year after *El Nino*, drought year of 2003, or flood of 2004. The more salient and peculiar event is, the more likely the associated piece of information will be accurately recalled.

Furthermore, was not possible to obtain time series dataset of maize yield at a village scale. In developing countries, availability of long-term agricultural data, not only at local levels but also at national level, is an endemic problem. A technique was

developed in order to get the long-term yield data. During the survey, each respondent was asked to recall the amount of maize he or she harvested and respective acreage planted during the first season since he or she got married. Association of marriage event was very successful in easing long-term recall, apart from being interesting to respondents. As respondents were married in different years, it was possible to generate the time series dataset of maize yield in each village.

3.3.2. Adjustment of household size to composition and scale economies

Comparative poverty studies based on expenditure or income measures of welfare centered on households as units of analysis need to adjust these households to their respective size. In comparative analysis of household welfare, the metric welfare is practically affected by the household size dimensions of composition and economies of scale. A simple total expenditure is not a suitable measure of household's welfare and cannot be used for comparison with the welfare of other households of different sizes. The measurement of absolute welfare in per capita basis is sensitive to the choice of either using or not using equivalent scales. Household equivalent scales take into consideration the relative needs of households of varying sizes, composition and scale economies in measuring poverty and come up with the welfare measure in per capita terms. The essence of adjusting the welfare to the composition and scale effect is that it typically costs less to feed five children than five adults (composition effect) and doubling the size of the family does not imply doubling the amount of expenditure necessary to maintain living standards (scale effect). In view of this, the households were adjusted for both adult equivalents and scale economies to make them comparable. The equivalence units as described in Richards *et al.* (2003) were

used to adjust the household size to which the consumption expenditure as a measure of welfare was expressed to reflect the per capita terms of welfare or poverty. Adjustment of households to reflect composition and economies of scale involved a systematic procedure.

The dataset was explored to reveal all household members in relation to their gender and age. Taking into account gender and age differences, each individual was adjusted to a respective adult equivalent scale. Then, the individuals adjusted to gender and age-weighted scales were summed to get the household size adjusted to composition to counteract what is termed as ‘composition effect’ in poverty analysis. This was done efficiently in SPSS software through a ‘compute’ command with flexibilities for use of ‘if’ condition in the command syntax. The mathematical expressions are as follows:

$$H_i = \alpha_1 N_1 + \alpha_2 N_2 + \alpha_3 N_3 + \dots + \alpha_n N_n$$

Where,

H_i = gender and age-weighted i^{th} household in the dataset/sample

$\alpha_1 \dots \alpha_n$ = relative weight given to individuals with respect to age and gender as shown in Table 2

$N_1 \dots N_n$ = size of each type of components of household with similar sex and age range

The adult equivalent scales used are the ones mostly used in developing countries (Mkenda *et al.*, 2004; Richards *et al.*, 2003). These scales are shown in Table 2.

Table 2: Adult equivalent scales for adjusting aggregate household size

Age category (years)	Sex based Adult Equivalent Scales		Household size*	Economies of Scale
	Male	Female		
0 to 2	0.40	0.40	0 to 2	1.000
3 to 4	0.48	0.48	2 to 3	0.946
5 to 6	0.56	0.56	3 to 4	0.897
7 to 8	0.64	0.64	4 to 5	0.851
9 to 10	0.76	0.76	5 to 6	0.807
11 to 12	0.80	0.88	6 to 7	0.778
13 to 14	1.00	1.00	7 to 8	0.757
15 to 18	1.20	1.00	8 to 9	0.741
19 to 59	1.00	0.88	9 to 10	0.729
60+	0.88	0.72	10+	0.719

Source: Richards *et al.* (2003)

* Measured in number of age and gender-weighted, adult equivalent units.

Afterwards, the gender and age-weighted household size was adjusted to economies of scale. The mathematical expression for scale economies correction is as follows:

$$HE_i = (H_i)^\psi$$

Where,

HE_i = household size of i^{th} household in the dataset adjusted for both composition and scale effect

H_i = gender and age-weighted i^{th} household in the sample

ψ = scale economies within the household

Therefore, the expenditure per capita (indicator of welfare/poverty) adjusted to composition and a scale effect was obtained through the following mathematical relation:

$$W_i = \frac{C_i}{(\alpha_1 N_1 + \alpha_2 N_2 + \alpha_3 N_3 + \dots + \alpha_n N_n)^\psi}$$

Where,

- W_i = adjusted welfare per capita of i^{th} household in the sample
- C_i = aggregate consumption (summed value of own production, purchases of food and non-food, and transfers). Where a need arose, other variables such as income and value of assets were also adjusted accordingly to offset composition and scale effects.

3.3.3. Development of acreage correction factor

Among the critical problems affecting the accuracy of yield estimation for smallholder farmers has been the challenge of getting the correct field sizes from recall surveys. This is because smallholder farmers do not practically take standard measures of their crop fields, and have their replies on acreage when asked by researchers or agricultural planners is merely a guess. In order to arrive at the best estimation of the acreage from farmers' recall, a special exercise was done to workout the correction factor (\pm actual value) in this study. This was undertaken by selecting one plot from a household and asking the farmer to give the size of the plot. Then, the plot was measured using GPS instrument and the respective area was determined using GIS-Arc View software. Seventeen (17) pilot farms for different farmers were surveyed. A regression model was estimated using STATA software to determine the

coefficient that was used as a factor to correct reported acreages in the vast survey sample. The correction factors of -0.2 was realized meaning that when a farmer says his/her plot is 1 acre the correct size is actually 0.8 of an acre. The scatter plot with a regression fit of measured and cited acreages did not reveal a serious problem of outliers (Appendix 4).

3.3.4. Characterization of poverty

In real world, poverty and vulnerability to risk are intertwined phenomena. The nexus between poverty and risk is obvious. If poor people are risk-averse to the extent that they are unwilling to invest in the acquisition of modern assets because that involves taking risks, they will tend to remain poor and develop the syndrome of lacking adequate defence against risk (Mosley and Verschoor, 2003). Given these views, it was important to integrate poverty aspects in risk analysis which was the main subject of this study.

The characterization of poverty involved conceptualization of two definitions of poverty. These definitions include subjective and relative absolute poverty. Subjective poverty refers to the way the community defines who falls in a certain wealth bracket according to local wealth criteria. For a comprehensive discourse on subjective poverty one may read De Weerd (2006), Bird and Shinyekwa (2005), and some related publications from the World Bank. In this study, with a few village leaders, the sample households which were randomly drawn from the village register of households were ranked into three wealth groups (upper, medium and lower). This brief wealth ranking exercise was done with reference to the wealth criteria identified

through PRAs conducted in these villages by soil and water management project (SWMRG, 2003). The material wealth criteria include type of housing, livestock owned, land ownership, food security, business enterprises, clothes, remittance and farm implements. Non-material wealth ranking criteria such as power and social position were taken into account too.

The relative absolute poverty line was based on the poverty line which was computed from consumption data collected during the household survey. More often, poverty lines are based on income and consumption data, hence consumption and income approaches are widely used. However, the consumption approach is more robust than income since the former tends to be smoother and less variable than the latter (Deaton and Zaid, 2002; Pradhan and Ravallion, 2000; Deaton and Grosh, 1998). In circumstances where income fluctuates a great deal from year to year, as in rainfed agriculture, the ranking of households' poverty by income will usually be much less stable than ranking by consumption. Observing consumption over a relatively short period, even a week or two, will tell us a great deal more about annual or even longer period living standards than will similar observations on income. It is for these reasons, this study used consumption expenditure as a measure of poverty.

Household consumption expenditures on food and non-food items were collated from respondents through standard questions adopted from the standard Living Standard Measurement Study (LSMS) questionnaire commonly used in poverty surveys (see Deaton and Zaid, 2002). Expenditure on food was collected for a basket of food items by taking actual purchases and valuing own produced food items at market prices.

The value of the amount of a particular food item consumed in a typical month and year was derived systematic questions, similarly non-food expenditure (see Appendix 1). To get total household expenditure per capita, the sum of recurrent expenditure on food and non-food was divided by the adjusted household size. The cut-off point for the relative poverty line was the median consumption expenditure per capita of 50% of the poorest, which was US \$ 153. The households whose consumption per capita fell below the median consumption threshold were considered relatively absolute poor and those with consumption above this threshold were considered non-poor.

3.3.5. Analysis of risks faced by farmers

a) Descriptive assessment of perceived severity of risks

Agricultural risks caused by rainfall variability formed the core of the analysis. In addition, this analysis assessed the extent of economic risks which were reinforcing with rainfall-related sources of risks. In the drylands where weather-dependent agriculture is the mainstay of the economy, the stochastic nature of rainfall inevitably affects the economic state of farming households. During the survey, respondents were asked whether they perceived a certain potential source of risk being a problem or not. The percentages and counts of multiple responses were cross-tabulated by biophysical locations in the watershed to capture spatial differences.

b) Quantitative analysis of agricultural risks

i) Analysis of yield fluctuation with rainfall

In order to highlight the relationship between yield fluctuation and rainfall variability the time series data of maize yield generated from recall were plotted against recorded

seasonal rainfall. Because of lack of rain gauge in the midland village, the analysis was restricted to the lowland and upland villages. The time series data of maize yield were longer than the rainfall data available. Therefore, the years of available yield were tallied to respective years with seasonal rainfall records. Graphical analyses involved plotting long-term yield and seasonal rainfall including the best lines of fit. Also, it was of interest to understand the existing relationships between yields in the downstream lowland village with upland rainfall, because rainfall in the upland catchment generates the runoff which is harvested and used for farming in the lowland. Furthermore, bivariate correlation analysis was undertaken to explain the relationship between time series data of maize yields and respective seasonal rainfall.

ii) Analysis of instability of long-term yield

The trend of yield instability was analyzed through a measure of dispersion under the central tendency paradigm. Statistics for measuring dispersion are widely used in risk analysis (Dennerberg, 1989). This study computed the absolute deviations from the median value of maize yield over recall years. Statistically, the median is the value of the point which is half the data smaller than that point and half the data larger than that point, i.e. if X_1, X_2, \dots, X_n is a random sample sorted from smallest value to largest value then the median, \check{Y} , is defined as

$$\check{Y} = X_{(n+1)/2}, \text{ if } n \text{ is odd,}$$

$$\check{Y} = (X_{(n/2)} + X_{(n/2)+1})/2, \text{ if } n \text{ is even,}$$

Then, the deviation from the median, τ_i , is

$$\tau_i = X_i - \check{Y}$$

The absolute median deviations of maize yields (τ_i) were plotted against respective years for different study locations. The scatter plots with trend lines were also presented to depict the extent of dispersion and direction of trends.

iii) Analysis of mean comparison of long-term yield

Time series data of maize yield were sorted in the ascending order and divided into two halves and four quarters. Then descriptive analyses involving t-test were used to give insights into the magnitude of average maize yield over time. The mean comparison was done for the maize yields associated with these halves and quarters for the lowland, midland and upland villages.

3.3.6. Analysis of farmers' perception and attitude to risks

a) Analysis of farmers' risk perception heterogeneity

Assessment of risk heterogeneity explains the diversity of farmers' perceptions to risks they are exposed to, and accounts for the factors behind this diversity. Dryland farmers are not necessarily in the same boat concerning the common risk hazards they face while pursuing their livelihoods. As mentioned earlier, an index termed as composite risk assessment (CRA) was developed to serve as a measure of risk perception heterogeneity. Potential sources of risks were categorized into those related to resource access, production, market and social/institutions. Four CRA

indexes were constructed based on these typologies of potential risk sources. In constructing CRA index, once a respondent identified potential risk sources that faced him/her, and then he/she ranked them according to severity. This process produced data that contained ordinal as well as categorical information on respondent's risk perception. The more the respondent perceived most of the potential risk sources which were likely to be disastrous to him/her, the larger is the risk CRA index.

CRA index assumes a range of numbers ranging from zero to one for both incidence and severity of different risk sources, where the former represents the frequency with which respondents identify a particular hazard and the latter captures the standardized ordinal ranking of identified hazards. CRA index therefore ranges from zero (not identified as a source of risk hazard) to one (identified as the primary source of risk hazard) for each respondent. Smith *et al.* (2000) used CRA index to evaluate risk assessment heterogeneity among pastoralists in East African drylands of Ethiopia and Northern Kenya with good results. Computationally, the CRA index is expressed as follows:

$$R_{ij} = I_{ij} \left(\frac{r_{ij}}{n_i} \right)$$

Where,

R_{ij} = CRA index for respondents $i = 1 \dots n$ and risk $j = 1 \dots m$;

I_{ij} = an indicator variable equal to one if respondent i identifies risk j as a hazard and equal to zero otherwise;

r_{ij} = represents the ordinal ranking given risk j among the n_i risks identified by respondent i , with $r_{ij} = n_i$ for the most important risk and $r_{ij} = 1$ for the least important.

From the CRA index, two analyses were carried out based on four typologies of CRA indexes of resource access, production, market and institutional sources of risks. The first analysis was descriptive in nature entailing cross-tabulation of different sources of risks and computation of mean and respective tests of statistical significance using a two sample t-test by location.

The second analysis involved identification of critical determinants of farmers' divergence in risk perceptions. To attain this, a censored model (tobit) was estimated against a set of biophysical, socio-demographic and economic factors. The tobit model was found to be ideal because the dataset to run this analysis was a censored one. Simply, a sample in which information is clusters of zeros in the dependent variables is regarded to be censored. Structurally, the CRA index is a non-binary latent variable with continuous values ranging from 0 to 1. For more econometric insights on tobit model and censoring problem, an interested reader is referred to Holloway *et al.* (2004), Greene (2002), Gujarati (1995), Goetz (1995) and other many literature on applied econometrics.

Generally, the tobit model uses Maximum Likelihood Estimation (MLE) method to estimate the parameters assuming normality and homoskedasticity conditions.

The general specification of the Tobit model is as follows:

$$y^* = \alpha x + \mu; \mu | x \sim N(0, \delta^2)$$

Where,

y^* is the latent variable, but we only observe $y = \max(0, y^*)$ and α estimates the effect of x on y^* , not y . The idea is that there is an underlying variable y^* that can be modelled as $y^* = \alpha_0 + \alpha x + e$, but we only observe $y = 1$, if $y^* > 0$, and $y = 0$ if $y^* \leq 0$.

Four censored models were estimated which are model I, II, III and IV for resource access, production, market and social/institutional related CRA indexes respectively. The general functional structure for the three models for respective CRA indexes measuring risk heterogeneity is as follows:

$$CRA = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \alpha_5 X_5 + \alpha_6 X_6 + \alpha_7 X_7 + \alpha_8 X_8 + \alpha_9 X_9 + \alpha_{10} X_{10} \\ + \alpha_{11} X_{11} + \alpha_{12} X_{12} + \alpha_{13} X_{13} + \alpha_{14} X_{14} + \alpha_{15} X_{15} + \alpha_{16} X_{16} + \alpha_{17} X_{17} + \alpha_{18} X_{18} + \mu$$

Where,

CRA = the dependent variable for all four censored models.

α_0 = the constant or an intercept of the regression equation

$\alpha_i \dots \alpha_n$ = the parameters to be estimated ranging from $i^{th} = 1$ to n^{th}

$X_1 \dots X_{18}$ = independent variables described in Appendix 5

μ = the error term

b) Analysis of farmers' attitude to risks

This analysis involved capturing responses on a number of attitude-measuring statements (axioms) addressed through structured interviews (Appendix 1). The development of these statements emanated from a review of previous pertinent research work, participatory group discussions and researchers experience in the study area. These attitudinal axioms were categorized into three different themes namely farmers' attitude towards risk, attitude towards market-orientation and attitude towards commitment in resource conservation. The first theme implied more of intrinsic risk behaviour explained by axioms which were more endogenous. Endogeneity means risk factors which are within one's control. The second and third themes comprised of axioms which explained more exogenous risk factors. Exogeneity refers to those risk factors which are beyond one's control. Arguably, endogeneity and exogeneity of decision factors would have a bearing on the ultimate attitude of the decision-maker towards a certain type of risk.

For each attitude-measuring statement, respondents were asked to state whether they strongly agree, agree, disagree, strongly disagree or undecided. During the analysis responses of 'strongly agree' and 'agree' were combined into a value of '+4' implying agreement (positive attitude) with the posed statement and responses for 'strongly disagree' and 'disagree' were accorded a value of '-4' indicating disagreement (negative attitude). All undecided responses, which were fewer in the dataset, were substituted with zero. In the case of attitude towards risk, the total positive and negative scores implied risk seeking and risk averting behaviour, respectively. With an exception of one statement, no more recoding of the initial responses was

necessary as almost all risk attitude statements in the questionnaire connoted positive measurement of risk. In view of this, the sample of farmers was divided into risk-averse farmers and risk taking farmers. The split was based on the average sum of the score on the items of the two extremes of the scale (-4 & 4). Farmers with a negative sum score are risk averse while farmers with positive sum score are risk takers. A respondent with a sum score of zero was considered risk neutral.

Conventional factor analysis was used to give descriptive insights into intrinsic risk attitude, attitude towards market orientation and resource conservation risks. Comprehensive details on factor analysis are found in Papanastasiou (2005), Senkondo (2000), Green *et al.* (2000), Negatu and Parikh (1999), and Kim and Muller (1978), cited by Senkondo (2000). The magnitude and direction of factor loadings for different attitudinal constructs were evaluated based on the researcher's hypotheses. In order to identify the statements which communally explain the variation, the sample variance was determined for each item. Items which showed infinitesimal variance were eliminated. The eliminated statements are those presented in the questionnaire (Appendix 1) but are not seen anywhere in Tables 18, 19 and 20. The factor analysis involved rotation of factors to maximize the variance (varimax). Robust factors, that is latent variables that had highest Eigen values (>1) were used to develop factor scores (factor loadings) for measuring attitude.

Beyond this descriptive analysis, the censored model (Tobit) was estimated to identify critical factors influencing risk attitude of farmers in dryland areas.

The functional structure and specification of the model is as follows:

$$RISKATT = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \alpha_5 X_5 + \alpha_6 X_6 + \alpha_7 X_7 + \alpha_8 X_8 + \alpha_9 X_9 + \alpha_{10} X_{10} \\ + \alpha_{11} X_{11} + \alpha_{12} X_{12} + \alpha_{13} X_{13} + \alpha_{14} X_{14} + \alpha_{15} X_{15} + \alpha_{16} X_{16} + \alpha_{17} X_{17} + \alpha_{18} X_{18} + \alpha_{19} X_{19} + \alpha_{20} X_{20} + \mu$$

Where,

$RISKATT$ = the variable measuring the 'risk attitude'. It was constructed as explained above.

α_0 = the constant or an intercept of the regression equation

$\alpha_i \dots \alpha_n$ = the parameters to be estimated ranging from $i^{th} = 1$ to n^{th}

$X_1 \dots X_{20}$ = independent variables described in Appendix 5

μ = the error term

3.3.7. Assessment of strategies used by farmers to adapt to risks

This analysis was undertaken using both community-level qualitative information and primary data collected through household questionnaires. Qualitative analysis of community-level qualitative information from key informants' was done by synthesizing the timeline of agro-climate hazards, societal impacts and adaptation, and reactions by the government and non-government agencies during such risky hazards. Here agro-climate hazards refer to climate related hazards which potentially disrupt agricultural production. The second analysis involved descriptive cross-tabulations of strategies used by the sample households to adapt to rainfall-related and economic risks. In order to make plausible inferences, the analysis of adaptation strategies was restricted to risk sources with statistically sufficient responses.

3.3.8. Analysis of economic viability of RWH for adapting to risks

Viability of RWH for risks mitigation was empirically analyzed in terms of levels of economic performance of maize under different RWH systems and seasonality settings. Interrelated economic performance indicators of RWH based maize enterprise include yield, returns to land and returns to labour. The level of economic performance signifies the importance of RWH to improve food and income security which are ultimate objectives of risk adaptation process. The basic intent of this analysis was to reveal how different levels of RWH could ensure production stability by smoothing out variability in soil moisture needed for plant growth. The concept of seasonality explained before was the stepping stone for analyzing viability of RWH systems. Broad domains for this analysis entail returns from maize enterprise, stability of maize yield, dominance of returns for different levels of RWH and economic appraisal of the community RWH scheme. Analyses of yield and price are implied under the broad analysis of returns which are a function of yield and price. Physical yield underscores the technical efficiency for different technologies of resource transformation. Returns underscore allocative efficiency as the price element is taken into account. Component analyses of returns include yield, returns to land and returns to labour.

a) Analysis of returns from maize enterprise

Economic evaluation of RWH systems might apply different techniques ranging from simple yield comparisons and more sophisticated risk analysis methods such as stochastic dominance analysis. This study applied gross margins to express returns realized from different level of RWH under different seasonality and biophysical

settings. Gross margins analysis is static, and does not take into consideration of the time value of money compared to investment analysis. Nonetheless, gross margins analysis is a useful tool, which can assist in improving the overall management as it addresses resource productivity in a given period. Anyone interested in the details on the theoretical shortcomings and strengths of gross margins analysis among other economic analyses can read Senkondo *et al.* (2004), Kunze (2000) and Fox *et al.* (2005).

The physical productivity (yield) for a given maize crop enterprise refers to the total farm output per unit of land for forms of RWH in different seasons. The total farm output include the total amount of maize harvested part of which was consumed at home, given out as social transfers or marketed. However, productivity is not only a function of water (moisture) as it also depend on land quality and level of husbandry practices, it is still recognized that in dryland areas water management is a critical factor of production. The equation for calculating average productivity (yield) is as follows:

$$Y_{ijk} = \frac{1}{n} \sum_{i=1}^n \frac{O_{ijk}}{L_{ijk}}$$

Where,

Y_{ijk} = average productivity for seven seasons by i^{th} farmer for j^{th} crop enterprise under k^{th} RWH system (ton/ha),

O_{ijk} = output for i^{th} farmer from j^{th} crop enterprise under k^{th} RWH system (ton)

- L_{ijk} = acreage for i^{th} farmer for j^{th} crop enterprise k^{th} RWH system (ha)
 n = number of farmers involved in j^{th} crop enterprise under k^{th} RWH ($i \dots n$)

Returns to land expressed in terms of gross margins were determined by multiplying the physical yield (ton/ha) and price (TAS/ton). The basic equation for gross margins computation is presented as follows:

$$GM_{ijk} = \frac{1}{n} \sum_{i=1}^n (P_{ijk} V_{ijk} - VC_{ijk})$$

Where,

- GM_{ijk} = average gross margins for seven seasons earned by i^{th} farmer for j^{th} crop enterprise under k^{th} RWH system (TAS)
 P_{ijk} = unit output price received by i^{th} farmer for j^{th} crop enterprise under k^{th} RWH system (TAS/ton)
 V_{ijk} = volume marketed/valued by i^{th} farmer for j^{th} crop enterprise under k^{th} RWH (ton),
 VC_{ijk} = total variable costs (that vary with level of output) incurred by i^{th} farmer for j^{th} crop enterprise under k^{th} RWH system (TAS)
 n = number of farmers involved in j^{th} crop enterprise under k^{th} RWH system,

Valuation of rural family labour has been another area of economic debate. Anyone interested in understanding different views on how to handle valuation family labour in rural contexts can read Senkondo *et al.* (2004), Kunze (2000) and Fox *et al.* (2005). Taking into account of the complexity surrounding valuation of family labour, the family labour was retained as person-days and not valued in monetary terms in this

study. One person-day was considered to be equal to one adult (aged 15 years and above) working manually in the farm for 8 full hours a day. In order to get returns to labour, the gross margins were expressed in per person-days of family workforce employed in different farm operations.

Descriptive analysis of producer prices at which the respondent farmers exchanged their maize produce aimed to show how prices related with levels of returns to land and labour. Also, this analysis sheds more light on the price pattern in the dryland farm-sector. The price analysis applied descriptive statistics of mean comparison with t-test statistics to explore the significance of mean differences.

b) Analysis of stability of maize yield for different RWH systems

Stability analysis aimed at illuminating the efficacy of RWH in stabilizing and minimizing the randomness of maize yields over time. System stability refers to the absence or minimization of year-to-year fluctuations in either production or value of output. Coefficients of variation (CV) of maize yields were used to show the stabilizing effect of RWH systems in both A-average and B-average long and short rain seasons. The t-test was used to test whether the mean differences of CV differed significantly. According to McConnell and Dillon (1997), yield and farm income stability is most conveniently measured in terms of the coefficient of variation.

Mathematically, the CV expresses the standard deviation, denoted by SD, or positive square root of the variance (V) of a sample of observations on a variable X as a percentage of the sample's mean value, \bar{X} . Thus

$$CV = 100 \left(\frac{SD}{\bar{X}} \right) = 100 \left(\frac{\sqrt{V}}{\bar{X}} \right) = 100 \left[\sum_{i=1}^n \frac{(X_i - \bar{X})^2}{n-1} \right]^{\frac{1}{2}} \div \left(\sum_{i=1}^n \frac{X_i}{n} \right)$$

Where,

- n = the number of observations,
- X_i = yield of maize in the i^{th} observation;
- Σ = summation sign entailing values for i from 1 to n .

c) Dominance analysis of returns from maize for different RWH systems

Stochastic dominance analysis is widely used in risk analysis (see Madden and Smith, 2000; Mishra and Goodwin, 1997; Howes, 1993). It should be noted that the dominance analysis as applied in this study is quite different to stochastic dominance analysis. In this study, the term 'dominance' refers to its normal usage meaning that one thing exceed another in magnitude. Dominance analysis technique was applied by plotting three cumulative distributions of returns to land from maize enterprise for rainfed, *in-situ* and external catchment RWH systems during both B-average long and short rain seasons. The choice of B-average seasons was because the efficacy of RWH systems over a typical rainfed system is clearly attested in bad years than in good years.

Operationally, if the cumulative distribution curve (CDC) of returns to land from maize enterprise under *in-situ* RWH system in B-average long rain seasons lie above that of maize under rainfed system in the same seasons, then the former system dominates the latter. This means, *in-situ* RWH system tends to perform better than rainfed system in terms of returns to land over a range of production B-average long rain seasons. Mathematically, let the cumulative distribution curve associated with the returns to land (x) from maize enterprise under *in-situ* RWH system be $F_i(x)$ and $F_r(x)$, respectively. For $F_i(x)$ to dominate $F_r(x)$ the CDC of the former system should lie on top of that of the latter. That is $F_i(x) \geq F_r(x)$. Graphically, the scenario is presented in Figure 2.

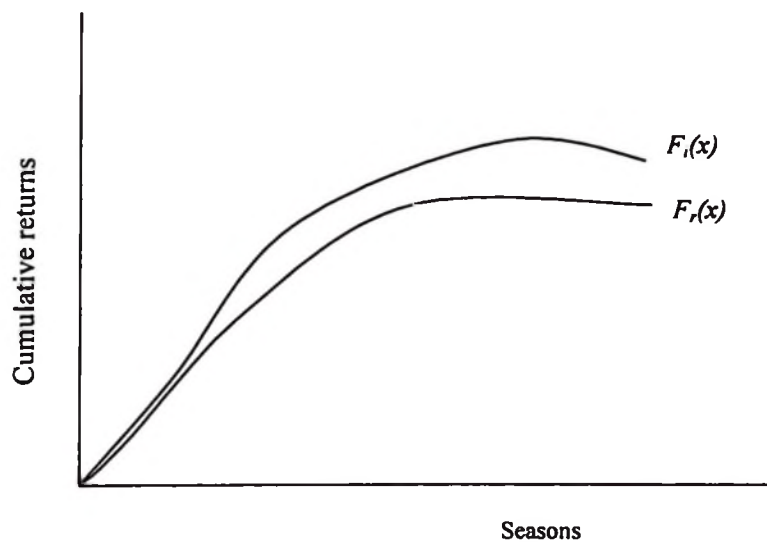


Figure 5: Dominance pattern of cumulative returns to land

d) Analysis of long-term economic viability of community RWH scheme

Analysis of the economic viability of community RWH scheme was pertinent to inform community targeting policy interventions. The traditional community RWH

scheme in the semi-arid village was evaluated for its community-wide financial stream of net benefits, net returns per capita, and the Drought Relief Saving (DRS). FAO/SAFR (2000) applied the DRS when appraising the economic viability of communal irrigation schemes in Zimbabwe. The discounted budgeting technique was used in these analyses. Nevertheless, budgeting techniques are subject to criticisms vested in its underlying static production economics theory which ignores dynamics practically facing farm firms in real world. The problem of static assumption is that budgeting cannot address the problem of future inflationary shifts, hence market prices of inputs and outputs (Bradford and Debertin, 1985). However, budgeting has remained to be a useful planning tool in farm production and management. Respective sub-analyses are as follows.

i) Analysis of present value of net benefits and net benefits per capita

Some data were obtained as part of the survey under this study and from previous research work. From the yield monitoring study conducted in the same scheme, Mutabazi *et al.* (2005) observed average yields of 1.4 and 1.0 ton/ha for maize in A-average and B-average seasons, respectively. They also observed respective lablab yield levels of 1.9 and 1.2 ton/ha. A 2-3 year return period of a bad season was considered in a 10-year project time horizon. Some plausible assumptions made under this analysis include: (a) the time horizon of 10 years was chosen to coincide with the terminal year of the Millennium Development Goals (MDGs) delivery timeframe; (b) Fixed costs were not considered because the components of what would have been part of such cost structure are either nature given or were done once forever. These include main gully serving as the main canal and secondary earth canals dug by the

community in the early 1900s. In this regard, maintenance of the canals by removing the silt and other runoff depositions through collective community labour is the major work; (c) the community labour used in canals maintenance work was imputed at the prevailing casual labour wage rate offered by the nearby sisal plantation company to get the overhead costs; (d) production costs were equated to 50% of the maintenance costs; and (e). The discount rate of 10% was assumed. This has been the interest rate on time deposit offered by commercial banks over the five years preceding the survey. The financial streams of revenues and costs streams were discounted to determine net present value (NPV) and Benefit/Cost Ratio (BCR). NPV is the present value of a series of future net benefits that will result from an investment. The criterion for the acceptance of a project is that the NPV value must be positive and BCR must be greater than 1 (see Stutely, 2002; Mullins *et al.*, 2002; Sloman, 2000). Computation of present value of the stream revenues and costs was directly done in Excel worksheet using a built-in command. Mathematical equations underlying the computation of NPV and BCR are as follows:

$$NPV_s = \sum_{t=1}^n R_t \left(\frac{1}{(1+r)^t} \right) - \sum_{t=1}^n C_t \left(\frac{1}{(1+r)^t} \right)$$

$$BCR_s = \frac{\sum_{t=1}^n R_t \left(\frac{1}{(1+r)^t} \right)}{\sum_{t=1}^n C_t \left(\frac{1}{(1+r)^t} \right)}$$

Where,

NPV_s = Net Present Value of the scheme (US \$)

- BCR_s = Discounted BCR of the scheme
 R_t = revenue in year t (US \$)
 C_t = costs in year t (maintenance plus production costs) (US \$)
 r = discount rate (10%)
 $t...n$ = year t to n^{th} of the project time horizon
 Σ = the sum of each of the years' discounted net benefit stream

Furthermore, sensitivity analysis was done to portray changes in the magnitude of net benefit streams by decreasing the cultivated acreage by certain proportions (25%, 50% and 75%). The amount and frequency of runoff available for harvesting is the major determinant of the area of the scheme to be cultivated. When farmers receive or anticipate receiving insufficient runoffs the area under cultivation is reduced. The sensitivity analysis evaluates the robustness of the community-based RWH given downside risk of insufficient runoffs to harvest.

The net returns or benefits per capita expressed the scheme entire benefits to the beneficiary population. The population of farmers served by the scheme was computed by multiplying the village average household size and the total of beneficiary households. The challenge is that for a 10-year time horizon the household size is not static, it will be changing over year. In view of this, the inter-censal (between 1988 and 2002) population growth rate of 1.6% for Kilimanjaro region which constitutes the study area was assumed. This rate holds for a span of 14 years from 1988 to 2002. In order to get the annual average population growth rate the inter-censal rate of 1.6% was divided by 14 years. Starting from the household size calculated survey data under this study, the household sizes in proceeding years were

projected based on determined average annual population growth rate. The basic assumption is that the determined annual population growth rate will continue to hold for the reference span of years. Sensitivity analysis was done by applying 25%, 50% and 75% decrease in acreage of the scheme under cultivation as to see changes in the magnitude of net benefits per capita. Mathematical equation underlying the computation of net benefits per capita is as follows:

$$NBC_t = NB_t / N_t$$

Where,

NBC_t = net benefits per capita in year t (US \$)

NB_t = net benefits in year t (US \$)

N_t = number of scheme beneficiaries in year t

ii) Analysis of drought relief saving of the community RWH scheme

The Drought Relief Saving (DRS) is the money value equivalent to overall costs of the relief food grain saved by the community by participating in RWH. The DRS concept is relevant in a place where crop production without any effort to practice RWH is impossible because of critical agricultural drought. Such drought would lead to crop failure that will inevitably call for relief food support to the affected community. The DRS was computed as follows:

In Tanzania, 300 kg per adult equivalent per year of cereal grain particularly maize is regarded nutritionally sufficient to provide for energy requirement. If relief food is

unlimited, this is supposed to be the basis in food provision to the needy households. In order to get the volume of required relief food grain (VR_t) in a particular year t , the nutritionally recommended amount of food grain per adult equivalent per year (RF_g) was multiplied by the number of individuals in the beneficiary households (BH_n) and respective household size (HS_t) in year t , determined as in (ii) above. Mathematically, the computation of VR_t is presented as follows:

$$VR_t = RF_g * BH_n * HS_t$$

The procurement price of US \$ 150/ton of maize (PP_g) at the national Strategic Grain Reserve (SGR) was multiplied by the volume of required relief grain (VR_t) to get the value of required relief food grain (RFV_t) in a particular year t . Transportation and administrative costs for relief food provision were accounted for as 10% of RFV_t , which was added to it to get the overall value of required relief grain in a particular year t (ORF_t). The ORF_t is equivalent to the DRS in a particular year of the project time horizon.

Mathematically, the parameter can be summarized as follows:

$$RFV_t = PP_g * VR_t$$

$$ORF_t = DRS = (0.1 * RFV_t) + RFV_t$$

Then, DRS was discounted as follows:

$$DRS_s = \sum_{t=1}^n DRS_t \left(\frac{1}{(1+r)^t} \right)$$

Where,

DRS_s = Present Value DRS for the community RWH scheme (US \$)

DRS_t = DRS streams for the scheme in year t (US \$)

r = rate of discount (10% expressed as decimal form: 0.1)

$t \dots n$ = year t to n^{th} of the project time horizon

Σ = the sum of each of the years' discounted DRS

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1. Characteristics of risks faced by farmers

4.1.1. Farmers' perceptions of severity of risks

Results in Table 3 indicate that drought was cited by most of respondents to be the severe problem. Drought here entailed two facets of rainfall variability of seasonal drought and dry spells. Bearing in mind that the lowland and midland villages which characteristically are prone to flooding, the flood and stormy rainfall hazards were not perceived to be a severe source of risk in these villages. These findings indicate the good side of flood in dryland areas which are critically water scarce. Whereas flood can have adverse impacts on public infrastructure and settlements, but with innovative practices it can be converted into the needed agricultural water. The problem of low income was perceived to be the severe source of economic risk in all three study locations. Lack of jobs did not feature widely as a serious economic source of risk in the lowland village since only 25% cited it to be a serious problem.

Table 3: Extent of climate variability and economic risks by location

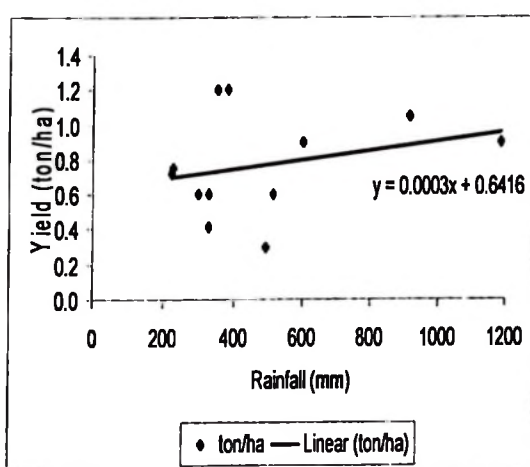
Sources of risk	Lowland village		Midland village		Upland village	
	Not a problem	Serious problem	Not a problem	Serious problem	Not a problem	Serious problem
Rainfall-related source						
Drought	7(11)	56(89)	3(6)	48(94)	4(9)	43(91)
Flood	44(70)	19(30)	44(86)	7(14)	34(72)	13(28)
Stormy rainfall	52(83)	11(17)	46(90)	5(10)	30(64)	17(36)
Economic sources						
End of source of livelihood	25(40)	37(60)	22(43)	29(57)	14(30)	33(70)
Unemployment	46(75)	15(25)	37(72)	14(28)	20(43)	27(67)
Low income	9(14)	54(86)	15(29)	36(71)	4(8)	43(92)
High prices of basic needs	16(26)	45(74)	17(33)	34(67)	8(17)	39(83)

Open figures are counts, and figures in brackets are percentages

4.1.2. Quantitative results of agricultural risks

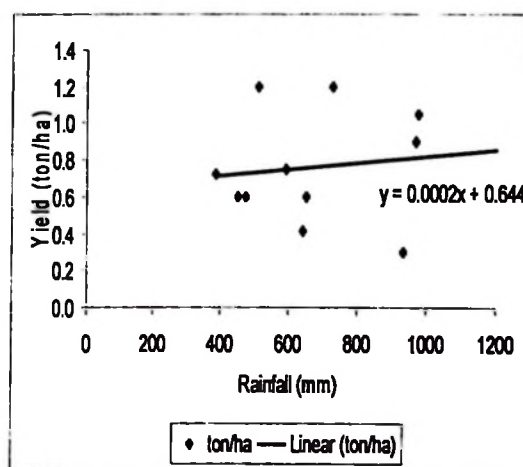
a) Yield fluctuation with rainfall

In the lowland village, long-term maize yields for exhibited a gradual increase with increasing recorded seasonal rainfall in the same area (Fig. 6). Such gradual increase is indicated by the positive gradient of the trend line. Fig. 7 shows a positive trend of yield in the lowland with upland rainfall. The purpose of comparing yield in the lowland and rainfall in the upland was done in order to reveal the possible influence of the latter through RWH which utilize runoff generated from the upland catchment in crop production. Bivariate correlation analyses show that the long-term maize yields in the lowland correlated positively but insignificantly ($P < 0.1$) with both lowland and upland rainfall. This means that in the lowland, direct rainfall alone could not make a difference in terms of crop yield unless extra moisture is concentrated in the root zone of the crop.



$R = 0.27$ not significant at $P < 0.1$

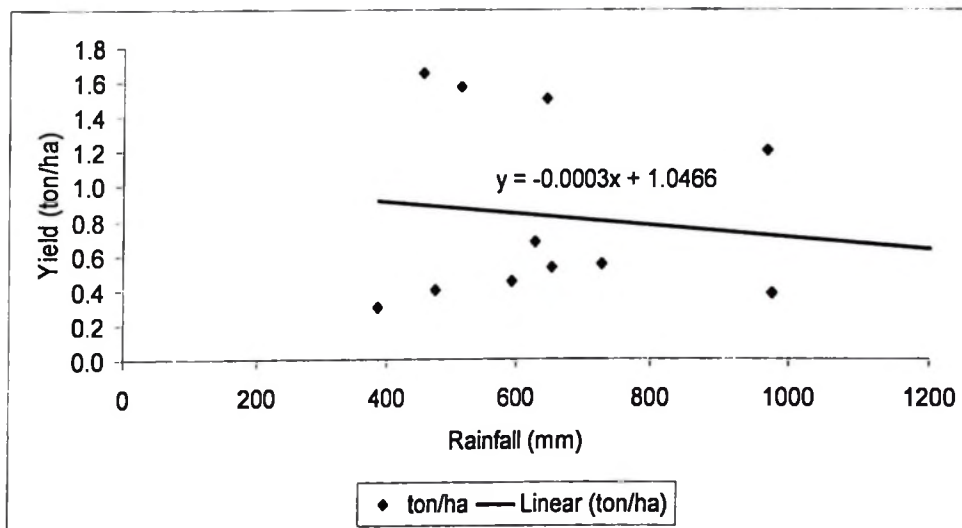
Figure 6: Crop yield in the lowland village with lowland rainfall



$R = 0.16$ not significant at $P < 0.1$

Figure 7: Crop yield in the lowland village with upland rainfall

In the upland village, the relationship of long-term maize yields and respective seasonal rainfall exhibited a negative gradient (Fig. 8). This implies that yield of maize tended to decrease with increasing rainfall. However, such inverse relationship was not statistically significant ($P < 0.1$) as indicated by the significance test result of the correlation. Negative relationship between maize yield and rainfall was not unexpected. This is because the upland village is found in a relatively wetter and humid climate which may affect yield of water sensitive crops like maize in seasons with more rainfall. That is why in the upland village, drainage is an important component of RWH systems.



$R = -0.16$ not significant at $P < 0.1$

Figure 8: Crop yield in the upland village with upland rainfall

b) Instability of long-term yield

Preliminary results are worth explaining as a backdrop for further analyses. For the lowland, farmers' recalls spanned from 1948 to 2004 giving the time series dataset of 37 years instead of 57 if there were no gaps in between. However, the success was 65% as the generated dataset fell short of only 20 observations. The generated time

series of maize yield was quite robust in depicting temporal pattern of yield swings. Fig. 9 shows that the downside yield departures from the median were predominant from 1977 to 2004. Declining trend in maize yield over years is clearly demonstrated by the trend line of best fit of the scatter plot in Fig. 10. Such a declining trend of own food supply would contribute to increasing vulnerability to food shortage by most of the farmers in the lowland.

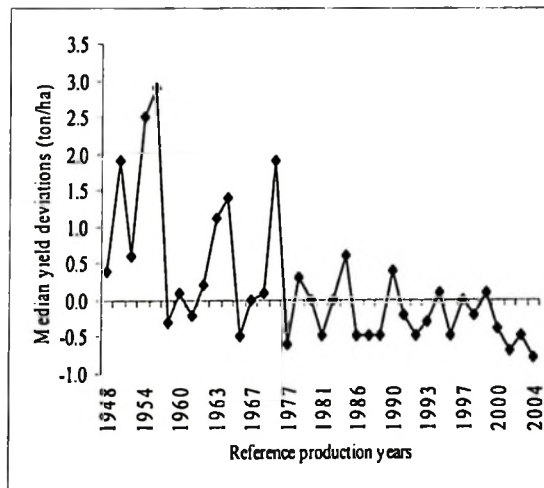


Figure 9: Trend of instability of maize yield in the lowland

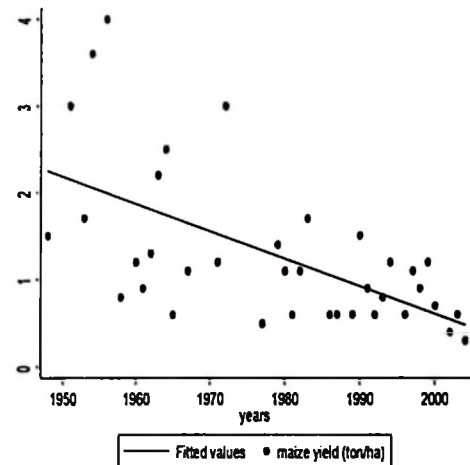


Figure 10: Scatter plot of maize yield trend for the lowland

In the midland, farmers' recalls spanned from 1932 to 2002 giving the time series dataset of 29 years instead of 71 if there were no missing years in between. This is an equivalent to 41% of success in generating the time series. Fig. 11 indicates more negative departures from the median than positive departures. Fig. 12 shows a declining trend of maize yield from 1932 through recent years. The randomness and declining trend in maize yield explains the underlying downside risk associated with maize production likely to aggravate food insecurity in the midland.

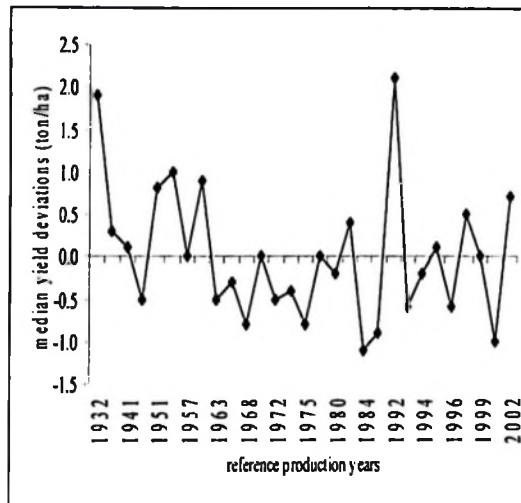


Figure 11: Trend of instability of maize yield in the midland

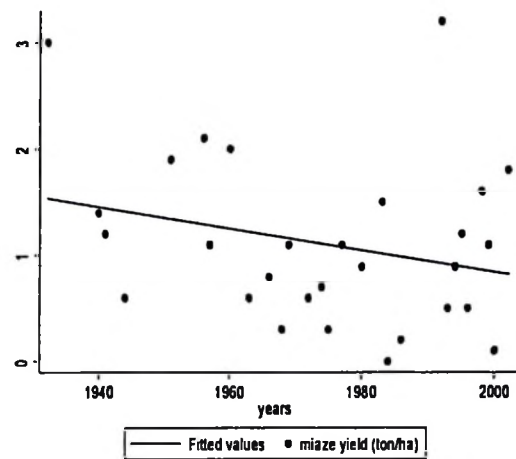


Figure 12: Scatter plot of maize yield trend for the midland

In the upland, farmers' recalls spanned from 1942 to 2003 giving the time series dataset of 26 years instead of 62 if there were no missing years in between. This is an equivalent to 42% of success in generating the time series of maize yield from recall survey. Compared to lowland and midland, in the span of 1942 to 2003, the instability pattern of maize yield in the upland village has a relatively even spread (Fig. 13). Half of the years of the time series demonstrated positive median yield deviations and the remaining half revealed zero and negative departures from the median value. This means contrary to other study villages, the chance of experiencing downside yield risk is the same as that of experiencing upside yield risk. Moreover, Fig. 14 reveals the declining trend of maize yield over time.

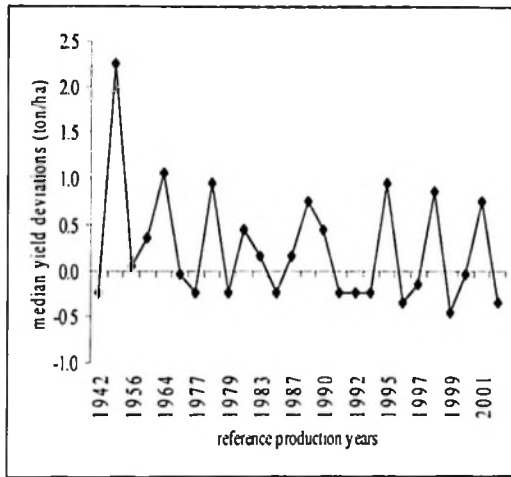


Figure 13: Trend of instability of maize yield in the upland

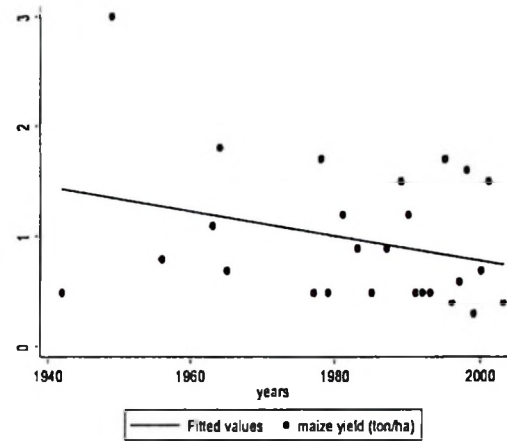


Figure 14: Scatter plot of long-term maize yield trend for the upland

For the overall study area, farmers' recalls spanned from 1932 to 2004 giving the time series dataset of 53 years instead of 73 if there were no missing years in between. This is an equivalent to 73% of success in generating the time series for maize yield. Fig. 15 shows that the yield instability pattern of pooled data indicates the dominance of downside departures from long-term median. Fig. 16 indicates that the trend of long-term maize yield in the study area was declining.

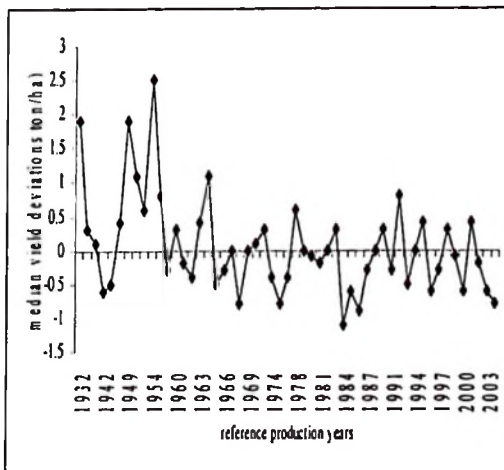


Figure 15: Trend of instability of maize yield in the study area

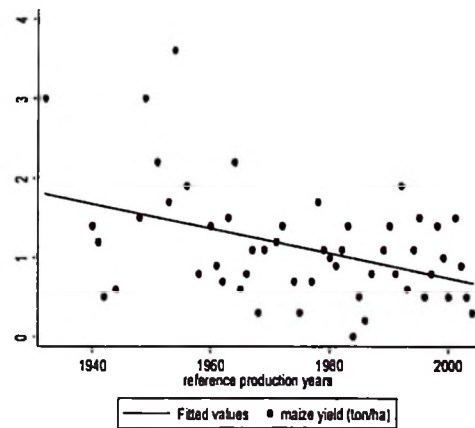


Figure 16: Scatter plot of maize yield trend for the study area

c) Mean comparison results of long-term yield

In the lowland, the yield in the first half covering the remotest 18 years was significantly higher ($P < 0.01$) than the yield for the second half of the recent 19 years (Table 4). The first half ranges from 1948-1980 and the second half from 1981-2004. The time series dataset was further categorized into four bands (quartiles) in order to show yield perturbations closely and clearly. The trend of long-term maize yield declined gradually from the first towards the fourth quartile. Results from inter-quartiles comparison show that the maize yield for the first quartile of years was not significantly higher than that of the second quartile. The yield realized in the first quartile was significantly higher ($P < 0.01$) than that of the third and fourth quartiles. The yield in the second quartile was significantly higher than that in third and fourth quartile ($P < 0.1$ and $P < 0.05$), respectively. However, the yield in the third quartile was not significantly ($P < 0.1$) higher than that realized in the fourth quartile. This explains a remarkable decline in yield in the relatively recent years compared to the past. Significant drop in maize yield over years suggests increasing vulnerability to food and income insecurity.

Table 4: Long-term (time series) maize yields in the lowland

Categories	Descriptive statistics of long-term maize yield (ton/ha)		
	N	Mean	Standard Deviation
Two halves			
First half (remotest years)	18	1.78	1.05
Second half (most recent years)	19	0.84	0.37
Quartiles			
First quartile (remotest years)	9	2.00	1.21
Second quartile	9	1.51	0.86
Third quartile	9	0.91	0.43
Fourth quartile (most recent years)	10	0.78	0.32
<i>Between halves</i>		<i>Inter-quartiles</i>	
1 st half Vs. 2 nd half: t = 3.57***		1 st Vs. 2 nd quartile: t = 0.98	1 st Vs. 3 rd quartile: t = 2.55**
		1 st Vs. 4 th quartile: t = 3.05***	2 nd Vs. 3 rd quartile: t = 1.86*
		2 nd Vs. 4 th quartile: t = 2.50**	3 rd Vs. 4 th quartile: t = 0.76

* Significant at $P < 0.1$, ** Significant at $P < 0.05$, *** significant at $P < 0.01$

In the midland village, the maize yield in the first half covering 14 years was insignificantly higher ($P < 0.1$) than in the second half of 15 recent years (Table 5). The first half refers to a band of years from 1932 to 1974 and the second half for years from 1975 to 2002. Insignificance of yield variation between the two halves indicates invariance in the level of maize yield amongst farmers in the midland. The mean maize yield in the first quartile exceeded the yield in the rest of the quartiles, but the yield between the second, third and fourth reveals no consistent trend. The mean yield in the third quartile insignificantly ($P < 0.1$) exceeded that of second and fourth quartiles, while that of the fourth insignificantly exceeded that of the second. The mean yield in the third quartile although it seems to be higher than that of the second and fourth, the difference is not significant due to its relatively high standard deviation (1.09). High standard deviation indicates high dispersion of yield values from the mean yield value in the respective band of years. Significant variation occurred between the first against the second and fourth quartiles ($P < 0.1$). This fact underscores an increasing vulnerability to food insecurity overtime. However, the

long-term maize yield differences between segments of years were less vivid in the midland than in the lowland.

Table 5: Long-term (time series) maize yields in the midland

Categories	Descriptive statistics of long-term maize yield (ton/ha)		
	N	Mean	Standard Deviation
Two halves			
First half (remotest years)	14	1.24	0.76
Second half (most recent years)	15	0.99	0.82
Quartiles			
First quartile (remotest years)	7	1.61	0.79
Second quartile	7	0.87	0.55
Third quartile	7	1.02	1.09
Fourth quartile (most recent years)	8	0.96	0.58
<i>Between halves</i>		<i>Inter-quartiles</i>	
1 st half Vs. 2 nd half: t = 0.85		1 st Vs. 2 nd quartile: t = 2.04*	1 st Vs. 3 rd quartile: t = 1.15
		1 st Vs. 4 th quartile: t = 1.84*	2 nd Vs. 3 rd quartile: t = 0.34
		2 nd Vs. 4 th quartile: t = 0.31	3 rd Vs. 4 th quartile: t = 0.15

* Significant at $P < 0.1$

In the upland, the mean yield for the first half of the remotest years was insignificantly higher than that of the second half of recent years ($P < 0.1$). In this respect, the maize yield in the first half of the time series covers a band of years from 1942 to 1987 and the second half years from 1989 to 2003 (Table 6). The yield in the first quartile insignificantly ($P < 0.1$) exceeded that realized in the rest of the quartiles.

Table 6: Long-term (time series) maize yields in the upland

Categories	Descriptive statistics of long-term maize yield (ton/ha)		
	N	Mean	Standard Deviation
Two halves			
First half (remotest years)	13	1.08	0.72
Second half (most recent years)	13	0.87	0.53
Quartiles			
First quartile (remotest years)	6	1.32	0.94
Second quartile	6	0.88	0.49
Third quartile	7	0.97	0.50
Fourth quartile (most recent years)	7	0.78	0.53
<i>Between halves</i>		<i>Inter-quartiles</i>	
1 st half Vs. 2 nd half: t = 0.84		1 st Vs. 2 nd quartile: t = 0.99	1 st Vs. 3 rd quartile: t = 0.84
		1 st Vs. 4 th quartile: t = 1.49	2 nd Vs. 3 rd quartile: t = 0.32
		2 nd Vs. 4 th quartile: t = 0.34	3 rd Vs. 4 th quartile: t = 0.66

Furthermore, it was also important to note the temporal maize yield levels in the broad arena of dryland agriculture. This was attained by pooling the time series of maize yield for lowland, midland and upland. The overall mean of maize yield in the first half covering 26 years in the remote side of the time series was significantly higher ($P < 0.05$) than the second half of 27 most recent years (Table 7). The first half category covered years from 1932 to 1975 while the second includes a spectrum of years from 1977 to 2004. The yield realized in the first quartile of the time series was significantly higher than that of the second quartile ($P < 0.05$), third quartile ($P < 0.01$) and fourth quartile ($P < 0.01$). Yield variations among the second, third and fourth did not differ significantly ($P < 0.1$), implying increasing trend of vulnerability to food and income insecurity. The decline of yield among dryland farmers overtime was an apparent phenomenon in the study area.

Table 7: Long-term (time series) maize yields in the study area

Categories	Descriptive statistics of long-term maize yield (ton/ha)		
	N	Mean	Standard Deviation
Two halves			
First half (remotest years)	26	1.37	0.86
Second half (most recent years)	27	0.93	0.43
Quartiles			
First quartile (remotest years)	13	1.75	0.96
Second quartile	13	0.98	0.52
Third quartile	13	0.92	0.48
Fourth quartile (most recent years)	14	0.95	0.47
<i>Between halves</i>		<i>Inter-quartiles</i>	
1 st half Vs. 2 nd half: $t = 2.31^*$		1 st Vs. 2 nd quartile: $t = 2.53^*$	1 st Vs. 3 rd quartile: $t = 2.80^{**}$
		1 st Vs. 4 th quartile: $t = 2.78^{**}$	2 nd Vs. 3 rd quartile: $t = 0.35$
		2 nd Vs. 4 th quartile: $t = 0.18$	3 rd Vs. 4 th quartile: $t = 0.19$

* Significant at $P < 0.05$, ** significant at $P < 0.01$

4.2. Farmers' perception and attitude to risks

4.2.1. Farmers' risk perception heterogeneity

With respect to resource access related risks, Table 8 shows that lack of water for domestic use was mostly cited to be the major source of risk in the lowland and midland (75%). In the midland, majority of the respondents were concerned with lack of pasture for livestock (56%). The concern on the problem of land tenure insecurity in its facets of acquisition and access arrangements increased consistently as you move from the lowland to upland which complies with increasing land pressure. In rural areas, common land access arrangements include transfers through inheritance, purchase, renting in, borrowing and open access. However, land acquisition through open access is diminishing because of increasing land pressure mainly caused by population growth. Forty percent (40%) of respondents in the upland cited land tenure insecurity to be a major source of risk. This proportion is 8 and 3 times (8% and 12%) more than the proportions of respondents who cited the problem of land tenure insecurity to be a major risk in the lowland and midland, respectively. Lack of pasture in the upland could be associated with land scarcity leading to allocating more land to farming and leaving little or none for grazing purposes. Furthermore, farmers are increasingly losing access to grazing land and resorting to harvesting forage from the Shengena forest which has been gazetted as a reserve forest by the central government.

Table 8: Distribution of respondents by resource access/tenure risk sources

Sources of risk	Lowland village		Midland village		Upland village	
	n	%	n	%	n	%
Problem of land acquisition	5	8	6	12	19	40
Land tenure insecurity	2	3	2	4	13	27
Resource disputes (land & water)	18	29	17	33	12	25
Lack of pasture	21	33	22	43	27	56
Lack of water for domestic use	47	75	39	75	17	35
Lack of water for livestock	29	46	7	14	7	15

In respect to production related sources of risk (Table 9), the most cited risk elements were seasonal drought in the lowland and upland (94%), and declining soil fertility in the upland (92%). In the upland, drought comes next to declining soil fertility (90%). Another production related source of risk which was of much concern in the study villages, was the problem of intra-seasonal dry spells, cited by 79%, 83% and 81% of respondents in the lowland, midland and upland, respectively. The problem of declining soil fertility overwhelmingly reported (92%) in the upland could be reinforced with another problem of soil erosion which was cited by 73% of the respondents. Farm plots in the upland are situated on steep slopes which make them vulnerable to runoff erosion which wash the fertile topmost part of the arable land. Morbidity (human diseases) which affects labour in terms of supply and quality was relatively felt much in the upland (69%) compared to lowland and midland (57% and 54% respectively). This can be attributed to limited access to health services by residents of the upland which is situated remote from the district and regional headquarters where better health services are provided.

Table 9: Distribution of respondents by production/supply related risk sources

Sources of risk	Lowland village		Midland village		Upland village	
	n	%	n	%	n	%
Too much rain (flood)	6	10	6	12	19	40
Stormy rainfall	5	8	4	8	18	38
Too low seasonal rainfall	59	94	49	94	43	90
Intra-seasonal dry spell	50	79	43	83	39	81
Strong wind	38	60	10	19	19	40
Soil erosion	10	16	14	27	35	73
Declining soil fertility	23	37	26	50	44	92
Pests and vermin attack	39	62	27	52	28	58
Animal diseases	33	53	18	35	22	46
Human diseases (poor labour)	36	57	28	54	33	69
Post harvest losses	25	40	23	45	16	33

Compared to other market related sources of risk (Table 10), majority of respondents (66%) in the lowland expressed concern on downside prices of crop and livestock products. Despite the relatively good physical market access characteristic to lowland, most farmers reported to be experiencing downside producer prices for their agricultural produce. This could be related to market exchange imperfections and participation barriers such as lack of entry capital and poor or asymmetric market information. In the midland village, 73% and 75% of the respondents identified low producer prices and high inflation food prices during food shocks, respectively. In the upland, the equally felt market risks perceived by the majority of respondents included poor transport and high input prices (85%), and lack of credit and inflationary food prices during shocks (75%). Compared to lowland village which has relatively good physical market access, only 52% of respondents cited the problem of inflationary food prices during shocks as compared to 75% who cited so in both the midland and upland. As you move upland from the lowland the quality of road network deteriorates. The concern of farmers regarding low producer prices and high price of food in market is an indication of their vulnerability to market risks.

Table 10: Distribution of respondents by market/demand related risk sources

Sources of risk	Lowland village		Midland village		Upland village	
	n	%	n	%	n	%
Lack of labour	20	33	21	42	19	44
Low crop & livestock prices	39	64	37	73	31	66
Deteriorating grain-livestock price ratio	31	51	22	43	15	32
Poor transport	7	11	13	25	40	85
Lack of credits	27	44	24	47	35	75
High input prices	31	52	33	65	40	85
Inflation of food prices during shocks	85	52	38	75	35	75

According to results in Table 11, the majority in the study villages (62%, 60% and 70% in the lowland, midland and upland, respectively) cited chronic food shortage (food self-insufficiency) as being a major socio-institutional source of risk. Consideration of food shortage problem as being socio-institutional rather than production is due to its eminent implications on social and institutional contexts. The food security problem is a critical syndrome of abject poverty making it a primary objective for the household as well as the nation to attain. The next two important socio-institutional sources of risk were lack of extension advice (33%) and poor district level safety nets (26%) for the lowland, poor household capacity to manage risk (43%) and lack of off-farm opportunities (39%) for midland village, and lack of extension services (53%) and lack of off-farm opportunities (47%) for the upland. Lack of extension service was mentioned to be among the top three major socio-institutional sources of risk throughout the study villages. The concern on lack of district level safety nets reported by respondents in the relatively urbanized lowland village implies high level of political awareness on the role of the government to the civil society in the governance process. They felt that the local government, which is the surrogate of the central government in policy implementation at local level, lacked appropriate policies and interventions to manage potential risk hazards. The current

national disaster management policy lacks emphasis on *ex-ante* measures especially on increasing adaptive capacities of the vulnerable communities, since the current national disaster management policy is colourful of *ex-post* relief support strategies as opposed to *ex-ante* mitigation strategies. Lack of off-farm opportunities expressed by respondents in the midland and upland could be associated with their remoteness from urban influence which offers job alternatives.

Table 11: Distribution of respondents by socio-institutional related risk sources

Sources of risk	Lowland village		Midland village		Upland village	
	n	%	n	%	n	%
Lack of extension service	20	33	14	28	25	53
Lack of farm implements	9	15	10	20	12	26
Lack of off-farm works	12	20	20	39	22	47
Chronic food shortage	38	62	31	60	33	70
Lack/poor district-level safety-nets	16	26	10	20	15	32
Lack/poor community-level safety-nets	14	23	12	24	10	21
Poor household capacity to manage risks	19	31	22	43	16	34

For resource access sources of risk, respondents in the midland reported a significantly higher risk assessment than their counterpart respondents in the lowland and upland at $P < 0.1$ and $P < 0.05$ respectively (Table 12). This means that farmers in the midland are more troubled with elements of resource access which make them vulnerable to risk.

With respect to production related sources of risks, farmers in the midland demonstrated CRA index which significantly exceeded ($P < 0.01$) that of colleagues in the lowland (Table 12). This implies that farmers in the midland village are highly worried and vulnerable to production related risks. Due to high depth of the common ephemeral river used for runoff farming, most farmers in the midland village are

denied of the possibility to divert the runoff. This situation aggravates the negative impact of drought particularly intermittent dry spells on crop production which could have been mitigated through RWH for supplemental irrigation. Respondents in the upland recorded a significant concern ($P < 0.01$) on production related sources of risk compared to farmers in the lowland village (Table 12). This finding unfolds interesting dimensions of the risk perception paradigm. Virtually, upland farming system is more favoured than lowland system in terms of availability of soil moisture which is central in agricultural production. Briefly, farmers in the lowland which is relatively dry were more concerned with production related risks than farmers in the upland which is relatively wet. For example, Smith *et al.* (2000) observed that farmers in the relatively high rainfall highlands of Ethiopia and Kenya still perceived the severity of drought risk. It seems to be the case that drought-related risk is pre-perceived to be serious in relatively high rainfall areas. Such perception can be supported by respondent's experience of impacts of drought in other places and the worry from increasing temporal and spatial variability of precipitation in his or her place.

Table 12: Risk perception heterogeneity CRA indices by location

Location/risk sources	Descriptive statistics of risk heterogeneity index		
	N	Mean	Standard Deviation
Resource access sources			
Lowland village	49	0.772	0.157
Midland village	41	0.829	0.166
Upland village	39	0.804	0.165
Production related sources			
Lowland village	57	0.601	0.076
Midland village	49	0.639	0.075
Upland village	47	0.658	0.115
Market related sources			
Lowland village	57	0.649	0.144
Midland village	48	0.620	0.128
Upland village	47	0.577	0.092
Socio-institutional sources			
Lowland village	44	0.743	0.190
Midland village	45	0.829	0.154
Upland village	43	0.802	0.163
Resource access risks		Production risks	
Lowland Vs. Midland: t = 1.699*		Lowland Vs. Midland: t = 2.602***	
Lowland Vs. Upland: t = 2.116**		Lowland Vs. Upland: t = 2.982***	
Midland Vs. Upland: t = 0.408		Midland Vs. Upland: t = 0.903	
		Market risks	
		Lowland Vs. Midland: t = 1.079	
		Lowland Vs. Upland: t = 2.958***	
		Midland Vs. Upland: t = 1.869*	
Socio-institutional risks: Lowland Vs. Midland: t = 2.351**, Lowland Vs. Upland: t = 1.561, Midland Vs. Upland: t = 0.794			

* Significant at $P < 0.1$, ** significant at $P < 0.05$, *** significant at $P < 0.01$

In relation to market related risk sources, farmers in the lowland and midland villages demonstrated CRA index which was significantly larger ($P < 0.01$ and $P < 0.1$), respectively than of farmers in the upland (Table 12). Contrary to remote upland, the lowland is endowed with market access opportunity since it is located close to the Dar es salaam – Arusha – Nairobi highway, the northern railway network, and the district headquarters. The midland village is next to lowland village in terms of access to trunk road which offers market linkage opportunity, whereas the upland is remote compared to the lowland and midland villages. Farmers in areas with good access to market by virtual of their location can be more worried of the odds which can happen to disrupt the market access they experience. Availability of market opportunity for all does not mean profitable participation in it. Differential market participation and benefits could be due to the reality that people differ in terms of command on capital

and business acumen. As noted earlier, Table 10 shows that the problem of downside producer prices was the commonest among respondents in the lowland compared to other market related risk sources.

In the case of socio-institutional sources of risk, respondents in the midland had a CRA index which significantly ($P < 0.05$) exceeded that of respondents in the lowland (Table 12). This implies that farmers in the midland were more concerned with elements of socio-institutional risks compared to farmers in the lowland. Comparison between wealth groups indicates that respondents in the relatively lower wealth bracket (those in medium and lower wealth groups) felt little concern on different sources of risk compared to their counterparts in the upper wealth group (Table 13). Similarly, respondents in the medium wealth category expressed a significant ($P < 0.1$) concern regarding resource access related sources of risk than those in lower wealth category did.

Table 13: Risk perception heterogeneity CRA indices by wealth groups

Wealth/risk sources	Descriptive statistics of risk heterogeneity index		
	N	Mean	Standard Deviation
Resource access sources			
Upper	14	0.829	0.164
Medium	71	0.833	0.166
Lower	44	0.773	0.157
Production related sources			
Upper	15	0.628	0.129
Medium	89	0.638	0.101
Lower	49	0.618	0.054
Market related sources			
Upper	15	0.658	0.154
Medium	87	0.605	0.115
Lower	50	0.627	0.141
Socio-institutional sources			
Upper	12	0.802	0.186
Medium	74	0.798	0.173
Lower	46	0.777	0.169
<i>Resource access risks</i>		<i>Production risks</i>	
Upper Vs. Medium: t = 0.069		Upper Vs. Medium: t = 0.354	
Upper Vs. Lower: t = 1.444		Upper Vs. Lower: t = 0.418	
Medium Vs. Lower: t = 1.895*		Medium Vs. Lower: t = 1.284	
<i>Market risks</i>			
Upper Vs. Medium: t = 1.557			
Upper Vs. Lower: t = 0.724			
Medium Vs. Lower: t = 1.030			
<i>Socio-institutional risks</i> : Upper Vs. Medium: t = 0.075, Upper Vs. Lower: t = 0.447,			
Medium Vs. Lower: t = 0.650			

* Significant at $P < 0.1$

Disaggregation of risk assessment measure of diversity by consumption based absolute poverty in Table 14 depicts interesting patterns between respondents in the absolute poverty groups. With regard to resource access related risks, the concern of the poor was relatively higher (82%) but not significant ($P < 0.1$) compared to that demonstrated by the non-poor. The pattern changed in case of production related risks where the non-poor expressed relatively higher but insignificant ($P < 0.1$) concern than the poor did (i.e. 64% versus 61% respectively). Of more interest, with regard to market risks, the absolutely poor expressed a significant concern ($P < 0.1$) compared to the non-poor. This explains increased access to markets by the non-poor and increased inaccessibility of the poor to the same. Exclusion of the absolutely poor from participating in market economy urges a need of intervening to make them actively participate in the markets otherwise there will be no prospects for poverty

reduction. With respect to institutional risks, there was no significant difference in the extent to which the poor and non-poor expressed their concern (all had CRA index of 79%).

Table 14: Risk perception heterogeneity CRA indices by absolute poverty

Poverty/risk sources	Descriptive statistics of risk heterogeneity index		
	N	Mean	Standard Deviation
Resource access sources			
Poor	33	0.822	0.159
Non-poor	96	0.808	0.166
Production related sources			
Poor	37	0.614	0.052
Non-poor	89	0.636	0.101
Market related sources			
Poor	40	0.649	0.142
Non-poor	112	0.606	0.120
Socio-institutional sources			
Poor	36	0.789	0.161
Non-poor	96	0.792	0.176
<i>Resource access risks</i>	<i>Production risks</i>	<i>Market risks</i>	
Poor Vs. Non-poor: t = 0.405	Poor Vs. Non-poor: t = 1.284	Poor Vs. Non-poor: t = 1.834*	
<i>Socio-institutional risks: Poor Vs. Non-poor: t = 0.069</i>			

* Significant at $P < 0.1$

Table 15 shows that contrary to women, men respondents were troubled more, though insignificantly ($P < 0.1$) by resource access, market and social/institutional related risks compared to production risks. This might be linked to fact that contrary to women, men are the ones who dictate resource ownership, who participate in market exchange and social/institutional issues. As a result, men are likely to be troubled by any possible downturn that affect their entitlement or command over resources, market and governance compared to women who have little or nothing to lose directly. It is interesting to note that women who practically undertake production activities in the crop fields expressed more concern on production risks compared to men who rarely participate in the routine farm operations.

Table 15: Risk perception heterogeneity CRA indices by gender of respondent

Gender/risk sources	Descriptive statistics of risk heterogeneity index		
	N	Mean	Standard Deviation
Resource access sources			
Male	113	0.814	0.166
Female	16	0.795	0.427
Production related sources			
Male	127	0.626	0.090
Female	26	0.654	0.098
Market related sources			
Male	125	0.623	0.129
Female	27	0.590	0.116
Socio-institutional sources			
Male	109	0.795	0.176
Female	23	0.770	0.152
	<i>Resource access risks</i>	<i>Production risks</i>	<i>Market risks</i>
	Male Vs. Female: $t = 0.427$	Male Vs. Female: $t = 1.414$	Male Vs. Female: $t = 1.154$
	<i>Socio-institutional risks: Male Vs. Female: $t = 0.629$</i>		

In order to go beyond descriptives to an understanding of the causal relations driving risk assessment heterogeneity, censored models (tobit) were estimated to reveal critical factors underlying risk perception divergence. A set of exogenous variables (biophysical, socio-demographic and economic) were econometrically estimated in four censored models. The censored models were based on the CRA indices for resource access (Model I), production related (Model II), market related (Model III) and institutional related sources of risks (Model IV).

According to the results in Table 16, important determinants of risk assessment divergence related with resource access risk sources (Model I) were literacy of respondents, amount of household labour force, household size, cattle herd size and aggregate consumption. The relationship of literacy in terms of number of years the respondent spent in formal schooling and risk assessment heterogeneity was significantly negative ($P < 0.1$) implying that more literate respondents tended to worry less on resource access related risks compared to the less literate and illiterates.

Literacy, which partly reflects the level of human capital, enhances entitlement or a command over other livelihood means and capability beyond the primary production sector. This probably could make the literate farmers bother less on resource access related risks. The primary production sector entails agricultural ventures and direct or indirect exploitation of ecological resources. The amount of household labour force fully available on the farm had a significantly ($P < 0.05$) negative correlation with resource access related sources of risks. Family labour is required in the transformation of whatever resources available to the family into livelihood outcomes. Households which had relatively more labour full time available in the farm worried less on resource access related risks than labour constrained households. The concern with resource access related risks increased significantly ($P < 0.05$) with increasing household size. This is probably related to the concern on division of the household resource endowments amongst many members.

Number of cattle owned had significant ($P < 0.05$) negative influence on perception of resource access related risks meaning that farmers who kept large herds of herds were to less extent troubled with uncertain access to resources contrary to those who kept fewer cattle. In the drylands, cattle serve as a store of wealth which can be considered as a mobile bank savings account. In this sense, cattle like other types of livestock can be liquidated to acquire other forms of assets or to smooth consumption and income in an uncertain future. The extent of worry about resource access related risks increased significantly ($P < 0.1$) with increasing level of aggregate consumption expenditure. The exhibited positive relationship is in contrast to expectation as it was thought that the absolutely wealthier households would feel less susceptible to

resource access risks compared to poorer households. This means that in the dryland livelihood system, increased absolute welfare does not completely rule out vulnerability to resource access risks.

Table 16: Tobit model results of risk heterogeneity determinants

Predictors	Model I	Model II	Model III	Model IV
	Z-value	Z-value	Z-value	Z-value
Coefficient of variation of income (TAS)	0.80	-0.34	-1.60	0.56
Crop diversification (number)	-0.01	-1.42	-0.72	-0.08
Years of education of the respondent (yrs)	-1.68*(-ve)	0.04	-0.30	-1.53
Age of household respondent (yrs)	1.26	1.24	0.24	0.30
Full time labour in the farm	-1.93**(-ve)	-1.15	0.88	-0.68
Gender of head (1= female)	1.06	0.28	-0.02	0.41
Gender of respondent (1= female)	-1.16	-0.29	-0.31	-1.52
Wealth dummy (1= poor)	-1.46	-0.85	-0.88	0.27
Location dummy (1= aridity)	-0.22	-1.52	-0.22	0.52
Dependence ratio (number)	-0.69	0.11	0.48	-0.42
Adjusted household size	2.04**(+ve)	1.70*(+ve/-ve)	-0.94	0.91
Number of cattle	-2.05**(-ve)	1.56	1.44	-0.74
Land accessible (acres)	-0.53	-0.33	0.68	0.26
Land with access to RWH (acres)	-1.53	-0.45	-0.62	0.41
Livelihood sources diversity	-0.29	-0.65	-0.26	0.39
Income (TAS)	0.52	1.95**(-ve)	1.57	-0.15
Total asset value (TAS)	-0.47	0.75	-0.05	-0.83
Recurrent consumption (TAS)	1.77*(-ve)	-1.95**(-ve)	-1.43	0.02
Constant	2.31	2.31	3.24	2.35

* Significant at $P < 0.1$, ** significant at $P < 0.05$, Expected sign for significant variables are in closed brackets

In the case of production related risk sources (Model II), significant determinants were household size, real income and consumption expenditure (Table 16). The concern with production related risks increased significantly ($P < 0.1$) with increasing household size. Household income increased significantly ($P < 0.05$) with increasing concern on production related risks. Virtually, the risky dryland agriculture covering crop and livestock production constitutes a significant share of income in the study area. In the context of risk, what matters most is not the magnitude of the income as such but how volatile this income is. As noted in the descriptive analysis of income instability, the coefficient of income variation in the study villages were mostly over

50%. Reflecting increased but unstable incomes as income increased with increasing concern on production risks. The extent of concern on production related risks decreased significantly ($P < 0.05$) with decreasing level of aggregate consumption. The sign of the respective coefficient is contrary to expectation as it was thought that household with high consumption level will bother less with production risks compared to those with low consumption level. Arguably, where own production constitutes large share of consumption aggregate, production risks robustly explains consumption vulnerability. It is widely held in literature that people tend to smooth consumption during shocks regardless of its magnitude. A household which is entitled to smaller but smoother future consumption is less vulnerable compared to a household entitled to larger but volatile future consumption. Assuming that current consumption reflects the past and future consumption capability, smoothness of current consumption rather than its magnitude would have characterized the direction of influence.

It is very interesting to note that micro-level household characteristics were not significantly ($P < 0.1$) important in explaining perception heterogeneity of market and social/governance related risks (Model III & IV) (Table 16). This means that in modelling attitudinal behaviour towards macro risk sources, the micro-level attributes were not important. This finding implies that market and social/governance related risks are passive macro attributes in explaining the pattern of smallholders risk behaviour. Psychometrically, macro risk factors would have little influence in shaping one's attitude. This is because of the likely faint connection and indirect impact of macroeconomic contexts in rural subsistence-dominated economies.

4.2.2. Farmers' attitude to risks

Indicative results for measuring the robustness of the output from factor analysis indicated that 66.8% of the cumulative variance was explained by the included statements (Table 17). The highest Eigen value demonstrated by the most critical factor was 6.809 vested in component 1. Keizer-Meyer-Olkin (KMO) test revealed a value of 0.744. The KMO measures the sampling adequacy, and should be greater than 0.5 for a satisfactory factor analysis to proceed. Furthermore, the Bartlett's test of Sphericity was significant ($P < 0.001$) meaning that the correlation matrix was not an identity matrix. All the factors identified for the three themes had factor loadings (correlations) greater than 0.3, which is acceptable Kim and Mueller (1978), cited by Senkondo (2000).

Table 17: Total variance explained and factor analysis robustness test

Components with Eigenvalue > 1	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
Component 1	6.809	28.370	28.370
Component 2	3.418	14.244	42.614
Component 3	2.011	8.381	50.995
Component 4	1.451	6.046	57.041
Component 5	1.198	4.991	62.032
Component 6	1.143	4.761	66.793

KMO and Bartlett's Test:

Kaiser-Meyer-Olkin Measure of Sampling Adequacy =	0.744
Bartlett's Test of Sphericity – Approx. Chi-Square =	935.399
df =	276
Sig. =	0.000

Extraction Method: Principal Component Analysis

a) Farmers' attitude toward intrinsic risks

As noted in the methodology, attitude toward risks comprised attitudinal axioms which explained risky decisions within the control and mandate of the respondent.

Only item S7 loaded negatively disagreeing with the researcher's hypothesis (Table 18). The attitude of respondents was such that even big farmers were bothered by rainfall problems. According to axiom S7 which loaded negatively, even big farmers bother with rainfall problems in the lowland farming context. The rainfall regime in the dryland farming system is erratic bothering both small and large farmers. Farmers' responses on items S3, S4 and S5 were contrary to researcher's postulations. Farmers' opinions were that in order to have nice things they should not be cautious, being cautious, since the opposite meant that they could not go ahead and hence they were forced to experiment if this meant losing money. The risk perception responses indicated positive attitude towards risk among farmers in the study area. Farmers' attitudinal perceptions which conformed to researcher's hypotheses were S1, S6, S7, S8, S9 and S11.

Table 18: Measurement of attitude towards intrinsic risks

Item	Researcher's hypothesis	Farmer's response	Factor loadings
S1- Without taking risk farming is not worthwhile	Agree	Agree	0.668
S3- Being cautious I could not go ahead	Disagree	Agree	0.666
S4- To have nice things I should not be cautious	Disagree	Agree	0.668
S5- I try new things on my farm even if I lose money on it	Disagree	Agree	0.731
S6- We always try new things on our farms	Agree	Agree	0.734
S7- Big farmers are not bothered by rainfall problems	Agree	Disagree	-0.463
S8- If I had more labour could construct a reservoir to avoid dry spell related crop failure	Agree	Agree	0.797
S9- If I had more labour could construct a reservoir to provide adequate water for animals	Agree	Agree	0.819
S11- If I had enough capital to invest in RWH I could get reliable crops, which do not fluctuate	Agree	Agree	0.791

b) Attitude towards market orientation risks

As noted in the methodology, attitude toward market orientation related risks comprised attitudinal axioms which explained market-related risky decisions which are exogenous to the respondent. All the statements measuring attitude towards market orientation loaded positively (Table 19). Farmers' opinions were different from researcher's hypotheses for S13 and S18. While the researcher thought that crop diversification was not only the best strategy to farmers, the farmers demonstrated the opposite. Rural farming is partly commercial where farmers are to produce extra to sell in the market in order to access goods and services they cannot produce themselves. Disagreeing with this narrative construct, the farmers' opinions demonstrated the significance they attach on subsistence production essentially to meet food requirement (S18). Emphasis on subsistence production, which suggest an absence of or a very loose connection to commodity and food markets, practically renders dryland farmers vulnerable to food and income insecurity. Farmers' opinions which complied with researcher's hypotheses were S14, S16 and S19. Under these statements both the researcher and farmers agreed in principle that price instability is a big problem, lack of market outlets which are profitable and reliable for RWH based crops is a limitation to increased investment in RWH, and farmers in lowland area grow crops with high water requirements due to poor linkage to external food grain markets.

Table 19: Measurement of attitude towards market orientation risks

Item	Researcher's hypothesis	Outcome from farmers	Factor loadings
S13- Growing as many crops for sale is the best way I can do for this farm	Disagree	Agree	0.627
S14- Frequent change in crop prices is the biggest problem	Agree	Agree	0.626
S16- With limited market outlet for RWH based crops I cannot invest adequately in RWH	Agree	Agree	0.525
S18- The most thing for a farming household is to grow all its own food requirement	Disagree	Agree	0.754
S19- We grow crops with high water requirement in lowland because of poor linkages to external food grain market	Agree	Agree	0.668

c) Attitude towards resource conservation risks

As noted in the methodology, attitude toward market orientation related risks comprised attitudinal axioms which explained resource conservation-related risky decisions which are exogenous to the respondent. Exceptionally, S30 loaded negatively in agreement to the researcher's hypothesis (Table 20). With respect to S30, the farmers' opinion was in disagreement in which farmers do not use manure to replenish the soil nutrients because the resource is scarce as hypothesized. Farmyard manure is in plenty supply in the dryland areas where this traditional livestock sector is prominent. The manure resource is under-utilized because of other reasons mainly lack of transport facility and uncertain rainfall. The situation of low and erratic rainfall partly undermines the decision to invest in input use. For S21, the farmers' opinions were contrary to the study's hypothesis that continuing with current farming practices will not exhaust the productivity of land. This is similar to saying that farmers believed the current farming practices were not sustainable. The thinking of

study was that farmers are rational resource users because they tend to embark on land husbandry practices that sustain resource productivity. Farmers' perceptions tallied to study's hypotheses for S20, S22, S23, S26, S27, S29, 30 and S31 statements.

Table 20: Measurement of attitude towards resource conservation risks

Item	Researcher's hypothesis	Outcome from farmers	Factor loadings
S20- The way we are farming now is not good and can not last forever	Agree	Agree	0.567
S21- If I continue farming like this I will exhaust the productive capacity of land	Disagree	Agree	0.464
S22- We need to preserve the way our ancestors farmed	Agree	Agree	0.820
S23- I am worried that our land will not produce when our children will take over farming	Agree	Agree	0.623
S26- Once the problem of water is addressed the next constraint is soil fertility	Agree	Agree	0.713
S27- Environmental degradation upstream causes floods and siltation downstream	Agree	Agree	0.675
S28- We need to consider issues of RWH and soil fertility inseparable	Agree	Agree	0.820
S29- I do not see the prospects of using fertilizers when the risk of crop failure due to drought is high	Agree	Agree	0.743
S30- We do not use manure in our fields because the resource is scarce	Disagree	Disagree	-0.679
S31- We believe that the use of manure is limited by lack of transport to distant fields	Agree	Agree	0.753

d) Nature of farmers' attitude to risks

Table 21 shows that all respondents in the lowland and upland behaved as risk takers (100%). In the upland village, at least 5% were risk averse while the rest 95% were risk takers. The lowland and midland are found in the more arid zone compared to upland village. Compared to respondent farmers in the upland village who have at least demonstrated to dislike risk (5%), none of their counterparts in the lowland and

midland who are used to live in the precarious nature disliked risk. All respondents in the midland village showed positive attitude towards commercialization and resource conservation (100%). The proportions of respondents with positive risk attitude towards commercialization and resource conservation did not differ appreciably (differed by 1% only). In general, dryland farmers demonstrated a positive attitude towards risk, market orientation and resource conservation risks. Similarly, Senkondo (2000) applied the latent variable approach and found that 70% and in some cases over 90% of farmers had positive attitude to risk. However, by applying the subjective expected utility model, Senkondo (2000) reported only 10% of the farmers who had positive attitude to risk. In sub-Saharan Africa, empirical studies that have applied different analytical techniques of risk in agriculture in the positivist paradigm are scanty. So, it cannot be confidently concluded that the latent variable approach which uses psychometric axioms to explain how the subjects feel about risk tends to underrates risk aversion contrary to expected utility model.

Table 21: Nature of attitude towards risk, market and resource related risks

Categories	Positive attitude		Negative attitude	
	n	%	n	%
Attitude towards risk				
Lowland village	39	100	0	0
Midland village	32	100	0	0
Upland village	37	95	2	5
Attitude towards market orientation:				
Lowland village	39	93	3	7
Midland village	23	100	0	0
Upland village	32	94	2	6
Attitude towards resource conservation				
Lowland village	42	98	1	2
Midland village	24	100	0	0
Upland village	36	97	1	3

e) Micro-level determinants of risk attitude

The only attitude towards intrinsic risk that was regressed against predictor variables of interest as specified in the methodology. In pursuit of this, the causal effect of micro-level variables on aggregate score for attitude towards risk was estimated using tobit model. Four most important predictor variables were gender of respondent, amount of land holding under RWH systems, livelihood diversification and attitude towards market orientation (Table 22). The level of attitude towards risk (risk preference) tended to increase significantly ($P < 0.1$) amongst female respondents. The direction of influence of gender on risk attitude is contrary to expectation. As explained earlier, almost all respondents demonstrated positive attitude towards risk. This means that in the drylands, irrespective of gender, farmers are used to live with risk and are positive towards it. Risk preference declined significantly ($P < 0.05$) with increasing amount of land holding under RWH. The hypothesis assumed the direction of causality between the land with access to runoff and risk attitude to be positive. The negative relationship can be explained by the fact that currently most of RWH systems rely on incidental rainfall due to lack of storage facilities. RWH systems which are linked to seasonal streams and storage facilities serve relatively small land holdings only in the upland. Livelihood diversification revealed to have a significant ($P < 0.05$) positive influence on risk attitude. This is congruent to saying that farmers with a diversified livelihood source tended to exhibit higher risk preference than those who had fewer options of livelihood sources. Livelihood diversification spreads risk such that different livelihood enterprises are affected differently by the sources of risk.

Attitude towards market orientation had a significant ($P < 0.01$) positive correlation with attitude towards risk. In the context of entrepreneurship theory characterized by profit seeking, an increased attitude to commercialization is associated with one's propensity to engage in risky prospects. As a result, attitude towards risk and attitude towards market orientation move together.

Table 22: Tobit model results of risk attitude determinants

Predictors	β	Expected sign	β /Std Error	Probability
Coefficient of variation of income (TAS)	0.00		0.47	0.638
Crop diversification (number)	-0.13		-0.79	0.430
Years of education of the respondent (yrs)	0.03		-0.39	0.699
Age of household respondent (yrs)	0.00		-0.35	0.730
Full time labour force in the farm	-0.14		-0.97	0.334
Gender of head (1= female, 0= male)	-0.31		-0.52	0.604
Gender of respondent (1= female, 0= male)	0.80	+ve	1.80*	0.072
Wealth dummy (1= poor, 0= otherwise)	-0.79		-1.56	0.119
Location dummy (1= aridity, 0= otherwise)	0.00		-0.01	0.992
Dependency ratio (number)	0.32		1.32	0.188
Adjusted household size	0.04		1.40	0.162
Number of cattle	-0.03		-0.40	0.689
Amount of land holding (acres)	0.10		0.96	0.340
Amount of land with access to RWH (acres)	-0.47	+ve	-2.05**	0.040
Livelihood sources diversity	0.00	+ve/-ve	2.20**	0.028
Income (TAS)	0.00		-0.20	0.841
Current consumption (TAS)	0.00		-1.54	0.123
Total asset value – durables and livestock (TAS)	-0.01		-0.08	0.937
Attitude towards market orientation	0.70	+ve	6.13***	0.000
Attitude towards resource conservation	0.54		0.41	0.682
Constant	0.00		0.47	0.638

* Significant at ($P < 0.1$), ** significant at ($P < 0.05$), *** significant at ($P < 0.01$)

4.3. Strategies used by farmers to adapt to risks

The local adaptation strategies were viewed at both community and household levels.

The discussion concentrates on the portfolio of strategies related to adaptation against rainfall variability risks. At community level these risks include seasonal drought, intra-seasonal dry spells, erratic rainfall and flood. However, responses on other

production risks are altogether presented in Appendices 6, 7, and 8 for lowland, midland and upland villages, respectively.

4.3.1. Timeline and adaptation strategies against seasonal drought

Results in Table 23 show that in the lowland village seasonal drought occurred in the years 1961, 1974, 1984, 1991 and 2003. In the midland village, the recalled years of occurrence of seasonal droughts were 1957, 1960, 1961, 1974, and 1997 (Table 23), while in the upland village, the seasonal droughts occurred in 1946, 1974, 1984, and 1996 (Table 23). Years of occurrence of seasonal droughts that were commonly cited across the study villages included 1974 and 1984, which conforms to a 10 years drought cycle common in Tanzania and in Africa (Mung'ong'o, 2002; Droogers, 2003). The results indicate that in the dryland climate of lowland and upland, seasonal drought might occur outside a 10 years cycle. For instance key informants in the midland reported consecutive occurrence of seasonal drought in 1960 and 1961. Across the study villages, extreme scarcity of food, that is famine, and lack of pasture and water for animals were reported to be the outcomes of seasonal drought. The communities had a portfolio of short-term to long-term mechanisms of protecting their livelihoods. Such portfolio of livelihood defensive mechanisms is referred to as adaptive and resilience strategies. Adaptation strategies involve short-term coping and long-term mitigation mechanisms which build a risk efficient and resilient community against future hazards. The assessment was undertaken for each study village because biophysical diversity offers varied livelihood opportunities especially for agrarian communities, which depend on primary production sectors.

Table 23: Timeline, impact and adaptation strategies to seasonal drought

Location	Years	Community impacts	Community adaptation strategies	Public responses
Lowland	1961, 1974, 1984, 1991, 2003	Famine and lack of pasture	<ul style="list-style-type: none"> ▪ Sell of livestock to buy food ▪ Seek wage work in nearby estate ▪ Seek distant farms with access to irrigation ▪ Move animals in search of water and pasture ▪ Adoption of fast growing and drought resilient crops (sorghum tried) ▪ Desire to have small-sized households 	<ul style="list-style-type: none"> ▪ Relief food in some cases ▪ Buy from cooperative stores
Midland	1957, 1960, 1961, 1969, 1974, 1997	Famine and Severe shortage of pasture	<ul style="list-style-type: none"> ▪ Move animals in search of water and pasture ▪ Dependence on food distant markets ▪ Sell livestock to buy food ▪ Borrow from relatives and friends ▪ Exchange of livestock with food grain ▪ Adoption of fast growing and drought resilient crops (sorghum never tried) ▪ Food remittances 	Relief food in some cases
Upland	1946, 1974, 1984, 1996	Famine	<ul style="list-style-type: none"> ▪ Collect wild edible herbs ▪ Depend on food markets ▪ Food for work programme in road construction ▪ Seek work for food and cash outside the village and district ▪ Sell livestock to buy food ▪ Borrow money from other people ▪ Adoption of fast growing and drought resilient crops (sorghum tried) ▪ Farmers planted perennial plantains 	Relief food in some cases

In the lowland, short-term coping strategies included sale of livestock, and seeking casual labour employment in the nearby sisal estate in order to earn money for immediate purchase of food (Table 23). Pastoralists moved their herds to distant places in search for water and grazing pasture. The modality of movement of animals during the crisis is twofold. First, the animals might be moved temporarily and brought back to original places after the crisis. Second, which is a risk spread strategy, part of the herd is permanently retained in distant places which are less prone to drought and normally closer to perennial water bodies. In the second case, either the remaining herd is managed by some members of the owner family or relatives and friends. Medium term adaptive and resilience strategies devised by the lowland community with respect to seasonal droughts included cultivation of drought tolerant

and early maturing crops mainly cassava, and a few tried to cultivate sorghum which is not a culturally preferred staple. As an *ex-post* medium-term coping strategy, farmers used to seek irrigable land in the estuary of the perennial Pangani River where they grew early maturing food crops (Table 23). This practice was readily feasible when most of the land resource was under open access tenure system under customary arrangements. However, under the current land reform of the Land Act No. 4 and 5 of 1999, such land falls under a certain village which is given the powers to grant right of use to non-villagers or otherwise. Another long-term *ex-ante* adaptive strategy reported by key informants was the concern on the need of having small sized households which they thought could be managed in case of a crisis or shock. *Ex-post* responses by the government and non-governmental agencies included provision of relief food handouts and release of maize grain stocked by the primary cooperatives for sale.

In the midland, the short-term strategies which were used to survive the seasonal droughts were more or less similar to those reported in the lowland (Table 23). Extra short-term strategies included borrowing from relatives and friends, and dependence on food transfers from folks residing in neighbouring places which were not affected and remittances from children in distant workplaces. Medium-term strategies involved planting cassava as pending food security crop to fall on in case of food shortage, and early maturing sweet potatoes to realize harvests in a relatively short period of 2-3 months. What seems to be a long-term adaptive strategy was the wider adoption of cassava and sweet potatoes which are now proactively planted as food security crops. As it was in the case of lowland village, the only response by the

government and non-governmental agencies was provision of drought relief food. However, the key informants affirmed that relief food was not guaranteed every time as some drought crises passed without any provision of relief food.

In the upland, strategies used by the community to survive the seasonal drought were similar to those reported in the lowland and midland villages. An extra strategy mentioned by key informants included collection of wild edible herbs locally known as *msele* and *matango* that were exchanged with cassava and plantains from unaffected neighbouring areas such as Mbaga ward which are endowed with irrigation possibilities. Another strategy used by the government was a 'food for work' programme where local people were urged to participate in road construction in exchange for relief food (Table 23). The upland has poor rural road network which degrades faster from abrasive runoff due to the steep terrain. Food for work is a win-win strategy where the relief food is provided at the same time realizing the long-term development objective of road construction. As in the case of the midland village, farmers also adopted production of cassava and perennial plantains. The government provided relief food at a subsidized price while relief food from religious organizations was given to people free of charge.

4.3.2. Timeline and adaptation strategies against intra-seasonal dry spells

Intra-seasonal dry spells is another critical rainfall related source of risk in dryland farming system. Results in Table 24 show that dry spells was cited to have started to manifest relatively earlier in lowland and midland villages (1950s) compared to upland village (1990s). Giving a message that the dry spells are a common occurrence

now than ever, key informants cited consecutive occurrence of devastating dry spells in the years 2000, 2001, 2002 and 2003 (Table 24). In all study villages, the food deficit was reported to be the major negative impact of intra-seasonal dry spells. In the lowland which spans into a drier steppe that is widely used for traditional grazing, the respective key informants did not report that dry spells led to critical shortage of pasture. This is because short-lived dry spells of a few days to one week as opposed to seasonal droughts cannot affect pastures. Furthermore, an array of local strategies of accommodating dry spells was cited by the key informants. Some of these strategies are common across study locations and some are location specific.

Table 24: Timeline, impacts and adaptation strategies to dryspells

Location	Years	Community impacts	Community adaptation strategies	Public responses
Lowland	1950s up to now	Food deficit	<ul style="list-style-type: none"> ▪ Sell of livestock to buy food ▪ Work for wage to buy food 	Advocacy to plant sorghum
Midland	1950s up to now (e.g. 2000, 2001, 2002, 2003)	Food deficit	<ul style="list-style-type: none"> ▪ Sell livestock to buy food ▪ Food remittances ▪ Borrow from relatives and friends ▪ Seek wage work in nearby Estate ▪ Engage in charcoal making business ▪ Improve of RWH with storage 	Insufficient relief food
Upland	1993, 1998 up to 2004	Food shortage	<ul style="list-style-type: none"> ▪ Utilise savings and livestock sales proceeds to buy food from the markets ▪ Emphasis on RWH ▪ Plant a variety of crops (diversification) ▪ Acquiring irrigable farms through purchase or hiring closer to River Pangani 	Occasionally religious agencies provided some food

In the lowland, the short-term strategies used to survive dry spells included selling of livestock and engagement in wage works to earn cash that could be used to procure food from the market (Table 24). No long-term strategies were reported to be in place for effective dry spell mitigation. Even adoption of RWH was not seen as strategy for dry spells mitigation because seasonal rainfall in the lowland village is so little to

provide for crop water requirement. Consequently, farmers in the community RWH scheme entirely depend on spate irrigation involving diversion of runoff generated upstream upon incidental rainfall events. However, if the rainfall events are not adequate to generate runoff and not spaced to coincide with critical dry spells, the efficacy of runoff harvesting which is not linked to storage facility is practically questionable. Another source of casual labour is the gypsum mines which offer and used to offer casual employment especially for youths in mining and loading gypsum in the trucks and railway wagons. Gypsum is used as a raw material in the domestic cement manufacturing factories. By implication, the development of the nearby sisal estate and gypsum mines in terms of its capacity to employ and offer better wages would make the lowland village much more resilient to shocks. Government's response to dry spells management has been only on advocacy of planting sorghum despite the persistent refusal by farmers to do so (Table 24).

In the midland, the key informants reported a portfolio of short-term strategies of living with persistent dry spells. These included selling of animals, borrowing cash from relatives and friends, seeking casual labour in the somewhat distant estate and engaging in charcoal making to get cash required to buy food and remittance in terms of food from relatives in other places who realized good harvests (Table 24). Although, charcoal making is a short-term strategy, it has long-term implication on the environment. The key informants cited improvement of RWH through construction of reservoirs '*ndiva*' being the strategy which increased adaptive and resilience capacity of the community to pursue livelihoods amidst the dry spells.

According to key informants, the government response to dry spells has been the occasional provision of food sold to affected households at a subsidized price.

In the upland, instant strategies mentioned to be practiced in response to the impact of dry spells included utilization of liquid savings and sale of livestock to buy food (Table 24). Medium and long-term strategies included adoption of crop diversification strategy, improvement of rainwater management through construction of reservoirs '*ndiva*' and seeking irrigable land near the perennial Pangani River through renting in and/or purchasing. Key informants did not mention any government assistance to reduce the effects of dry spells. However, they acknowledged food assistance from religious agencies.

4.3.3. Timeline and adaptation strategies against erratic rainfall

The uncertainty of rain in terms of its onset, duration and stop in a particular production season is another dimension of risk associated with rainfall variability. Overly, manifestation of erratic rainfall regime was cited by interviewed key informants to have happened much earlier in the midland village compared to lowland and upland. The problem of erratic rainfall started in 1970s, 1950s and 1990s in the lowland, midland and upland as presented in (Table 25), respectively. In the study villages, the major impact of erratic rainfall was food deficit following disrupted crop production.

In the lowland, immediate strategies and practices which evolved to counter the problem of erratic rainfall are twofold. These include dry sowing before the first rain which is an *ex-ante* measure and sowing in the wild field once the first rain sets in and

weeding later after the seeds have germinated, is an *ex-post* measure (Table 25). Sowing in the wild field is locally known as 'kitan'gan'ga'. However, the government has been discouraging sowing in wild field in favour of early cultivation. The government's response to the problem of erratic rainfall has on emphasizing adoption of sorghum crop which has never been a success.

Table 25: Timeline, impacts and adaptation strategies to erratic rainfall

Location	Years	Community impacts	Community adaptation strategies	Public responses
Lowland	1970s up to now	Persistent food deficit	<ul style="list-style-type: none"> ▪ Early planting before onset of the first rain (dry sowing) ▪ Sowing in the wild field (uncultivated) once the first rain sets in and cultivate later after the seeds have germinated 	<ul style="list-style-type: none"> ▪ Advocacy to plant sorghum
Midland	1950s up to now	Persistent food deficit	<ul style="list-style-type: none"> ▪ RWH (improve reservoirs and runoff harvesting) ▪ Clean irrigation canals earlier ▪ Acquiring irrigated farms in areas served with perennial rivers ▪ Dry sowing ▪ Borrow cash from relatives and friends ▪ Wider adoption of cassava and sweet potatoes crops ▪ Application of indigenous knowledge in weather forecasting 	Occasional food handouts
Upland	1996 up to 2004	Decline in agricultural production	<ul style="list-style-type: none"> ▪ Early farm preparation and planting before the first rain ▪ Adoption of fast maturing crops ▪ RWH 	None

In the midland, the strategies which have been in use to cope and adapt to the problem of erratic rainfall included *ex-ante* mitigation practice of dry sowing and improved RWH (Table 25). *Ex-post* coping and adaptive strategies included borrowing cash from relatives and friends, adoption of cassava and sweet potatoes, acquiring irrigated farms in the estuary of perennial Pangani River and in lower Moshi irrigation scheme, and indigenous weather forecasting. According to key informants, an indigenous weather forecast consists of alerts which are known to the community since ancestry.

These include signs like revival of new shoots of the wild cassava after the dry season defoliation and appearance of certain specie of bird, which all indicate that the beginning of the rain season is near. According to the interviewed key informants, the response by the government and assistance agencies has been *ex-post* provision of relief food.

In the upland, the strategies used by the local community to counteract the problem of erratic rainfall are all *ex-ante*. These include early planting before the onset of the first rain and improved management of rainwater (Table 25). Key informants in the upland did not cite dry sowing and sowing to be among the strategies used by farmers in their area. This is because the upland place is relatively moist hence giving farmers a room to prepare the land and sow timely. Results from key informants show that there was no government response to erratic rainfall and its consequences.

4.3.4. Timeline and adaptation strategies against floods

Flood is another important rainfall variability risk. As expected, interviewed key informants in the upland did not cite flood to be a threat. The recalled years of flood occurrence in the lowland included 1956, 1976, 1983, 1998 and 2004 (Table 26). In the midland village, recalled years of devastating floods were 1998 and 2004 (Table 26). The common negative impact of floods in the two villages was demolition of houses and road infrastructure. In the lowland, floods resulted into deposition which affects the soil quality. However, farmers in the lowland do not experience crop damage from floods as it is experienced in the valley bottoms '*vitivo*' in the midland, since floods in the former can be managed through installed traditional furrow

irrigation and drainage canals. In the lowland and midland, incidental floods are managed to provide for crop moisture requirement.

Table 26: Timeline, impacts and adaptation strategies to floods

Location	Years	Community impacts	Community adaptation strategies	Public responses
Lowland	1956, 1976, 1983, 1998, 2004	<ul style="list-style-type: none"> ▪ Deteriorating soil quality due to deposition of sands ▪ Damage of houses ▪ Increased crop yield in the next season 	Improvement of irrigation and drainage canals	<ul style="list-style-type: none"> ▪ Minimum support in to rehabilitate infrastructure ▪ Some relief food handouts
Midland	1998, 2004	<ul style="list-style-type: none"> ▪ Farms in the valley bottoms were buried from depositions ▪ Farms situated outside the valley bottoms realized bumper harvest of maize ▪ Road infrastructure especially the bridges were affected 	<ul style="list-style-type: none"> ▪ Participated in the government reconstruction activities ▪ Discourage planting of crops sensitive to logging like maize in valley bottoms (vitivo), instead farmers plant bananas and sugarcane 	Assisted to reconstruct the bridges

In the lowland, farmers have accommodated the adversity of floods through RWH practices and drainage canals in the community scheme (Table 26). Such rainwater management initiatives have enabled farmers to convert the seeming hazardous flash floods to provide for the soil moisture required by the crop. For example, the 1997/98 *El Nino* and 2004 flash floods which affected the infrastructure resulted into a maize bumper harvest. Government responses to flood disaster has been in terms of rehabilitation of public infrastructure and very rarely houses of a few people who were adversely affected. Further, the government also used to provide food that was sold at a subsidized price in case of significant crop failure.

In the midland, the community responded to flood by participating in government backed rehabilitation of demolished road infrastructure through communal work (Table 26). Planting crops tolerant to water logging like plantains and sugarcane in the valley bottoms as opposed to water sensitive crops such as maize has been a proactive strategy which emerged as an experiential lesson from the consequences of floods. The response by the government with respect to flood disaster has been restricted to rehabilitation of public road infrastructure.

4.3.5. Household level adaptation strategies

As mentioned earlier, the management of drought risk was mainly done through RWH accounting for 80%, 84% and 76% of all respondents in the lowland, midland and upland, respectively (Table 27). Other unpopular drought risk management strategies pointed out by respondents were crop diversification and adoption of drought tolerant crops. In the lowland, the three most prominent strategies used to manage the risk associated with low income were diversification of livelihood sources (37%), borrowing cash (24%) and reducing consumption (20%). In the midland, the most widely used strategies to manage low income risk include diversification of livelihood portfolio and borrowing (26%), reduced consumption (22%), reliance on social remittances and child support (15%). In the upland, the three most important strategies used to manage low-income related risk were livelihood diversification (34%), social remittances and child support, and borrowing (21%) and reducing consumption (15%). The portfolio of livelihood diversification by wealth groups, absolute poverty and gender is presented and discussed thoroughly in Appendix 14 (Tables 45, 46 and 47).

Table 27: Adaptation strategies to climate and economic risks

Sources of risk	Lowland village		Midland village		Upland village	
	n	%	n	%	n	%
Drought (rainfall variability)						
Rainwater harvesting and management	42	80	38	84	29	76
Crop diversification	5	10	1	2	1	3
Adoption of drought tolerant crops	5	10	6	14	8	21
Low income (economic)						
Diversification of livelihood sources	15	37	7	26	11	34
Transfers/extended family support	1	2	4	15	7	21
Asset/savings utilization	7	17	3	11	2	6
Reduced consumption of basic goods	8	20	6	22	5	15
Borrowing cash (debt)	10	24	7	26	7	21
Temporal migration	0	-	0	-	1	3

4.4. Economic viability of RWH for adapting to risks

Viability of RWH as an adaptation strategy is illuminated at two levels of individual farmer and community scheme. At farmer level, RWH systems are described in terms of associated returns to land and labour, stability of maize yields and dominance of cumulative returns for different seasonality settings and locations. Physical yield and producer prices are discussed under the section on returns because returns are derived from yield and price variables. Viability of RWH at community level is described through NPV, BCR, returns per capita which indicate distributed economic impact of the community RWH scheme, and DRS concept.

4.4.1. Returns from maize enterprise

a) Returns from maize enterprise in long rain seasons

Table 28 shows that maize grown under rainfed system resulted into significantly ($P < 0.01$) higher yield in A-average seasons (1.5 ton/ha) than in B-average seasons (0.8 ton/ha). Under *in-situ* RWH, the mean maize yield obtained in A-average seasons was insignificantly a bit higher (0.9 ton/ha) than of B-average seasons (0.8 ton/ha). The

mean yield difference under *in-situ* RWH in A-average seasons (0.6 ton/ha) and B-average seasons (0.7 ton/ha) did not differ significantly ($P < 0.1$). For RWH with external catchment the recorded mean maize yield of 1.3 ton/ha in A-average seasons, was significantly higher ($P < 0.05$) than that obtained in B-average seasons (0.8 ton/ha). Furthermore, comparison of the performance of different levels of RWH in A-and B-average seasons based on mean yield differences showed statistical significance. In A-average seasons, rainfed system performed significantly better ($P < 0.01$) than in A- and B-average seasons for *in-situ* RWH system. Maize yield under rainfed system in A-average seasons was significantly higher than yields realized under RWH with external catchment in B-average seasons ($P < 0.05$). RWH with external catchment gave significantly ($P < 0.01$) higher maize yield than *in-situ* system in A-average seasons.

Table 28: Yield of maize under RWH for long rain seasons

RWH system/seasonality	Descriptive statistics of yield (ton/hectare)		
	N	Mean	Standard Deviation
Rainfed			
A-average seasons	12	1.5	0.72
B-average seasons	12	0.8	0.61
<i>In-situ</i>			
A-average seasons	19	0.6	0.34
B-average seasons	12	0.7	0.38
External catchment			
A-average seasons	36	1.3	0.83
B-average seasons	25	0.8	0.72
<i>Rainfed</i>		<i>In-situ</i>	
A-average. Vs. B-average. - t = 2.41**		A-average. Vs. B-average: t = 0.91	
		A-average. Vs. B-average: t = 2.11*	
<i>Rainfed Vs. In-situ</i>		<i>Rainfed Vs. Ext. catchment</i>	
A-average Vs. A-average: t = 3.55***		A-average Vs. A-average: t = 0.79	
A-average Vs. B-average: t = 3.22***		A-average Vs. B-average: t = 2.55**	
B-average Vs. B-average: t = 0.47		B-average Vs. B-average: t = 0.06	
		<i>In-situ Vs. Ext. catchment</i>	
		A-average Vs. A-average: t = 3.34***	
		A-average Vs. B-average: t = 1.30	
		B-average Vs. B-average: t = 0.51	

* Significant at $P < 0.1$, **significant at $P < 0.05$, ***significant at $P < 0.01$

Table 29 shows that returns to land realized from maize grown under rainfed system in A- and B-average seasons did not differ significantly ($P < 0.1$), though A-average seasons were relatively higher than B-average seasons (156 579 versus 132 183 TAS/ha). Contrary to physical yields, returns to land realized under *in-situ* RWH were significantly higher ($P < 0.1$) in B-average seasons than those obtained in A-average seasons. For RWH with external catchment, returns to land did not differ significantly between A-average and B-average seasons ($P < 0.1$), though the former exceeds that of the latter. However, the yields realized under A-average under RWH with external catchment were significantly higher than that of B-average but returns to land were not. This implies that maize producer prices were responsive to seasonality (Table 31). RWH with external catchment in both A-average and B-average seasons demonstrated higher mean return to land than rainfed and *in-situ* systems, indicating the potential of the former in reducing production-related poverty and vulnerability. In both A-average and B-average long rain seasons, returns to land associated with rainfed and RWH with external catchment did not differ significantly ($P < 0.1$).

Table 29: Returns to land from maize under RWH in long rain seasons

RWH system/seasonality	Descriptive statistics of yield (ton/hectare)		
	N	Mean	Standard Deviation
Rainfed			
A-average seasons	12	156 579	82 604
B-average seasons	12	132 183	93 187
<i>In-situ</i>			
A-average seasons	19	65 811	47 673
B-average seasons	12	118 695	65 752
External catchment			
A-average seasons	36	185 765	125 280
B-average seasons	25	141 819	141 321
<i>Rainfed</i>		<i>In-situ</i>	
A-average Vs. B-average: $t = 0.67$		A-average Vs. B-average: $t = 2.59^*$	
<i>Rainfed Vs. Ext. catchment</i>		<i>Rainfed Vs. Ext. catchment</i>	
A-average Vs. A-average: $t = 0.75$		B-average Vs. B-average: $t = 0.21$	

* Significant at $P < 0.01$

Results in Table 30 show that the pattern of returns to labour followed a similar trend like returns to land. For rainfed condition, financial reward to family labour input during A-average significantly ($P < 0.05$) exceeded that of B-average. For *in-situ* and RWH involving external catchment, returns to labour did not differ significantly between A-average and B-average seasons. This indicates the possibility that during B-average seasons farmers tended to allocate less labour than in A-average seasons for labour demanding systems like *in-situ* and RWH with external catchment. Generally, RWH with external catchment in both A-average and B-average seasons demonstrated higher mean return to labour than rainfed and *in-situ* systems, indicating the potential of the former in reducing poverty and vulnerability associated with crop failure. In long rain seasons, returns to labour from two extreme levels of rainwater utilization, that is, rainfed and runoff harvesting from external catchment did not differ significantly ($P < 0.1$).

Table 30: Returns to labour from maize under RWH in long rain seasons

RWH system/seasonality	Descriptive statistics of returns to labour (TAS/person-day)		
	N	Mean	Standard Deviation
Rainfed			
A-average seasons	12	5 483	4 386
B-average seasons	12	4 561	3 171
<i>In-situ</i>			
A-average seasons	19	1 451	1 846
B-average seasons	12	3 003	1 954
External catchment			
A-average seasons	36	6 128	5 085
B-average seasons	25	5 636	6 284
<i>Rainfed</i>		<i>In-situ</i>	
A-average Vs. B-average: t = 2.41**		A-average Vs. B-average: t = 0.91	
		A-average Vs. B-average: t = 0.34	
<i>Rainfed Vs. Ext. catchment</i>		<i>Rainfed Vs. Ext. catchment</i>	
A-average Vs. A-average: t = 0.39		B-average Vs. B-average: t = 0.56	

*Significant at $P < 0.05$

b) Producer price of maize in long rain seasons

Table 31 shows that producer prices were responsive to downside seasonality effect, being significantly ($P < 0.01$) higher in B-average than in A-average seasons. This finding confirms the paradigm of price swings under conventional theory of demand and supply. In such localized markets, during A-average the supply is higher than in B-average as indicated by yield results in Table 28. When the supply is high, the level of producer price in most cases tends to decline, and the reverse holds true when the supply is low.

Table 31: Producer prices of maize in long rain seasons

RWH system/seasonality	Descriptive statistics of price (TAS/ton)		
	N	Mean	Standard Deviation
Rainfed			
A-average seasons	12	104 125	23 432
B-average seasons	12	153 766	24 836
In-situ			
A-average seasons	19	120 111	26 537
B-average seasons	12	162 880	29 443
External catchment			
A-average seasons	36	149 634	21 968
B-average seasons	25	172 932	34 436
	Rainfed	In-situ	Ext. catchment
A-average Vs. B-average:	A-average Vs. B-average:	A-average Vs. B-average:	
t = 45.04**	t = 4.19**	t = 3.23**	

** Significant at $P < 0.01$

c) Returns from maize enterprise in short rain seasons

Results in Table 32 show that consistently yields under all three types of RWH systems were insignificantly higher in A-average ($P < 0.1$) than were in B-average seasons. As in case of long rain seasons, *in-situ* RWH did not show remarkable improvement in yield level over rainfed system. Despite the fact that maize yield in A-average being higher than in B-average, the yield difference between the two is statistically insignificant ($P < 0.1$). In addition to giving relatively high yield, RWH

with external catchment shows to be risk efficient in terms of smoothing out the effects associated with seasonality in B-average seasons. Inter-systems comparison indicates that in both A-average and B-average seasons, the yields realized with *in-situ* RWH were not significantly different from those obtained under a typical rainfed condition. As in case of long rain season this implies that no added advantage of practicing *in-situ* RWH per se with no extra runoff harvested from outside the crop field. In A-average seasons, RWH with external catchment resulted into significantly ($P < 0.05$) higher yields than rainfed and *in-situ* systems in both A-average and B-average seasons. However, in B-average seasons, RWH with external catchment gave yield which was not significantly higher ($P < 0.1$) than that obtained under rainfed system.

Table 32: Yield of maize under RWH in short rain seasons

RWH system/seasonality	Descriptive statistics of yield (ton/hectare)		
	N	Mean	Standard Deviation
Rainfed			
A-average seasons	24	0.9	0.7
B-average seasons	20	0.7	0.6
<i>In-situ</i>			
A-average seasons	29	0.8	0.3
B-average seasons	24	0.7	0.7
External catchment			
A-average seasons	57	1.4	0.8
B-average seasons	35	1.2	0.9
<i>Rainfed</i>	<i>In-situ</i>	<i>Ext. catchment</i>	
A-average Vs. B-average: t = 1.16	A-average Vs. B-average: t = 0.33	A-average Vs. B-average: t = 0.76	
<i>Rainfed Vs. In-situ</i>	<i>Rainfed Vs. Ext. catchment</i>	<i>In-situ Vs. Ext. catchment</i>	
A-average Vs. A-average: t = 1.13	A-average Vs. A-average: t = 2.07*	A-average Vs. A-average: t = 3.55**	
A-average Vs. B-average: t = 1.08	A-average Vs. B-average: t = 1.23	A-average Vs. B-average: t = 2.50**	
B-average Vs. B-average: t = 0.13	B-average Vs. B-average: t = 2.25*	B-average Vs. B-average: t = 2.26*	

* Significant at $P < 0.05$, ** significant at $P < 0.01$

Results in Table 33 show that returns to land in A-average long rain seasons were insignificantly higher ($P < 0.1$) than in B-average seasons for different levels of RWH. However, comparison of yield between extreme levels of RWH reveals that

returns to land realized under RWH with external catchment were significantly higher in both A-average and B-average seasons ($P < 0.1$ and $P < 0.01$ respectively). Further, returns to land under RWH with external catchment in both A-average and B-average seasons were more than twice the national official poverty line of 73,877 TAS/person/year based on 1995 prices. This indicates the robustness of RWH with external catchment in income poverty reduction. Insignificant variability of returns to land for RWH with external catchment system during A-average and B-average years implies the effectiveness of the system in smoothing out effects of seasonality. Instability of farm incomes associated with seasonality is a major source of income risk and vulnerability to poverty. RWH with external catchment is a worth intervention in relation to system improvement through investment and technology transfer, and ultimately out-scaling it in dryland areas.

Table 33: Returns to land from maize under RWH in short rain seasons

RWH system/seasonality	Descriptive statistics of yield (ton/hectare)		
	N	Mean	Standard Deviation
Rainfed			
A-average seasons	24	150 436	109 037
B-average seasons	20	101 868	99 886
In-situ			
A-average seasons	29	116 483	52 567
B-average seasons	24	107 051	91 989
External catchment			
A-average seasons	57	207 263	138 818
B-average seasons	35	200 242	161 416
Rainfed		In-situ	
A-average Vs. B-average: $t = 1.52$		A-average Vs. B-average: $t = 0.46$	
Rainfed Vs. Ext. catchment		Rainfed Vs. Ext. catchment	
A-average Vs. A-average: $t = 1.78^*$		B-average Vs. B-average: $t = 2.46^{**}$	

* Significant at $P < 0.1$, ** significant at $P < 0.01$

For rainfed and *in-situ* systems, returns to labour were insignificantly higher in A-average ($P < 0.1$) than in B-average seasons (Table 34). For RWH with external

catchment, respective returns to labour in A- and B-average seasons were almost the same. Returns to labour under RWH with external catchment were significantly higher ($P < 0.01$) than that of rainfed system in B-average seasons implying the potential of RWH in reducing income poverty, since the returns to labour under external catchment based RWH system in bad years were 7 times higher than the global poverty line of US \$ 1/capita/day (at an exchange rate of 1 000 TAS to US \$ 1).

Table 34: Returns to labour from maize under RWH in short rain seasons

RWH system/seasonality	Descriptive statistics of returns to labour (TAS/person-day)		
	N	Mean	Standard Deviation
Rainfed			
A-average seasons	24	4 863	5 524
B-average seasons	20	2 722	2 780
In-situ			
A-average seasons	29	4 902	8 482
B-average seasons	24	4 100	4 527
External catchment			
A-average seasons	57	7 001	6 740
B-average seasons	35	7 021	6 889
	<i>Rainfed</i>	<i>In-situ</i>	<i>Ext. catchment</i>
A-average Vs. B-average: t = 1.56	A-average Vs. B-average: t = 0.41	A-average Vs. B-average: t = 0.01	
	<i>Rainfed Vs. Ext. catchment</i>	<i>Rainfed Vs. Ext. catchment</i>	
A-average Vs. A-average: t = 1.37		B-average Vs. B-average: t = 2.66*	

* Significant at $P < 0.01$

d) Producer price of maize in short rain seasons

Results in Table 35 show that the price difference among farmers who grew maize under rainfed system was significantly higher in B-average than in A-average seasons. This is contrary to expectation, because low marketable supply in B-average seasons was expected to increase producer price above the one that could prevail during A-average seasons. This may be due to market imperfection and/or divergence in pricing decisions of individual farmers. Producer prices experienced by other farmers who

grew maize under *in-situ* and RWH with external catchment did not differ significantly with seasonality ($P < 0.1$).

Table 35: Producer prices of maize in short rain seasons

RWH system/seasonality	Descriptive statistics of price (TAS/ton)		
	N	Mean	Standard Deviation
Rainfed			
A-average seasons	24	156,141	11,259
B-average seasons	20	141,004	17,363
<i>In-situ</i>			
A-average seasons	29	149,376	15,204
B-average seasons	24	152,358	28,390
External catchment			
A-average seasons	57	152,047	24,848
B-average seasons	35	150,810	33,453
	<i>Rainfed</i>	<i>In-situ</i>	<i>External catchment</i>
	A-average Vs. B-average: $t = 3.48^{**}$	A-average Vs. B-average: $t = 0.49$	A-average Vs. B-average: $t = 0.20$

* Significant at $P < 0.01$

4.4.2. Stability of maize yield for different RWH systems

a) Stability of maize yield in long rain seasons

Table 36 shows that for all levels of RWH, the variability (CV) of maize yield during long rain seasons between 2004 and 1998 was over 50%. For rainfed system, the extent of yield variability was insignificantly higher in B-average ($P < 0.1$) than in A-average seasons. However, for *in-situ* and RWH with external catchment, the extent of yield instability was insignificantly higher in A-average ($P < 0.1$) than in B-average. The extent of yield variability did not differ significantly ($P < 0.1$) between the rainfed system and RWH with external catchment system. Relatively high CV was observed in A-average seasons under *in-situ* (70%) and the relatively low CV in B-average seasons under RWH with external catchment (55%). Generally, for all RWH systems and irrespective of seasonality, the variability of maize yield during long rain

seasons is enormous (> 50%) underscoring the reality of widespread production risk in the dryland agriculture.

Table 36: Coefficient of variation of maize yield in long rain seasons

RWH system/seasonality	Descriptive statistics of yield variation (CV) in %		
	N	Mean	Standard Deviation
Rainfed			
A-average seasons	8	56.96	45.91
B-average seasons	9	67.44	22.02
<i>In-situ</i>			
A-average seasons	18	69.65	41.40
B-average seasons	5	64.63	47.49
External catchment			
A-average seasons	26	60.79	37.42
B-average seasons	16	55.02	26.32
<i>Rainfed</i>		<i>In-situ</i>	
A-average Vs. B-average: t = 0.61		A-average Vs. B-average: t = 0.23	
<i>Rainfed Vs. Ext. catchment</i>		<i>Rainfed Vs. Ext. catchment</i>	
A-average Vs. A-average: t = 0.24		B-average Vs. B-average: t = 1.19	

b) Stability of maize yield in short rain seasons

Table 37 shows that the level of yield instability was high as demonstrated by CV which was over 50% with exception of B-average seasons under *in-situ* RWH which had a CV of 47%. Relatively high CV was observed in B-average under rainfed system (71%) and the relatively low in B-average under *in-situ* RWH (47%). Inter-systems comparison shows that the extent of yield fluctuation did not differ significantly ($P < 0.1$) between rainfed and RWH with external catchment. As in case of long rain seasons, the extent of maize yield variability was still substantive again reflecting the production risk underlying dryland agriculture.

Table 37: Coefficient of variation of maize yield in short rain seasons

RWH system/seasonality	Descriptive statistics of yield variation (CV)		
	N	Mean	Standard Deviation
Rainfed			
A-average seasons	22	52.51	24.27
B-average seasons	7	70.70	51.85
<i>In-situ</i>			
A-average seasons	27	63.78	34.94
B-average seasons	12	46.94	31.86
External catchment			
A-average seasons	52	57.97	28.08
B-average seasons	26	61.04	33.78
	<i>Rainfed</i>	<i>In-situ</i>	<i>External catchment</i>
	A-average Vs. B-average: t = 1.29	A-average Vs. B-average: t = 1.42	A-average Vs. B-average: t = 0.42
	<i>Rainfed Vs. Ext. catchment</i>	<i>Rainfed Vs. Ext. catchment</i>	
	A-average Vs. A-average: t = 0.79	B-average Vs. B-average: t = 0.59	

4.4.3. Dominance of returns from maize for different RWH systems

Dominance results of returns to land from maize under different RWH systems are presented for both B-average long and short rain seasons. The aim of doing so is to capture the temporal effect of seasonal variances on the robustness of different RWH systems.

a) Dominance of returns from maize in long rain seasons

In the lowland, the curve of cumulative returns to land from maize for *in-situ* RWH system dominated other curves in four out of six B-average long rain seasons (Fig. 17). The cumulative returns curve for RWH with external catchment dominated the rest in 2003 and 2004. Apparently, *in-situ* and RWH with external catchment would assure better income to farmers than a typical rainfed system. The cumulative returns can be regarded as the money that would be cumulatively saved in the bank over time. In view of this, by the year 2004, RWH with external catchment and *in-situ* systems made higher income contribution than rainfed system.

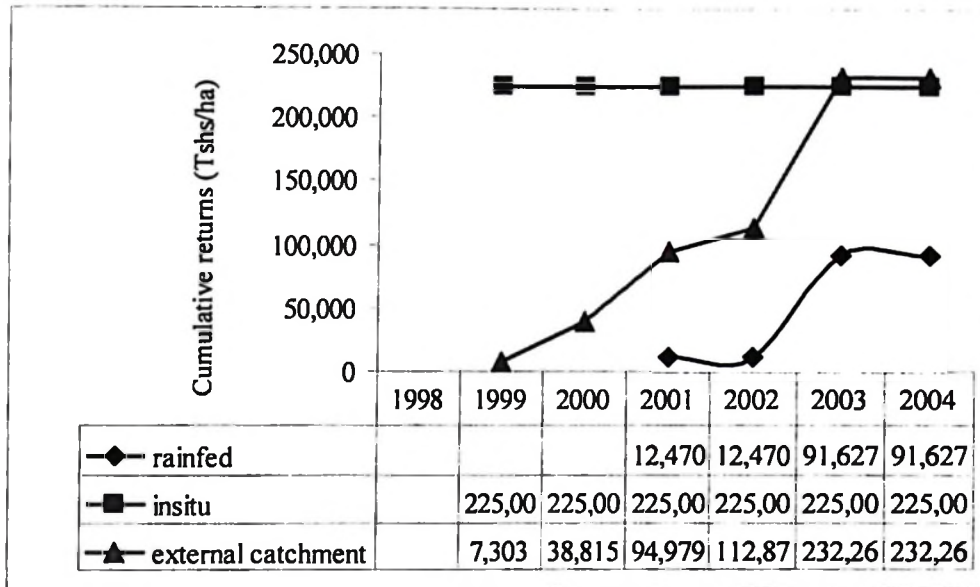


Figure 17: Dominance of RWH in long rain seasons (B-average) in the lowland

In the midland, rainfed system consistently dominated *in-situ* and RWH with external catchment in terms of associated returns over a range of B-average long rain seasons (Fig. 18). The dominance of rainfed system in terms of returns may be associated with high output of maize realized in the year 1998 which recorded more rainfall due to *El Nino*. When the rainfall is higher than normal, RWH initiatives hardly demonstrate having a clear added advantage over rainfed system in relation to yield improvement and thereafter associated returns. This situation is likely to hold in the midland whose climate is an intermediate of drier semi-arid and less dry sub-humid.

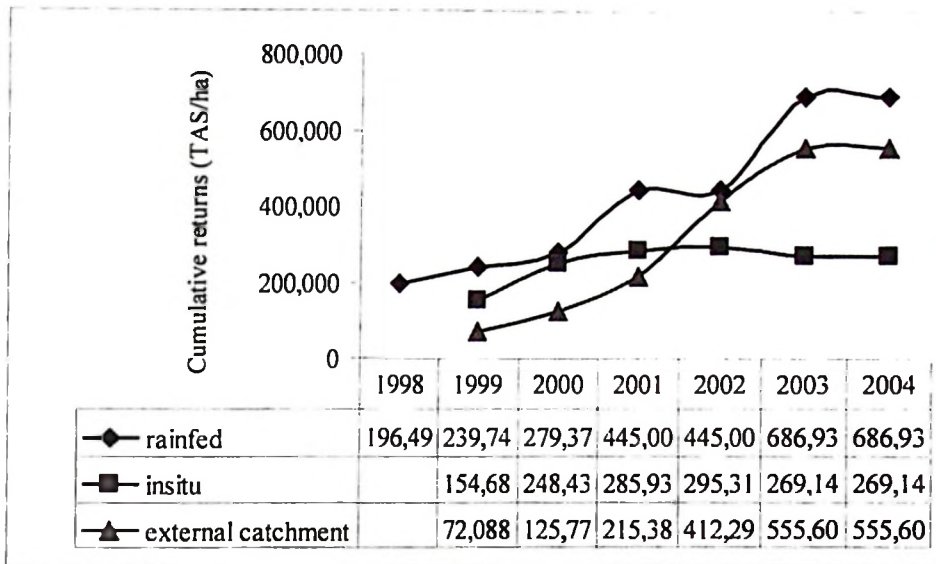


Figure 18: Dominance of RWH in long rain seasons (B-average) in the midland

In the upland, over a range of B-average long rain seasons, RWH with external catchment recorded the highest terminal cumulative returns to land by the year 2004 (Fig. 19). By practicing RWH with external catchment, farmers managed to accumulate more income from maize than those who practiced in-situ and rainfed systems.

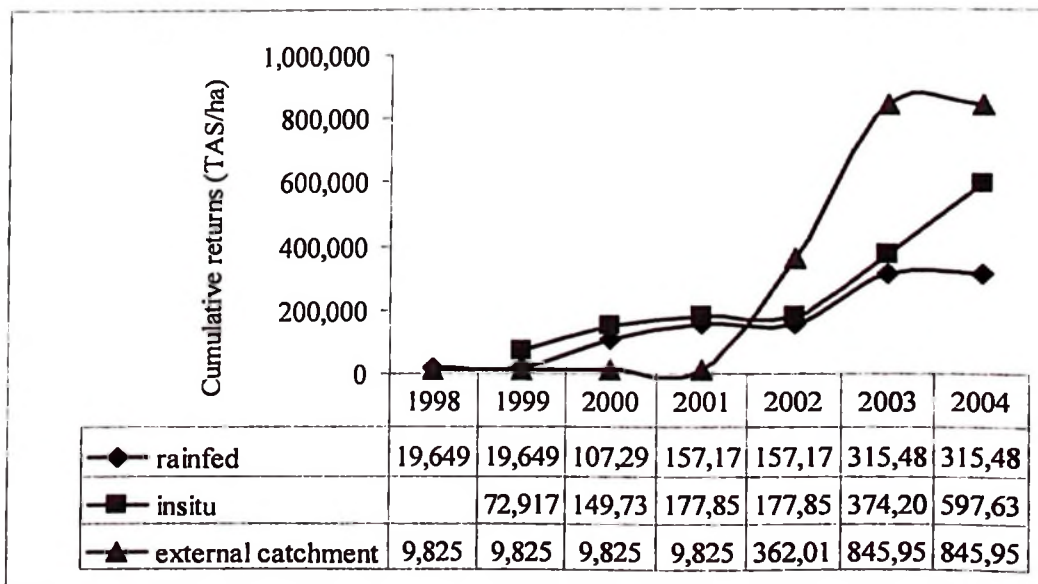


Figure 19: Dominance of RWH in long rain seasons (B-average) in the upland

b) Dominance of returns from maize in short rain seasons

In the lowland, the cumulative returns associated with RWH with external catchment surpassed that of *in-situ* and far that of rainfed which were constantly negative (Fig. 20). The robustness of external catchment in short rain seasons was also reflected in terms of higher yield of 1.2 ton/ha compared to 0.7 ton/ha of both *in-situ* and rainfed systems (Table 32). Furthermore, income generation potential of RWH is clearer in the context of semi-arid lowland in short than in long rain seasons.

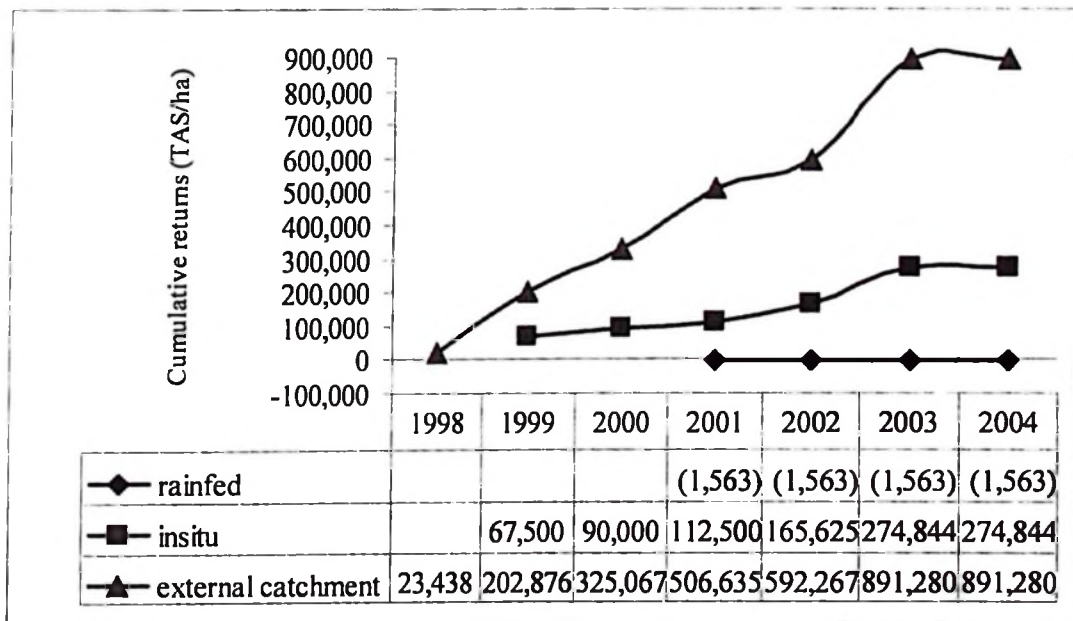


Figure 20: Dominance of RWH in short rain seasons (B-average) in the lowland

In the midland, the cumulative returns from maize under RWH with external catchment were predominantly higher than that of rainfed and *in-situ* RWH systems (Fig. 21). Again as in case of semi-arid lowland, the income generation potential of RWH with external catchment was apparent in B-average short rain seasons as opposed to long rain seasons (Fig. 17).

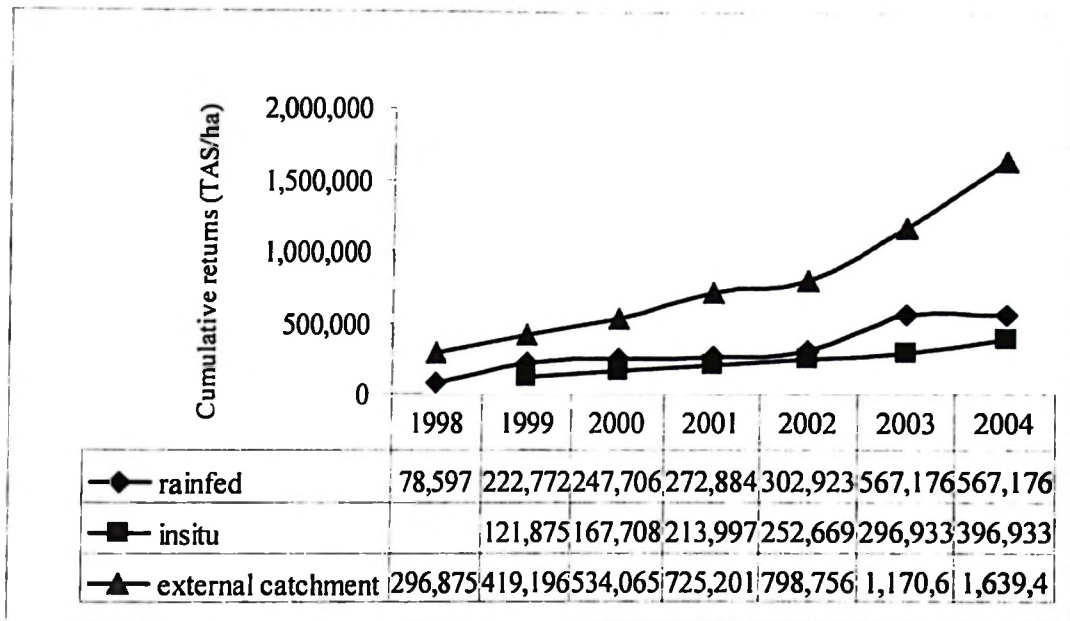


Figure 21: Dominance of RWH in short rain seasons (B-average) in the midland

In the upland, *in-situ* RWH system appeared to be more robust than RWH with external catchment and rainfed systems (Fig. 22). Inherently, the rainfall amount in the short rain seasons was relatively higher than in long rain seasons (Fig. 4). Agronomically, maize is sensitive to excessive soil moisture hence calling for drainage practices. In this respect, *in-situ* practices such as open ridges and drainage furrows which allow excess water to drain from the crop field would improve the crop yields and associated returns from increased output.

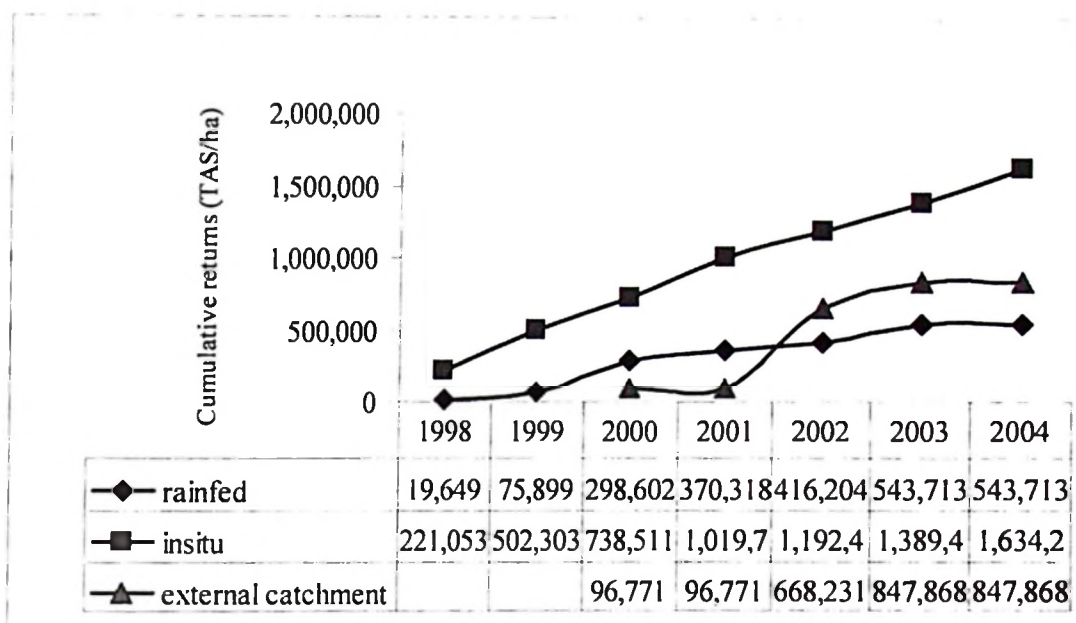


Figure 22: Dominance of RWH in short rain seasons (B-average) in the upland

4.4.4. Long-term economic viability of community RWH scheme

a) Present value of net benefits and net benefits per capita

Table 38 presents the economic viability indicative parameters extracted from Appendices 9, 10, 11 and 12. The stream of annual net crop revenues realized from the scheme in both A-average and B-average seasons were impressive. In the first year of the project evaluation time horizon, total revenue covered total costs, implying attainment of break-even point. NPV and BCR reflect the economic viability of community RWH scheme. The NPV is positive amounting to about US \$ 3 million when 1 480 hectares of the 700 ha scheme are cumulatively utilized for two consecutive seasons in a year and US \$ 700 000 when cumulative acreage drops to 370 ha under the worst risk scenario. The BCRs ranged from 30, 23, 15 and 8 under full utilization of the scheme area and hypothesized risk scenarios, respectively. Even under worst risk scenario of 75% decrease in the scheme area the NPV and BCR remained good enough to the tune of US \$ 76 200 and 8, respectively. NPV reflects

the economic worthiness and opportunity cost of investment and operating capital. In other words it is the money that the community is qualified to borrow from the lending commercial institution and invest in the scheme. Where a choice has to be made between mutually exclusive projects, the project with highest NPV will be chosen since it maximizes the net benefit to the community. The BCR expresses the level of returns to investment where a project will only be considered for funding if the BCR is greater than 1.

Table 38: Economic viability of the RWH scheme under different risk scenarios

Indicative parameters (in US \$)	Entire scheme area cultivated	% decrease of the cultivated area		
		25	50	75
Net benefits in A-average season	548 500	407 100	265 700	124 300
Net benefits in B-average season	365 100	262 800	169 500	76 200
Net benefits/capita in A-average season – max.	500	371	242	113
Net benefits/capita in A-average season – min.	434	322	210	98
Net benefits/capita in B-average season – max.	311	230	148	67
Net benefits/capita in B-average season – min.	276	204	67	59
Benefit/Cost Ratio (BCR)	30	23	15	8
Net present value (NPV)	3 065 973	2 273 212	1 480 451	687 689

Max. = maximum; Min. = minimum

In order to reflect the economic impact of the scheme at individual level, the overall scheme benefits were expressed into per capita terms. It is only either when the entire scheme is cultivated or just 25% is left uncultivated and respective seasons are A-average when the per capita net benefits are above a dollar poverty line (> US \$ 365/person/year). Otherwise, the streams of net benefits per capita are less than the dollar poverty line, and far less when only 25% of the scheme is cultivated during B-average seasons (Table 38).

It is clear that aggregated scheme benefits seemed to be very high and relatively modest when distributed among the beneficiary population. In addition to arguments presented earlier in the methodology, traditional RWH undertakings are inevitably lucrative when subjected to classical benefit-cost analysis. This is because significant capital infrastructure such as natural gullies and waterways serving as runoff conveying structures are nature given investments whose replacement cannot be thought of within the project timeframe of 10-50 or more years. The major cost components remain to be maintenance and transactions costs of such natural investments. In this study, non-pecuniary transaction costs such as time used in meetings for scheme management and water allocation were excluded in the analysis. Sensitivity analysis by considering the risk scenarios of reducing cultivated acreage due insufficient runoff to harvest was used to off-set over-amplification of overall net benefits. Meaning that the net benefits under say 50% decrease in the scheme size (Table 38) could be realistic to the situation where important transactions costs would have been part of the cost equation, given other factors.

b) Drought relief saving of the community RWH scheme

Table 39 presents DRS parameters extracted from Appendix 13. By applying the DRS concept, the scheme saves about US \$ 50 000 and 60 000 in the first and tenth years of analytical timeframe by feeding 1 100 and 1 300 people with maize grain, respectively. These savings are attached to the presence of the scheme because without it beneficiary population would have needed relief support from the government and/or relief agencies. In the semi-arid lowland where the scheme is found is a drier place where production of cereals like maize is not feasible without

any RWH initiative to confine water in the plant root zone. The present value of DRS stream over the period of 10 years was US \$ 354 336 (Table 39). The discounted DRS highlight the amount of finance which can justifiably be invested into the scheme as of now to uplift the technical efficiency in the production process. The economic rationale of this scheme is indisputably clear as it contributes enormously to the food security of beneficiary households. In most cases these farmers grow maize for both subsistence and income, and lablab mainly for cash.

Table 39: Economic viability of the RWH scheme in terms of DRS

Parameters	Year 1	Year 10
Households served by the scheme	300	300
Average household size (with annual increment of 0.1%)	3.66	4.29
Scheme beneficiaries/population	1 098	1 288
Nutritionally sufficient cereal grain per capita (kg)	300	300
Maize grain requirement for 300 households (ton)	329	386
Maize grain requirement for 300 households (ton)	150	150
Gross value of relief food grain (US \$)	49 410	57 955
Transport and administrative costs (10% value of relief food grain)	4 941	5 796
Annual food grain relief costs (saving) (US \$)	54 351	63 751
Discounted DRS		354 336

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

The general objective of this study was to examine perceptions, attitude and adaptation of smallholder farmers to risks caused by rainfall variability in the dryland areas of Northern Tanzania. Specific objectives of the study included: (a) To analyse the characteristics of agricultural risks caused rainfall variability agricultural risks; (b) To analyse farmers perceptions and attitudes to risk and heterogeneity in risk perception; (c) To assess farmers' adaptation strategies against risks caused by rainfall variability; and (d) To analyse economic viability of RWH as a strategy for adapting to risks caused by rainfall variability. The overall thrust of this study was to inform policies and interventions for improving adaptive capacity of farmers to rainfall-related risks by building on locally developed solutions within local contexts.

The study was conceptualized in the social adaptation framework crafted on three elements of Exposure, Sensitivity and Vulnerability (ESV). The contexts of these elements generate a portfolio of local coping and adaptation strategies for tracking the path to social resilience. This study made a bold attempt to illuminate the contexts of agricultural risks caused by rainfall variability and local adaptation strategies as to inform risk management policies and interventions in dryland areas. Based on the results which addressed the objectives, the following conclusions and policy-relevant recommendations were made.

5.1. Characteristics of risks faced by farmers

Drought is the most severe climatic risk disrupting the performance of agriculture in the drylands. Direct rainfall alone without efforts to concentrate rainwater in the root zone of the crop, cannot make significant improvements in yield as long-term maize yield weakly correlated with recorded rainfall. Crop yields were low and unstable, mostly with a coefficient of variation above 50%, a situation which aggravates vulnerability to food and income risks. Hence, efforts to reduce poverty and vulnerability of smallholder farmers to production risks should focus on managing drought through efficient management of agricultural water.

5.2. Perceptions and attitude of farmers to risks

The problem of declining soil fertility was perceived to be more critical in the highland than in the mid and lowland areas. The dryland highlands are prone to declining land quality mainly from pressure on land caused by high human population and steep slopes which make land vulnerable to erosion and landslides. Therefore, interventions to address the problem of moisture stress in the dryland highlands should go hand in hand with proper management of land in addressing the problem of declining soil fertility.

The relatively absolute poor farmers felt much exposed and vulnerable to market-related risks compared to their counterpart non-poor farmers. An entry point to reducing income poverty among the relatively absolute poorer households in the drylands should aim at addressing the market risks which reduce their active participating in the market economy.

Based on the way they perceived potential risks, farmers demonstrated to be risk takers contrary to what is thought under peasantry theory. This might not mean that they were risk-proof in the sense of being sufficiently resilient to risks, but this may be because for decades they have been used to live with a range of uninsured risks. Such an overwhelming positive attitude to risk is a gateway to promoting lucrative small and medium scale ventures in the dryland farm-sector. Based on econometric estimation, important policy-relevant micro-level aspects which significantly explained this positive attitude of smallholder farmers to risks included extent of livelihood diversification and attitude towards market orientation. It is recommended that diversification of livelihood enterprises should be promoted and the positive attitudes to risk, which implies the readiness to venture in new activities, be exploited increase resilience to risks.

However, interventions to reduce poverty and vulnerability of households to risks should recognize that these households are not necessarily in the 'same boat' with regard to the risks they are exposed to. This is because households differ in terms of endowments, experiences and safety mechanisms which distinguish them in terms of exposure, sensitivity and adaptive capacity. Policy-relevant aspects which were found to reduce exposure and sensitivity while increasing adaptive capacity to resource access and production risks included improvement of literacy level, advocacy of family planning to reduce household size, improving welfare capability and promoting accumulation of livestock. In the current national policy arena, accumulation of livestock might seem undesirable because the government is equivocally against keeping large herds of cattle because the environmental

consequences. Nevertheless, this study cannot deny the finding that farmers felt more secure against risks with more stock of cattle, which is like one having more deposit in his/her formal savings account in a commercial bank.

5.3. Strategies used by farmers to adapt to risks

A range of short and long-term strategies were used to cope and adapt to rainfall variability risks whose major outcomes were critical food shortage, lack of pasture and water for animals. However, the conclusions and recommendations are drawn only on those which are more policy-relevant. The short-term strategies of interest include selling of livestock to buy food, dependence on markets, distant search of pasture and water for animals, early land preparation and seeding, dry seeding and seeding in uncultivated fields. Long-term strategies suggested for adaptation against rainfall variability risks include RWH, habitual seeking of irrigable farms near the perennial river, sustainable adoption of crops resilient to moisture stress such as cassava and sweet potatoes and indigenous weather forecasting.

Improving the linkages to profitable livestock markets for agro-pastoralists in the drylands is important. Sustained linkage to profitable livestock markets would build economic resilience of agro-pastoralists to future food shocks by increasing their ability to buy food grain brought to their local markets by traders during bad years. What is clear is that drylands are net importers of food grain hence such places should be integrated to supply centers through improved infrastructure and market information. Distant search of pasture and water for animals which concentrates unbearable number of animals in places endowed of water and pasture is a renowned

cause of environmental degradation and conflicts between pastoralists and farmers. Such problem can be mitigated by improving water points in the dryland areas. Timing of farming operations such as land preparation and seeding is a challenge in drylands where the onset of rains is highly random and unpredictable in addition to being erratic when it occurs. Promotion of mechanization through appropriate technologies such as use of animal-powered implements would improve timing of farm operations.

Historically, farmers used to seek irrigable land near to the perennial river where they cultivated early maturing food crops in case of crisis or proactively cultivate spare plots for sure harvest. This arrangement was easily possible in that distant historical times because of free access regime which does not hold under the current land tenure laws. The village authority in which the irrigable land falls might decide not to grant land access to non-resident farmers. Arrangements for granting non-resident farmers' access to irrigable land is difficult to achieve. However, through participatory approaches, the government can facilitate arrangements through dialogue. In addition, increased investment and transfer of improved technology would make smallholder irrigation schemes more accommodative.

Some households in the community have continued to grow some crops which are resilient to moisture stress as a strategy of coping with rainfall variability risks. For several decades, the government has been unsatisfactorily advocating adoption of sorghum in dryland areas. Among the widely reported reasons for poor adoption of sorghum are negative cultural food preference and poor marketability. The

government should provide farmers with options of choice among the high-value crops cum technologies which save and optimize use of water, hand in hand with improving utilization and marketability of these crops.

Indigenous weather forecasting (IWF) has a key role to play especially in poor countries where modern forecasting systems are lacking or are still underdeveloped. IWF provides immediate and more localized expected weather change signals that influence current decisions. The policy implication is on how such indigenous knowledge underlying IWF can be tested scientifically and its robust elements be integrated in modern forecasting systems.

Adaptation to the odds of climate is not only restricted to vulnerable local communities, but also the institutions of the government and the international development community. It was found in this study that public responses to rainfall variability risks were reactive disaster mitigation mainly involving relief food handout rather than proactive management of risky hazards. Such reactive measures do not strengthen local adaptive capacities for increased resilience to rainfall variability risks. A radical shift from short-lived reactive disaster mitigation measures to proactive management investments is needed in order to forge long-term adaptive capacity of vulnerable communities. For instance, the value and management costs of drought relief provisions could be proactively invested to improve community RWH initiatives to mitigate droughts and end dependence on relief food.

5.4. Economic viability of RWH for adapting to risks

In both above and below average short and long-rain seasons, RWH with external catchment consistently assured significantly higher yields of maize than *in-situ* and rainfed systems. Despite lack of public investment and technology transfer in the reference community RWH scheme, long-term economic worth indicators have shown that RWH would make a difference in terms of combating poverty and hunger in the drylands. The net present value, benefit-cost ratio and net benefits per capita associated with community RWH scheme drought relief food saving attributable to the scheme were overly attractive. Economic viability of RWH to justifies public investment and technology transfer to improve the efficiency of traditional RWH initiatives. Improved efficiency of traditional RWH initiatives will improve adaptive capacity of dryland farming households and communities against agricultural risks caused by rainfall variability.

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7.0 APPENDICES

Appendix 1: Household questionnaire

A: BACKGROUND INFORMATION

Respondent's Name _____

Name of enumerator _____

Date of interview _____

Time started _____ Time finished _____

Questionnaire ID _____

Q1. Village name _____

Q2. Ward _____

Q3. Division _____

Q4. District _____

Q5. Were you born in this village? [] 1= Yes 2= No

Q6. In case you were not born in this village, fill in the following table

Where migrated from (village, district)	Year of migration	Reason for migration

Codes

Reasons for immigration

1 = Marriage, 2 = Accompanied parents, 3= Farming in RWH served area, 4= Employment transfer, 5= Searching for wage work, 6= other(s) Specify

Q7. Are you married? []

1= Yes, still together 2 = Yes, separated 3 = No, Single 4 = Widowed

5 = Other(s) Specify

If Yes, how many wives in the marriage ____

Q8. Fill in the following household Roaster

Name	R/ship	Sex	Age	Health	Education	Working on farm	Yrs in education	Other occupation
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								

Codes	Relationship with head	Sex	Health status	Education	Working on farm	Other main occupation
1=	Head	1= Male	1= Able	1= None	1= Doesn't participate in farming	1= None
2=	Spouse	2= Female	2= Very young	2= Std 4	2= Rarely participate in farming	2= Herding/stockman
3=	Child		3= Very old	3= Std 8	3= Always/frequently participate in farming	3= Salaried employment
4=	Father		4= Disabled/permanently sick	4= Adult education		4= Businessman/woman
5=	Mother			5= Primary school		5= Handcraft
6=	Other relative			6= Secondary school		6= Student
7=	Non relative			7= Collage		7= Others (specify) _____
8=				8= University		

B: ECONOMICS OF WATER HARVESTING FOR CROP AND LIVESTOCK PRODUCTION

Q9a Main season (Masika)

SN	Crop enterprises	2004		2003		2002		2001	
		Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield
1	Maize (rainfed)								
2	Maize (<i>in-situ</i>)								
3	Maize (external catchment)								

Q9a Cont.>>>

SN	Crop enterprises	2000		1999		1998	
		Acres	Yield	Acres	Yield	Acres	Yield
1	Maize (rainfed)						
2	Maize (<i>insitu</i>)						
3	Maize (external catchment)						

Q9b (i) Short season (Vuli)

SN	Crop enterprises	2004		2003		2002		2001	
		Acres	Yield	Acres	Yield	Acres	Yield	Acres	Yield
1	Maize (rainfed)								
2	Maize (<i>insitu</i>)								
3	Maize (external catchment)								

Q9b (i) Cont.>>>

	Crop enterprises	2000		1999		1998	
		Acres	Yield	Acres	Yield	Acres	Yield
1	Maize (rainfed)						
2	Maize (<i>insitu</i>)						
3	Maize (external catchment)						

Q9c (iii) Average commodity prices and individual perception for that year with respect to rainfall amount

Crop	2004	2003	2002	2001	2000	1999	1998
Prices:							
Maize (Unit price)							
Seasonality perception*:							

*Codes for Seasonality: 1= Above average 2= Below average

D: INCOME FROM OFF-FARM LIVELIHOOD OPTIONS

Q10. Please quantify the income sources for the PAST 6 years from off-farm activities and associated constraints

Source of income	Gross incomes (TAS/year)					
	2003	2002	2001	2000	1999	1998
Livestock production						
Business						
Remittances (monetized & in-kind items)						
Wages/salary						
NR*-based (honey, charcoal etc)						
Artisan works (weaving, b. repair)						
Pension						

E: LAND TENURE AND ACCESS TO RAINWATER/RUNOFF

Q11. Size of land holdings, means of acquisition (tenure) and typology of access to rainwater

Farm ID	Acreage	Means of acquisition (tenure)*	Major water harvesting system*
1			
2			
3			
4			
5			
6			

Codes:

Land acquisition: 1= opened new land, 2= inherited, 3= purchased, 4= given by village government, 5= granted by relative/friend, 6= rented in, 7= rented out, 8= borrowed temporal use

Water harvesting system: 1: rainfed, 2= enters with difficult, 3= channelled, 4= direct entrance

Q12b. Household expenditure on non-food items

[Item] consumed in the past 12 months	What is the money value of the amount purchased or received in-kind by you household in the past	
	30 days (TAS)	12 months (TAS)
Consumer goods (household items, clothes, footwear)		
Medical expenses		
Development levies, taxes, cess, license, fees		
Social occasions (funerals, weddings, ngoma etc)		
Drinks, refreshments		
Gifts		
Transport & fare		
House repair		
Water bills or costs		
Electricity, kerosene, charcoal, firewood, candles, battery		
Education expenses (fees, contributions, school stationeries)		
Other (s) Specify		

Q12c. Housing quality (main dwelling) (Ask rent for WPLL was not asked in the first survey)

Construction			No. of rooms occupied by people	No. rooms for other purposes (kitchen, store, toilets, shop etc)	Total rooms	No. of people sleeping in the house	Monthly rent (explicit/implicit)
Roof	Wall	Floor					
Codes: Construction: Roofing: 1= Iron sheet, 2= Metal remnants, 3= Plastic material, 4= Grass/mud/cow dung Wall: 1= Cement blocks, 2= Burnt earth bricks, 3= Raw earth bricks, 4= Mud/cow dung Floor: 1= Cement, 2= Earth							

Q12d. Livestock herd value

Item/Livestock	Adults		Calves/yearlings	
	No.	Total value	No.	Total value
Cattle:				
Goats:				
Sheep:				
Chicken:				
Donkeys:				

Q12e. Household inventory of durable items

[Item] owned by the household	Year bought, received If more than one item ask about most recently acquired item	How many does your household own now? If more than one item ask about most recently acquired item	*How did you get it?	How much was it worth when you acquired it?	If you wanted to sell this [item] today how much would you receive for it? If more than one item ask about total value of all items
House					
Radio					
Sprayer					
Sewing machine					
Bicycle					
Motorcycle					
Canoe/boat					
Boat engines					
Fishing nets					
Car/vehicle					
Tractor					
Spongy mattress					
Torch					
Hurricane lamp					
Charcoal stove					
Kerosene stove					
Hand hoe					
Axe					
O-implements					
O-cart					
Panga					
Debe/drum					
Television set					
Refrigerator					

Q14: Nature, effect and response to shocks, and livelihood situation by the household in the last five years

Nature, effect and response to shocks				Livelihood situation now compared to the past five years	
Event/shock	When happened (date)	Effect of the event/shock	Response to event/shock	During the past five years, how is the livelihood situation for your household? 1= improving, 2= worsening, 3= the same	What are reasons for such livelihood situation

Event/Shock: 1= drought, 2= floods, 2= theft (specify), 3= illness, 4= death of important family member, 5= pest/disease outbreak (crops/livestock); 6= strong wind/hurricane; **Effect of event/shock:** 1= hunger, 2= loss of crop, 3= loss of animal, 4= house damage. 5= Other (specify); **Response to event/shock:** 1= sale of animal for cash, 2= exchange animal for food, 3= received relief help (specify source), 4= remittances from relatives/friends, 5= sale of crop stock, 6= sale of land, 7= renting out land, 8= sale of household durables, 9= borrowed from relatives/friends, 10= spend cash savings, 11=seek wage work for food, 12= seek wage work for cash, 13=hhd members migrated

Q15: Please indicate whether the following sources of risks are major, rank them, and verify impact and coping/resilience mechanisms

Risks and vulnerability sources	Is it a major risk?	Rank major risks (within category)	Impact to your household 1= not a problem, 2= small 3= big	How do you cope with it?
	1= yes; 2= no	Within category		
Resource access and tenure:				
Problems of land acquisition (scarcity, prices, rent)				
Tenure insecurity (land, water, forest)				
Increasing land disputes				
Lack of pasture				
Lack of water for domestic use				
Lack of water for livestock				
Production/supply related:				
Too much rain				
Stormy rainfall				
Too low seasonal rainfall				
Intermittent dry spell				
Strong wind (hurricane)				
Soil erosion				
Declining soil fertility				
Pests and vermin attack				
Animal diseases				
Human diseases				
Post harvest losses				
Market/demand side related:				
Lack of labour				
Low crop & livestock prices				
Deteriorating grain-livestock price ratio				
Poor transport				
Lack of credits				
High input prices				
Inflation of food prices during shocks				
Social/institutional:				
Lack of extension advise				
Lack of farm implements (oxen, plough, hand hoe etc)				
Lack of off-farm works				
Chronic food shortage (food self-insufficiency)				
Lack/poor district-level safety-nets				
Lack/poor community-level safety-nets				
Poor capacity of the household to mitigate and manage risks				

Q16: Please indicate whether your attitude with regards to the following statements

Attitudinal statements	Responses (1= Strongly agree, 2= Agree, 3= not decided, 4= disagree, 5= Strongly disagree)
Attitude towards risks:	
Without taking risk, farming is not worthwhile	
I believe that the most farmers take the most risks	
By always being cautious in farming I could not go ahead	
To have nice things in life I cannot be cautious in farming as I should be	
I try new things on my farm even if I lose money on it	
We always try new things on our farms	
I believe that big farmers are not bothered by rainfall problems	
If I had more labour I could construct a reservoir for irrigating my crops to reduce avoid crop failure due to dry spell	
If I had more labour I could construct a reservoir to provide adequate water for my animal during dry period	
If I had more labour I could construct a reservoir to provide adequate water for domestic use	
If I had more capital to invest in my farm and RWH I could get reliable crops, which do not fluctuate	
Attitude towards market orientation:	
If there is an opportunity to make money I will use it	
Growing as many crops for sale is the best way I can do for this farm	
Frequent change in crop prices is the biggest problem for my income	
Information on producer prices helps me to decide on what crops to produce for sale	
With limited market outlet for RWH-based crops I can not invest adequately in water harvesting technologies	
If the water shortage is overcome through RWH we will grow more and more crops with high market value	
The most thing for a farming household is to grow all its own food requirements	
We cultivate crops even those with high water requirement in lowland to provide own food as our areas are poorly integrated to external food grain markets	
Attitude towards resource conservation:	
The way we are farming now is not good and cannot last forever	
If I keep farming like this I will exhaust the productive capacity of land	
We need to preserve the way our parents and ancestors farmed	
I worry that the land will not produce much when our children will take over farming	
We are required to conserve our environment in order to have higher yields	
Cropping systems that conserve soil and water are the only ones that will help us during low rainfall	
Once the problem of water is addressed through improved RWH the net constraint is soil fertility	
Environmental degradation upstream causes hazards of floods and siltation downstream	
We need to consider the issues of RWH and soil fertility inseparable	
I do not see the prospect of using expensive fertilizers when the risk of crop failure due to drought is high	
We don't use manure in our fields because the resource is scarce	
I believe that the use of manure is limited by lack of transport to distant fields	

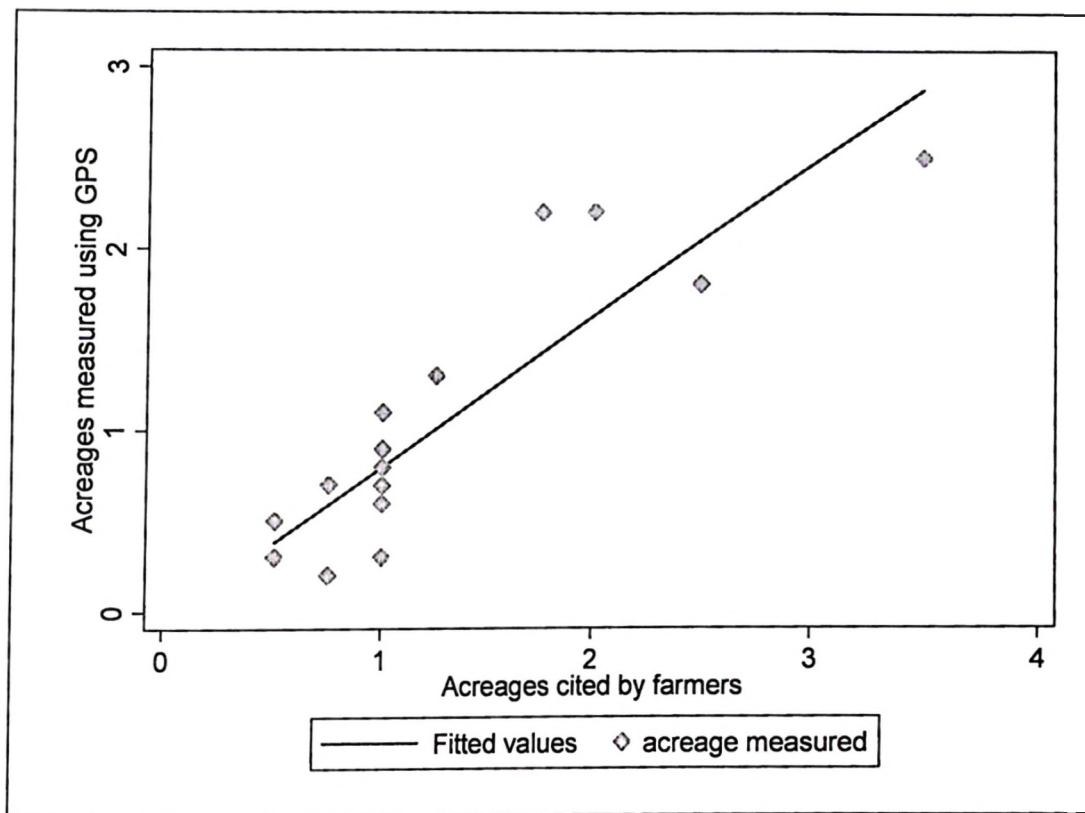
Q17: Types of risk livelihood risks, severity and household risk reduction measures

Type of livelihood risks	How serious is this a threat to your household? 1= non-existent, 2= serious, 3= very serious	Major risk reduction measures (only one most important)
Lifecycle		1= Women as family welfare providers, 2= Hygiene, preventive health, 3= Asset/savings depletion, 4= Debt 5= other (specify)
Hunger, children's stunted development		
Illness/injury/disease		
Disability		
Old age		
Death		
Economic		1= diversified sources of livelihood, 2= private transfers/extended family support, child labour, 3= Depletion of assets/savings, 4= Reduced consumption of basic goods, 5= Debt, 6= Migration 7= other (specify)
End of source of livelihood (i.e. crop failure, cattle disease)		
Unemployment		
Low income		
Changes in prices of basic needs		
Economic crisis/or transition		
Environmental		1= rainwater harvesting, 2= crop diversification, 3= adoption of drought resistance crops, 4= avoid settlement in flood prone areas, 5= tree planting around home (windbreak), 6= migration, 7= resource partitioning (e.g. herd split)
Drought		
Flood		
Stormy rainfall		
Strong wind		
Land slides/mud flows		
Earthquake		
Fire outbreak (specify)		
Social/governance		1= Efforts to maintain social capital, 2= Compliance to laws, rules, norms and values, 3= avoid multipartism, 4= live independent life 5= other (specify)
Exclusion, losing social status/capital		
Extortion, corruption		
Crime, domestic violence, social anomie		
Political instability		

Q18 The question which will provide time series data of yield over time

When did you marry? _____ (year), the same season you got married how many acres of land did you cultivate maize crop _____ (acres) out of this acreage how many bags did you harvest _____ (bags)

Appendix 4: Scatter plot and regression fit of measured against recall acreages



Appendix 5: Theoretical description of predictor variables

Variables	Theoretical and logical specifications
Coefficient of variation of income <i>(CVINC=X_1)</i>	For every respondent household, the coefficients of variation was computed for the total income from 2003 back to 1998 for different livelihood sources including crops, livestock, business, social transfers, wage payment, natural resources and artisanal work. Instability of income is what characterizes the income risk and vulnerability rather than the magnitude of it. In other words, low but relatively stable income is better than relatively high but volatile income. Therefore, the attitude towards risk was expected to decline with increasing extent of income variation.
Extent of crop diversification <i>(CROPDIV=X_2)</i>	This variable represents the number of crops the household cultivates in its vast land holdings. In rural African rural farm sector, crop diversification is one of the strategies for mitigating downside production risk. Different crops differ in terms of sensitivity to potential risk sources such as drought and flood. Farmers who are more worried of the production risk, that is who dislike risk, would tend to diversify more in terms of crop mix compared to risk preferers. It was therefore expected that the risk attitude and extent crop diversification to be inversely related.
Literacy of the respondent <i>(LITRACY=X_3)</i>	This was expressed as the number of years the respondent spent in formal schooling. Literacy level is the correlate of human capital which increases the ability to manage risk. Attitude towards risk was expected to increase with increasing level of literacy.
Age of the respondent <i>(AGE=X_4)</i>	Risk aversion tends to increase with age. Young decision makers are more willing to engage in risky ventures than elders. This is the case because by virtue of longevity of their existence, elders may have bad memory of unfortunate events that make them dislike risks compared to the relatively young. Expectedly, attitude towards risk and age variable are negatively correlated.
Labour force available full time in the farm <i>(FULFLA=X_5)</i>	This is the total number of household adult members (≥ 15 years) working full time on the farm. Increased availability of the labour force in the household increases the confidence for managing the labour demanding tasks. Such tasks may include managing large land holding, rushing for planting and/or harvesting the runoff once the first rain sets in and timely undertaking of labour intensive farm operations like land preparation and weeding. Therefore, the attitude towards risk and the household full time labour supply were expected to be positively correlated.
Gender of household head <i>(GENDH=X_6)</i>	This is a dummy variable constructed by coding all female-headed households as '1' and '0' otherwise. Since all respondents were not household heads, the logic behind the inclusion of the sex of the household head was that the circumstance of the household might have a bearing on the behaviour of individual members. As women are socio-economically less fortunate than men, the female heads are likely to demonstrate more risk aversion than their counterpart male heads. The attitude towards risk and gender of household head were expected to be inversely related.
Gender of respondent <i>(GENRES=X_7)</i>	The formulation of this variable and the logic behind its relation with attitude towards risk are similar to those of the gender of household head. Because women are socio-economically less fortunate compared to men, female respondents are expected to be risk averse. In view of this, the gender of respondent and attitude towards risk were supposed to be negatively correlated.
Wealth of the household <i>(WEALTH=X_8)</i>	This was fitted in the censored model as a dummy coded '1' for the relatively poor and '0' otherwise. As used in this study, the term 'wealth' is the relativistic grouping of poverty based on local criteria. Respondents in the relatively lower ladder of wealth in society, that is the relatively poor, are expected to dislike risk. Therefore, the coefficient attached to the wealth dummy was expected to bear a negative sign.

Appendix 5: cont...

<p>Location of the household in the watershed</p> <p><i>(LOCATN=X_9)</i></p>	<p>This is a dummy variable representing the biophysical status of the respondent with respect to aridity. All respondents from lowland and midland were coded '1' and those from the upland village were coded '0'. Aridity which is the major source production risk is more severe in the lowland and midland villages than in the upland village. Farmers in the arid climate are expected to be more risk takers than their counterparts living in a relatively wetter place. Farmers inhabiting the relatively arid place would have learned to live with production risk and devised robust mechanisms to manage such risk through adaptive learning. In this regard, the coefficient attached to this variable was expected to bear a positive sign implying a positive correlation of risk preference and living in relatively more arid places.</p>
<p>Dependency ratio of the household</p> <p><i>(DEPRAT=X_{10})</i></p>	<p>The dependency ratio is the number of dependents defined as younger than 15 years, the sick, disabled and older than 60 years over the rest who have ability within a household. A household with low dependency ratio or does not have dependents at all, is less vulnerable than one with a high dependency ratio, in terms of entitlements, which has exhibits large dependency ratio. Thus, a respondent from a more vulnerable household is likely to dislike risk compared to a respondent from a less vulnerable household which has relatively low dependency ratio. Therefore, attitude towards risk was expected to decrease with increasing dependency ration and vice versa.</p>
<p>Household size</p> <p><i>(HOUSIZE=X_{11})</i></p>	<p>This variable entails the total number of household members which has been adjusted to composition and scale economies. As in case of other household attributes, household size has an influence on the risk behaviour of its members, in this regard, the respondent. Taking a household as a social system unit, largeness of households may lead to intra-household fractionalization as a result of increased relational distance between members. On top of the concern about divisibility of household wealth, individuals from large-sized households may be more aggressive for achieving self advancement which corresponds to increasing attitude towards risk than their counterparts from small-sized households. Therefore, the coefficient attached to household size in the model was expected to bear a positive sign.</p>
<p>Cattle herd size</p> <p><i>(CATHSIZ=X_{12})</i></p>	<p>The herd size used in this study does not reflect the herd structure which needs adjustment of animals in cattle adult equivalent. Given inherent reluctance of pastoralists to disclose their livestock assets, plus time and resource constraints, it was not possible to collate data on variables such as age of every animal which are required in computing cattle adult equivalence. The social and economic role of cattle among the pastoral communities in African drylands is known. Cattle are a source of social prestige and power, and serve as source of food and income, and buffer against shocks and other emergent claims. In this respect, attitude towards risk and the cattle herd size were supposed to be positively correlated.</p>
<p>Land holding (acres) accessible by the household</p> <p><i>(LAHOLD=X_{13})</i></p>	<p>The variable as it is used in this model encompasses the land that a household had access to whether it is owned or outsourced through other use arrangements such as renting in and borrowing. Given increasing land pressure along with developing rural land markets, access to land is what matters most than ownership as such. Assuming the quality of land being the same, the household with access to a larger land may be in a good position to manage farm risks compared to one with access to a smaller land. Such advantage could be realized through selling, renting out and using part of the land as security in securing informal credit, and assisting the needy landless in the society which in turn augment the social capital base. Further, possession of large land holding gives a farmer an opportunity to practice fallow as a least cost strategy of replenishing soil nutrients. Considering a respondent being a surrogate of a household he/she comes from, the attitude towards risk was expected to increase with increasing size of land holding.</p>

Appendix 5: cont...

<p>Land holding (acres) under rainwater harvesting</p> <p><i>(LHOLRW=X_{14})</i></p>	<p>The aim of including this variable was to capture the effect of land quality which was not considered together with the variable of total land holding. In dryland farming system, a household entitled to a large chunk of land which is ideal RWH is in a good position to bit the odds of rainfall variability compared to one having none or just a smaller plot of land. Attitude towards risk was expected to increase with increasing size of accessible land holding which is ideal for RWH.</p>
<p>Extent of livelihood diversification</p> <p><i>(LIVDIVE=X_{15})</i></p>	<p>The livelihood sources included crop, livestock, business, social transfers, wage payment, natural resources and artisanal work. Livelihood diversification is among the risk mitigation strategies in the context of rural Africa. However, how it influences the risk attitude of rural decision-makers is indistinct. A more diversified livelihood portfolio can be positively correlated with risk preference as one may feel secure against uncertain future. It can be a case that people who dislike risk tend to be proactive by having a more diversified portfolio of livelihood sources. In this respect, the relationship between risk attitude and livelihood diversification could be negative as well as positive.</p>
<p>Value of assets (TAS)</p> <p><i>(ASSETV=X_{16})</i></p>	<p>The variable was constructed by adding the metric value of the durables and livestock assets captured at the moment of the survey. The variable was not expressed in per capita terms. This is because attitudinally, household members feel of collective ownership of the household wealth as most of the shared durable assets are promptly indivisible unless they are liquidated. So, what simply influences one's risk attitude is the aggregate wealth of the household rather than apportioned wealth. A household with highly valued stock of assets is resilient to risk compared to a household with least valued stock of assets. The valued stock of assets was expected to be positively correlated to risk attitude.</p>
<p>Household consumption aggregate (TAS)</p> <p><i>(CONSUMP=X_{17})</i></p>	<p>This was expressed as the aggregate yearly consumption expenditure based on the past 12 months preceding the survey. Similar arguments raised in case of assets do hold for this case too. The construct strands of a consumption variable were food and non-food purchases, service payments, social transfers, and value of own produce consumed at home. Expectedly, aggregate consumption and risk attitude were supposed to be positively correlated.</p>
<p>Household income (TAS)</p> <p><i>(INCOME=X_{18})</i></p>	<p>Construction of this variable involved addition of yearly aggregate real incomes collated from respondents through recall from 2003 back to 1998. The nominal incomes in the respective years were expressed in real terms based on 2001 consumer price index to make them reflect time comparable values. Similar to consumption, income being an indicator similar to wealth was expected to be positively correlated with risk attitude.</p>
<p>Attitude towards market orientation'</p> <p><i>(ATMKTOR=X_{19})</i></p>	<p>As presented earlier, the -4s, +4s and 0s for disagreeing, agreeing and risk neutral with the positivistic attitude measuring statements, respectively, were summed across to obtain the sum score standing for attitude towards market orientation. The attitude towards market orientation was expected to be positive correlated with risk attitude. Because farmers with commercial orientation are likely to exhibit risk preference than farmers who are much oriented to subsistence production.</p>
<p>Attitude towards resource conservation'</p> <p><i>(ATRCONS=X_{20})</i></p>	<p>The procedure of constructing the variable is as in case of attitude towards market orientation. The direction of relationship of risk attitude and attitude towards market orientation could either be positive or negative. The positive correlation could be a case because farmers who are risk preferers could still have more concern on sustainable productivity of the environment. The negative correlation could be a case as risk averters may not be worried on the future productivity of the environment. Risk averters normally comprise resource-poor whose livelihoods rely more on the environment, so they may not bother on the future integrity of the environment when pursuing current livelihoods.</p>

Appendix 6: Timeline of climate hazards, and adaptation in the lowland

Hazard	Years	Community impacts	Community adaptation strategies	Public responses
Seasonal drought	1961, 1974, 1984, 1991, 2003	Famine and lack of pasture	<ul style="list-style-type: none"> Sell of livestock to buy food Seek wage work in the nearby Sisal Estate Seek distant farms with access to irrigation (Pangani river) Move herds in search of distant pasture Plant fast growing and drought tolerant crops such as cassava and few tried sorghum People started to realize the rationale of having small-sized households 	<ul style="list-style-type: none"> Food handouts from the government and relief agencies Release of maize stocks for sale by the farmers cooperatives
Dry spells	1950s up to now	Food deficit	<ul style="list-style-type: none"> Sell of livestock to buy food Work for wage to buy food 	<ul style="list-style-type: none"> Advocacy for planting drought tolerant crops particularly sorghum
Erratic rainfall	1970s up to now	Persistent food deficit	<ul style="list-style-type: none"> Early planting before onset of the first rain locally known as '<i>kupanda kwenye vumbi</i>' that is 'dry sowing' Sowing in the wild field (uncultivated) once the first rain sets in and cultivate later after the seeds have germinated locally called '<i>kiang'ang'a</i>' 	<ul style="list-style-type: none"> Advocacy for planting drought tolerant crops particularly sorghum
Floods	1956, 1976, 1983, 1998, 2004	<ul style="list-style-type: none"> Deteriorating soil quality due to deposition of sands Damage of houses Increased crop yield the next season 	Improvement of irrigation and drainage canals	<ul style="list-style-type: none"> Little support in rehabilitating the demolished structures Some relief food handouts
Stormy rainfall	1990s	Roofs are blown away	Reinforcement of roofing material	None
Strong wind	1980s	Roofs are blown away	Reinforcement of roofing material	None
Insect pests	1980s	Low yield leading to food deficit	Spray insecticides	Subsidized insecticides in case malicious pests like Army Worms
Extreme temperature	1996	<ul style="list-style-type: none"> Skin rushes for infants Increase incidences of malaria because people stop using nets 	<ul style="list-style-type: none"> Sleep outside Takeoff the clothes People started to build houses with large windows to ensure ventilation 	None

Appendix 7: Timeline of climate hazards, and adaptation in the midland

Hazard	Years	Community impacts	Community adaptation strategies	Public responses
Seasonal drought	1957, 1960, 1961, 1969, 1974, 1997	Famine Severe shortage of pasture resulting into death of animals	<ul style="list-style-type: none"> ▪ Pastoralists emigrated in search water and pasture for animals ▪ Dependence on food markets in Gonja ward accessible to irrigation ▪ Sold livestock to buy food ▪ Borrow from relatives and friends ▪ Barter exchange of livestock with food grain within and with sweet potatoes outside the village in the mountains ▪ Wider adoption of cassava and sweet potatoes but farmers refused to adopt sorghum despite of the emphasis by the government ▪ Food transfers from unaffected relatives in other places 	Food handouts in some years but in some nothing was provided
Dry spells	1950s up to now (e.g. 2000, 2001, 2002, 2003)	Food deficit	<ul style="list-style-type: none"> ▪ Sell animals to buy food ▪ Food transfers from unaffected relatives in other places ▪ Borrow from relatives and friends ▪ Seek wage work for cash in the Sisal Estate to buy food ▪ Generate income from charcoal making ▪ Improvement of rainwater management with storage (reservoirs) 	Insufficient subsidized food handouts from the government
Erratic rainfall	1950s up to now	Persistent food deficit	<ul style="list-style-type: none"> ▪ Rainwater management (improvement of reservoirs and runoff harvesting) ▪ Clean irrigation canals earlier ▪ Acquiring irrigated farms in areas served with perennial rivers including Ruvu in same district and Uchira in Moshi district ▪ Dry sowing locally known <i>kitan' gan' ga</i> ▪ Borrow from relatives and friends to buy food during the shock ▪ Wider adoption of cassava and sweet potatoes crops ▪ Application of indigenous knowledge in weather forecasting, e.g. revival of new leaves and shoots of wild cassava after dry period defoliation, and appearance of a certain specie of birds indicate onset of a rain season 	Occasional food handouts

Appendix 7: cont....

Hazard	Years	Community impacts	Community adaptation strategies	Public responses
Floods	1998, 2004	<ul style="list-style-type: none"> ▪ Farms in the valley bottoms were buried from depositions ▪ Farms situated outside the valley bottoms realized bumper harvest of maize ▪ Road infrastructure especially the bridges were affected 	<ul style="list-style-type: none"> ▪ Participated in the government reconstruction activities ▪ Discourage planting of crops sensitive to logging like maize in valley bottoms (vitivo), instead farmers plant bananas and sugarcane 	Assisted to reconstruct the bridges
Stormy rainfall	2000, 2003	Defoliation but did not coincide with crops in the field	<ul style="list-style-type: none"> ▪ None 	None
Strong wind (including cyclone – turbulent winds)	Every October, November, December, January and March each year (e.g. 1980, 1990, 1997)	<ul style="list-style-type: none"> ▪ Roofs of some houses in the village were blown away ▪ Excessive evaporation 	<ul style="list-style-type: none"> ▪ The community assisted the affected households in replacing the roofs ▪ People started to strengthen their roofs and planting trees around their houses as windbreaks ▪ Tree planting around homes 	Usually the government rehabilitates schools and hospitals in replacing the roofs
Insect pests	1960s up to now, recurrent after every two years	Defoliation of crops which led to decreased production as a result of an invasion of army worms	<ul style="list-style-type: none"> ▪ Report the outbreak to the government extensionist ▪ Spray of insecticides acquired from the government free or at subsidized prices ▪ Undertake some traditional rituals to expel the pests (predominantly army worms) 	The government provided insecticides free or at subsidized prices
Extreme temperature	2000, 2001, 2002, 2003	<ul style="list-style-type: none"> ▪ Wilting of crops in the field ▪ Increased mosquitoes hence malaria ▪ Skin rashes amongst infants 	<ul style="list-style-type: none"> ▪ Taking the sick to hospital ▪ Putting on lighter clothes 	None
Extreme cold	1987, every June, July and August of each year	<ul style="list-style-type: none"> ▪ Pneumonia and cough especially amongst the infants ▪ Stunting of off season crops (mainly vegetables) 	<ul style="list-style-type: none"> ▪ Taking the sick to hospital ▪ Putting on heavier clothes ▪ Some affected people associated the sickness with witchery ▪ Spray fungicides in vegetables 	None

Appendix 8: Timeline of major climate hazards, and adaptation in the upland

Hazard	Years	Community impacts	Community adaptation strategies	Public responses
Seasonal drought	1946, 1974, 1984, 1996	Famine	<ul style="list-style-type: none"> ▪ Collect wild edible herbs (Msele, Matango) for exchange with cassava and bananas in neighbouring areas of Mbaga, Mamba and Gonja that are served with permanent rivers for irrigation ▪ Depend on food markets ▪ Food for work programme in road construction ▪ Seek work for food and cash outside the village and district ▪ Sell livestock to buy food, borrow money from other people ▪ Plant early maturing and drought tolerant crops including sweet potatoes and cassava; even sorghum was tried but now no one grows it ▪ Farmers planted perennial plantains that withstand seasonal drought 	Relief food handouts (handout from the government are not free instead are sold at subsidized price, but those from religious agencies are free)
Dry spells	1993, 1998 up to 2004	Food shortage	<ul style="list-style-type: none"> ▪ Depend on food markets by spending cash savings and proceeds from livestock ▪ Emphasis on rainwater management ▪ Plant a variety of crops (diversification) ▪ Acquiring farms through purchase or hiring closer to River Pangani where irrigation is possible throughout 	Occasionally religious agencies provided some food
Erratic rainfall	1996 up to 2004	Decline in agricultural production	<ul style="list-style-type: none"> ▪ Early farm preparation and planting before the first rain ▪ Adoption of early maturing crops including cassava and sweet potatoes ▪ Rainwater management (increased improvement and reliance on rainwater) 	None
Stormy rainfall	1970s	Decreased yield as it stormed crops in the field	<ul style="list-style-type: none"> ▪ Plant early maturing crops including cassava and sweet potatoes ▪ It happened in 'vuli' then farmers capitalized on the following 'masika' season 	None
Strong wind	1999, 2003	The roofs were blown away	<ul style="list-style-type: none"> ▪ Villagers worked together to rehabilitate the affected houses (including a school) 	The government provided iron sheets for schools
Crop insect pests	1920s, 1930s, 1947, 1998	Devegetation of crops which led to food shortage (locusts and army worms)	<ul style="list-style-type: none"> ▪ Manual killing of Locust and larvae through collective action ▪ The local chiefs with doctors conducted rituals that made the locusts leave the same day ▪ Replanted maize in the farms affected by army worms ▪ Dependence on food markets using cash savings and proceeds from livestock sales 	Aerial spray in the locust breeding grounds by the government
Crop diseases	1980s up to now	Reduced incomes from drying up of coffee branches, leaves and berries	<ul style="list-style-type: none"> ▪ Replant new coffee ▪ Use traditional and industrial insecticides ▪ Adopt vegetables and spices production as an alternative source of income (beans, onions, tomatoes, round potatoes and ginger) 	Introduced new coffee cultivars in 2003
Extreme cold	1946, 2004	Severe fever	Use traditional and industrial drugs	None

Appendix 9: Cash flow analysis of community RWH scheme in the lowland

ITEMS	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
SCHEME BENEFICIARIES										
Households served by the scheme [1]	300	300	300	300	300	300	300	300	300	300
Average household size (with 1.6 growth rate) [2]	3.66	3.66	3.74	3.81	3.89	3.97	4.05	4.13	4.21	4.29
TOTAL NUMBER OF BENEFICIARIES [3=1x2]	1 098	1 099	1 121	1 144	1 166	1 190	1 214	1 238	1 263	1 288
OUTPUT AND BENEFITS										
Area under Maize (ha)- short rain season [4]	700	700	700	700	700	700	700	700	700	700
Area under Maize (ha)- long rain season [5]	220	220	220	220	220	220	220	220	220	220
Yield (ton/ha) - Maize [6]	1.4	1.4	1.4	1	1.4	1.4	1	1.4	1.4	1
Area under Lablab (ha)- long rain season [7]	560	560	560	560	560	560	560	560	560	560
Yield (ton/ha) - Lablab - long rain season [8]	1.9	1.9	1.9	1.2	1.9	1.9	1.2	1.9	1.9	1.2
Average price - Maize US \$/ton [9]	150	150	150	150	150	150	150	150	150	150
Average price - Lablab US \$/ton [10]	350	350	350	350	350	350	350	350	350	350
Total acreage under maize (ha) [10=1+2]	920	920	920	920	920	920	920	920	920	920
Total acreage under Lablab (ha) [11]	560	560	560	560	560	560	560	560	560	560
Total annual output - Maize (ton) [12=6x10]	1288	1288	1288	920	1288	1288	920	1288	1288	920
Total annual output - Lablab (ton) [13=6x11]	1064	1064	1064	672	1064	1064	672	1064	1064	672
Annual revenue (US \$) - Maize [14=8x12]	193 200	193 200	193 200	138 000	193 200	193 200	138 000	193 200	193 200	138 000
Annual revenue (US \$) - Lablab [15=9x13]	372 400	372 400	372 400	235 200	372 400	372 400	235 200	372 400	372 400	235 200
GROSS BENEFITS (US \$) [16=14+15]	565 600	565 600	565 600	373 200	565 600	565 600	373 200	565 600	565 600	373 200
OVERHEAD AND PRODUCTION COSTS										
Community labour for maintenance (person-days) [17]	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700
Wage rate per person-day (US \$) [18]	2	2	2	2	2	2	2	2	2	2
Scheme maintenance costs (US \$) [19=17x18]	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400
Production costs (50% of [19]) (US \$) [20=0.5x19]	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700
INVESTMENT COSTS (US \$) [21=19+20]	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100
NET BENEFITS (US \$) [22=16-21]	548 500	548 500	548 500	356 100	548 500	548 500	356 100	548 500	548 500	356 100
DISCOUNTED REVENUE (US \$) [23]	3 171 045									
DISCOUNTED COSTS (US \$) [24]	105 072									
BENEFITS/COSTS RATIO [25= 22/21]	30									
NET BENEFITS PER CAPITA (US \$) [23=22/3]	500	499	489	311	470	461	293	443	434	276
NPV (US \$)	3 065 973									

* = Exchange rate - 1 US \$ = 1,000 T.A.S.; Discount rate = 10%

Appendix 10: Sensitivity analysis with 25% decrease in the scheme area

ITEMS	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
SCHEME BENEFICIARIES										
Households served by the scheme [1]	300	300	300	300	300	300	300	300	300	300
Average household size (with 1.6 growth rate) [2]	3.66	3.66	3.74	3.81	3.89	3.97	4.05	4.13	4.21	4.29
TOTAL NUMBER OF BENEFICIARIES [3=1x2]	1 098	1 099	1 121	1 144	1 166	1 190	1 214	1 238	1 263	1 288
OUTPUT AND BENEFITS										
Area under Maize (ha) - short rain season [4]	525	525	525	525	525	525	525	525	525	525
Area under Maize (ha) - long rain season [5]	165	165	165	165	165	165	165	165	165	165
Yield (ton/ha) - Maize [6]	1.4	1.4	1.4	1	1.4	1.4	1	1.4	1.4	1
Area under Lablab (ha) - long rain season [7]	420	420	420	420	420	420	420	420	420	420
Yield (ton/ha) - Lablab - long rain season [8]	1.9	1.9	1.9	1.2	1.9	1.9	1.2	1.9	1.9	1.2
Average price - Maize US \$/ton [9]	150	150	150	150	150	150	150	150	150	150
Average price - Lablab US \$/ton [10=1+2]	350	350	350	350	350	350	350	350	350	350
Total acreage under maize (ha) [11]	690	690	690	690	690	690	690	690	690	690
Total acreage under Lablab (ha) [12=6x10]	420	420	420	420	420	420	420	420	420	420
Total annual output - Maize (ton) [13=6x11]	966	966	966	690	966	966	690	966	966	690
Total annual output - Lablab (ton) [14=8x12]	798	798	798	504	798	798	504	798	798	504
Annual revenue (US \$) - Maize [15=9x13]	144 900	144 900	144 900	103 500	144 900	144 900	103 500	144 900	144 900	103 500
Annual revenue (US \$) - Lablab [16=14+15]	279 300	279 300	279 300	176 400	279 300	279 300	176 400	279 300	279 300	176 400
GROSS BENEFITS (US \$) [16=14+15]	424 200	424 200	424 200	279 900	424 200	424 200	279 900	424 200	424 200	279 900
OVERHEAD AND PRODUCTION COSTS										
Community labour for maintenance (person-days) [17]	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700
Wage rate per person-day (US \$) [18]	2	2	2	2	2	2	2	2	2	2
Scheme maintenance costs (US \$) [19=17x18]	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400
Production costs (50% of [19]) (US \$) [20=0.5x19]	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700
INVESTMENT COSTS (US \$) [21=19+20]	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100
NET BENEFITS (US \$) [22=16-21]	407 100	407 100	407 100	262 800	407 100	407 100	262 800	407 100	407 100	262 800
DISCOUNTED REVENUE (US \$) [23]	2 378 284									
DISCOUNTED COSTS (US \$) [24]	105 072									
BENEFITS/COSTS RATIO [25=22/21]	23									
NET BENEFITS PER CAPITA (US \$) [23=22/3]	371	370	363	230	349	342	217	329	322	204
NPV (US \$)	2 273 212									

*--Exchange rate - 1 US \$ = 1,000 TAs; Discount rate = 10%

Appendix 11: Sensitivity analysis with 50% decrease in the scheme area

ITEMS	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
SCHEME BENEFICIARIES										
Households served by the scheme [1]	300	300	300	300	300	300	300	300	300	300
Average household size (with 1.6 growth rate) [2]	3.66	3.66	3.74	3.81	3.89	3.97	4.05	4.13	4.21	4.29
TOTAL NUMBER OF BENEFICIARIES [3=1x2]	1 098	1 099	1 121	1 144	1 166	1 190	1 214	1 238	1 263	1 288
OUTPUT AND BENEFITS										
Area under Maize (ha)- short rain season [4]	350	350	350	350	350	350	350	350	350	350
Area under Maize (ha)- long rain season [5]	110	110	110	110	110	110	110	110	110	110
Yield (ton/ha) - Maize [6]	1.4	1.4	1.4	1	1.4	1.4	1	1.4	1.4	1
Area under Lablab (ha)- long rain season [7]	280	280	280	280	280	280	280	280	280	280
Yield (ton/ha) - Lablab - long rain season [8]	1.9	1.9	1.9	1.2	1.9	1.9	1.2	1.9	1.9	1.2
Average price - Maize US \$/ton [9]	150	150	150	150	150	150	150	150	150	150
Average price - Lablab US \$/ton [10=1+2]	350	350	350	350	350	350	350	350	350	350
Total acreage under maize (ha) [11]	460	460	460	460	460	460	460	460	460	460
Total acreage under Lablab (ha) [12=6x10]	280	280	280	280	280	280	280	280	280	280
Total annual output - Maize (ton) [13=6x11]	644	644	644	460	644	644	460	644	644	460
Total annual output - Lablab (ton) [14=8x12]	532	532	532	336	532	532	336	532	532	336
Annual revenue (US \$) - Maize [15=9x13]	96 600	96 600	96 600	69 000	96 600	96 600	69 000	96 600	96 600	69 000
Annual revenue (US \$) - Lablab [16=14+15]	186 200	186 200	186 200	117 600	186 200	186 200	117 600	186 200	186 200	117 600
GROSS BENEFITS (US \$) [16=14+15]	282 800	282 800	282 800	186 600	282 800	282 800	186 600	282 800	282 800	186 600
OVERHEAD AND PRODUCTION COSTS										
Community labour for maintenance (person-days) [17]	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700
Wage rate per person-day (US \$) [18]	2	2	2	2	2	2	2	2	2	2
Scheme maintenance costs (US \$) [19=17x18]	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400
Production costs (50% of [19]) (US \$) [20=0.5x19]	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700
INVESTMENT COSTS (US \$) [21=19+20]	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100
NET BENEFITS (US \$) [22=16-21]	265 700	265 700	265 700	169 500	265 700	265 700	169 500	265 700	265 700	169 500
DISCOUNTED REVENUE (US \$) [23]	1 585 523									
DISCOUNTED COSTS (US \$) [24]	105 072									
BENEFITS/COSTS RATIO [25=22/21]	15									
NET BENEFITS PER CAPITA (US \$) [23=22/3]	242	242	237	148	228	223	140	215	210	132
NPV (US \$)	1 480 451									

* = Exchange rate - 1 US \$ = 1,000 TAs; Discount rate = 10%

Appendix 12: Sensitivity analysis with 75% decrease in the scheme area

ITEMS	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
SCHEME BENEFICIARIES										
Households served by the scheme [1]	300	300	300	300	300	300	300	300	300	300
Average household size (with 1.6 growth rate) [2]	3.66	3.66	3.74	3.81	3.89	3.97	4.05	4.13	4.21	4.29
TOTAL NUMBER OF BENEFICIARIES (3=1x2)	1 098	1 099	1 121	1 144	1 166	1 190	1 214	1 238	1 263	1 288
OUTPUT AND BENEFITS										
Area under Maize (ha)- short rain season [4]	175	175	175	175	175	175	175	175	175	175
Area under Maize (ha)- long rain season [5]	55	55	55	55	55	55	55	55	55	55
Yield (ton/ha) - Maize [6]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Area under Lablab (ha)- long rain season [7]	140	140	140	140	140	140	140	140	140	140
Yield (ton/ha) - Lablab - long rain season [8]	1.9	1.9	1.9	1.2	1.9	1.9	1.2	1.9	1.9	1.2
Average price - Maize US \$/ton [9]	150	150	150	150	150	150	150	150	150	150
Average price - Lablab US \$/ton [10=1+2]	350	350	350	350	350	350	350	350	350	350
Total acreage under maize (ha) [11]	230	230	230	230	230	230	230	230	230	230
Total acreage under Lablab (ha) [12=6x10]	140	140	140	140	140	140	140	140	140	140
Total annual output - Maize (ton) [13=6x11]	322	322	322	230	322	322	230	322	322	230
Total annual output - Lablab (ton) [14=8x12]	266	266	266	168	266	266	168	266	266	168
Annual revenue (US \$) - Maize [15=9x13]	48 300	48 300	48 300	34 500	48 300	48 300	34 500	48 300	48 300	34 500
Annual revenue (US \$) - Lablab [16=14+15]	93 100	93 100	93 100	58 800	93 100	93 100	58 800	93 100	93 100	58 800
GROSS BENEFITS (US \$) [16=14+15]	141 400	141 400	141 400	93 300	141 400	141 400	93 300	141 400	141 400	93 300
OVERHEAD AND PRODUCTION COSTS										
Community labour for maintenance (person-days) [17]	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700
Wage rate per person-day (US \$) [18]	2	2	2	2	2	2	2	2	2	2
Scheme maintenance costs (US \$) [19=17x18]	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400	11 400
Production costs (50% of [19]) (US \$) [20=0.5x19]	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700	5 700
INVESTMENT COSTS (US \$) [21=19+20]	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100	17 100
NET BENEFITS (US \$) [22=16-21]	124 300	124 300	124 300	76 200	124 300	124 300	76 200	124 300	124 300	76 200
DISCOUNTED REVENUE (US \$) [23]	792 761									
DISCOUNTED COSTS (US \$) [24]	105 072									
BENEFITS/COSTS RATIO [25= 23/21]	8									
NET BENEFITS PER CAPITA (US \$) [23=22/3]	113	113	111	67	107	104	63	100	98	59
NPV (US \$)	687 689									

* = Exchange rate = 1 US \$ = 1,000 TAs; Discount rate = 10%

Appendix 13: Discounted Drought Relief Savings from the RWH scheme

ITEMS	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Households served by the scheme	300	300	300	300	300	300	300	300	300	300
Average household size (with 1.6% growth rate)	3.66	3.66	3.74	3.81	3.89	3.97	4.05	4.13	4.21	4.29
Scheme beneficiaries	1 098	1 099	1 121	1 144	1 166	1 190	1 214	1 238	1 263	1 288
Nutritionally sufficient grain per capita (kg)	300	300	300	300	300	300	300	300	300	300
Maize requirement for 300 households (ton)	329	330	336	343	350	357	364	371	379	386
SGR procurement price per ton (US \$)	150	150	150	150	150	150	150	150	150	150
Gross value of relief food grain (US \$)	49 410	49 464	50 454	51 463	52 492	53 542	54 613	55 705	56 819	57 955
Transport and administrative costs (10%)	4 941	4 946	5 045	5 146	5 249	5 354	5 461	5 570	5 682	5 796
Annual relief costs (saving)	54 351	54 411	55 499	56 609	57 741	58 896	60 074	61 275	62 501	63 751
Discounted (DRS)	354 336									

*-Exchange rate = 1 US \$ = 1,000 TAs

Appendix 14: Characteristics of sample households

Characteristics of respondent households are presented here after the results from participatory poverty and vulnerability assessment and semi-structured key informants interviews. They also precede presentation of results from rigorous analyses fostered to realize the specific objectives. Insights into the characteristics of respondent households provide a better and elaborate understanding of the livelihood dimensions and enrich interpretation of results from rigorous analyses. Discussion of household characteristics was partitioned into demographic, social and economic perspectives. Demographic characteristics consisted of gender of household head, household size, and migration. Education of household head is discussed under social characteristics. Economic characteristics include major livelihood options, dependency ratio and modes of land acquisition or tenure arrangements. These characteristics were systematically cross-tabulated against biophysical location, subjective wealth and absolute relative poverty parameters.

1. Demographic characteristics

Most of the African dryland areas have been increasingly subjected to demographic pressure as a result of immigration of human and livestock herds. Major problems associated with influx of people and livestock include increased scarcity of resources such as land, water and pastures coupled by unprecedented degradation of these resources. This fact creates a need of investigating the migration pattern to unveil underlying drivers. Table 40 indicates that immigration was relatively higher in the lowland where 40% of the respondents were non-native compared to 12% and 4% who were non-native in the midland and upland, respectively.

Generally, people immigrating into the study villages are from within the district accounting for 77%, 62% and 50% of all immigrants in the lowland, midland and upland, respectively (Table 40). However, of policy-relevance are reasons behind such migrations. Results in Table 40 indicate the major three push factors for people to migrate into the study areas. These included accompanying parents, engagement in wedlock and looking for RWH possibilities. Accompanying parents accounted for 29% and 67% of all respondents in lowland and upland respectively. In the midland, marriage as a source of migratory mobility was cited by 63% of all immigrant respondents. Sixteen percent (16%) of the respondent households immigrated into the lowland village because of runoff farming possibility. Interestingly, which was not the case in other villages, some households (7%) pointed out that they immigrated into the lowland village in search of life. The lowland is a sub-urban settlement along the Dar Es salaam – Nairobi Highway, it is close to the sisal Estate and it has gypsum mines which in combination offer off-farm livelihood opportunities.

Table 40: Migration status of respondent households by locations

Gender/size/structure	Lowland village (n= 77)		Midland village (n= 65)		Upland village (n= 58)	
	n	%	n	%	n	%
Were you born here?						
Yes, born here	46	60	57	88	56	96
No, migrated from other place	31	40	8	12	2	4
Where did you migrate from?						
From within district	24	77	5	62	1	50
From within region	1	3	1	12	0	0
From within country	6	20	2	25	1	50
Reasons for migration:						
Marriage	6	19	5	63	1	33
Accompanied parents	9	29	-	-	2	67
Looking for RWH possibility	5	16	-	-	-	-
Employment transfer	4	12	1	12	-	-
Search for wage work	1	3	-	-	-	-
To occupy clan land	2	7	2	25	-	-
Search for life	2	7	-	-	-	-
Look for pasture	2	7	-	-	-	-

The findings in Table 41 show that the proportion of male-headed households accounted for 86%, 85% and 91% of all respondent households in the lowland, midland and upland, respectively. Dominance of male headship is a wide phenomenon in rural Africa. In the case household size which is unadjusted to household composition and scale economies, households in lowland village had the size of 1 to 4 and 6 to 10 people comprising 36% and 35% of interviewed households, respectively. Households in the midland and upland demonstrated relatively large unadjusted sizes of 6 to 10 people respectively, which exceeded both the regional and national average of 4 and 5 people respectively according to 2002 census. However, when the aggregate household size was adjusted to scale and composition the trend changed where the midland and upland villages had more smaller sized households of 1 to 4 people (86% and 83%, respectively) than lowland (78%). It is important to note that unadjusted household size which is used in national census tends to rate most of the households larger than they actually are when composition and economies of scale are taken into account.

Table 41: Gender of head, household size and structure by locations

Gender/size/structure	Lowland village (n= 77)		Midland village (n= 65)		Upland village (n= 58)	
	n	%	n	%	n	%
Gender of head:						
Male	66	86	55	85	53	91
Female	11	14	10	15	5	9
Household size (unadjusted):						
1 to 4	28	36	22	33	18	31
5 (regional and national average)	12	16	14	22	13	22
6 to 10	27	35	26	40	27	47
Household size (adjusted):						
1 to 4	61	78	56	86	48	83
5 (regional and national average)	8	11	8	12	10	17
6 to 10	8	11	1	2	-	-

2. Social characteristics

Among other social factors, literacy is a central strand of human capital. This necessitated assessment of formal literacy of the household heads who are key decision-makers. Assessment of formal literacy level was based on subjective wealth, absolute relative poverty and gender of household head. Primary education involved merging responses for standard

four, eight and seven. Results in Table 42 reveal that across all the study villages, primary education was the predominant level of formal literacy among the household heads irrespective of wealth status. In the lowland village, household heads with primary education were more than half and less than three quarters of all respondents in the rich (60%) and middle (68%) wealth groups compared to over three quarters (80%) for similar categories in the midland and upland villages. No attention has been paid on discussing the secondary and tertiary education levels due to relatively insignificant observations. The proportions of household heads who did not acquire any formal education, particularly among the rich and middle wealth categories (30% and 22% respectively) were much higher in the lowland than in the other study villages. With respect to primary education, the formal literacy (human capital) was relatively lower in the lowland than in the midland and upland villages.

Table 42: Education level of household head by wealth and locations

Location/wealth	None		Adult		Primary		Secondary		Tertiary	
	n	%	n	%	n	%	n	%	n	%
Lowland village										
Upper	3	30	-	-	6	60	1	10	-	-
Medium	9	22	1	3	28	68	2	7	-	-
Lower	2	8	-	-	23	88	-	-	-	-
Midland village										
Upper	-	-	-	-	6	86	1	14	-	-
Medium	1	5	-	-	20	90	1	5	-	-
Lower	3	8	-	-	32	89	1	3	-	-
Upland village:										
Upper	-	-	-	-	-	-	-	-	-	-
Medium	3	6	1	2	44	88	1	2	1	-
Lower	-	-	-	-	7	87	1	13	-	-

Table 43 shows that the relationship between the level of primary education, which is the prominent level and absolute poverty, does not reveal a consistent trend across the study villages. In the lowland, percentages of the absolutely poor based on the relative poverty line who had primary education slightly exceeded that of non-poor by 4% points that is 77% versus 74%. In the upland village, the proportion of the absolutely poor who acquired primary education surpassed that of non-poor by 16% points that is 100% versus 84% respectively. However, in the midland village, the proportion of absolutely non-poor household heads who had attained primary education exceeded that of their counterparts poor by 8% points that is 92% versus 84%. Whereas, categorical levels of formal literacy do not demonstrate a clear relationship with absolute poverty, it will be interesting to test using the econometric model the effect of number of years in school on poverty as the best proxy of the extent of human capital.

Table 43: Education level of household head by absolute relative poverty

Location/Gender	None		Adult		Primary		Secondary		Tertiary	
	n	%	n	%	n	%	n	%	n	%
Lowland village										
Poor	4	23	-	-	13	77	-	-	-	-
Non-poor	10	16	1	2	44	73	4	7	1	2
Midland village										
Poor	2	11	-	-	16	84	1	5	-	-
Non-poor	2	4	-	-	42	92	2	4	-	-
Upland village										
Poor	-	-	-	-	14	100	-	-	-	-
Non-poor	3	7	1	2	37	84	2	5	1	2

Furthermore, formal literacy was assessed with respect to gender of the household head. Considering primary education as an indicative level of formal literacy, with the exemption of upland village, Table 44 shows that the level of formal illiteracy in the lowland and midland villages was higher among male heads than their counterpart female heads (79% versus 46% and 90% versus 80% respectively). With an exception of lowland village where the percentage of male heads with primary education was 33% points more than female heads, in the midland and upland villages, a good proportion of female heads recorded attainment of primary education close to that of men. Such relative equity with regards to primary education would be linked to remarkable government policy advocating primary education for all.

Table 44: Education level of household head by gender and locations

Location/Gender	None		Adult		Primary		Secondary		Tertiary	
	n	%	n	%	n	%	n	%	n	%
Lowland village										
Male	10	15	-	-	52	79	4	6	-	-
Female	4	36	1	9	5	46	-	-	1	9
Midland village										
Male	2	4	-	-	50	90	3	6	-	-
Female	2	20	-	-	8	80	-	-	-	-
Upland village										
Male	3	6	1	2	46	86	2	4	1	2
Female	-	-	-	-	5	100	-	-	-	-

3. Economic characteristics

Results in Table 45 show that the livelihoods of most of the medium and lower wealth groups in the lowland village relied on crop production (34% and 38% respectively) compared to the rich (50%) who depended on livestock. In the midland village, most households in the much upper wealth category (43%) lived on crop production and petty business, and the moderately wealthier (36%) relied mostly on livestock while those in the lower wealth category (64%) survived mostly on crop production. In the upland village, all the randomly selected respondents were from the medium and lower wealth categories. In the upland village, crop production was the common livelihood option among households in the medium and lower wealth groups (54% and 62%, respectively) followed by livestock (22% and 38%, respectively). In the lowland and midland villages, petty business was more common among households in the rich and middle wealth categories than in the remote upland village. Throughout the study villages, the relatively worse-off households in the lower and medium wealth groups tended to have a more diversified livelihood portfolio than the relatively better-off in the upper wealth group. Excluding the upland village which had no households in the upper wealth category in the sample, interviewed households in the medium and lower wealth groups depended on all 6 livelihood options (100%) compared to those in upper wealth group who lived on 4 out of 6 options (67%). In the midland village, households in the medium and lower wealth categories depended on 4 to 5 out of 6 (67% to 83%) compared to those in the upper wealth group who survived on 3 out of 6 livelihood options (50%).

Table 45: Major household livelihood options by wealth groups

Location/Livelihood options	Upper		Medium		Lower	
	n	%	n	%	n	%
Lowland village						
None apart from crop production	3	30	18	44	10	38
Herding/stockman	5	50	8	20	8	30
Salaried employment	-	-	4	9	2	8
Petty business (retail sector)	1	10	6	14	1	4
Artisanal works	-	-	4	10	1	12
Traditional healing	1	10	1	3	2	8
Midland village						
None apart from crop production	3	43	7	32	23	64
Herding/stockman	-	-	8	36	9	25
Salaried employment	1	14	2	9	-	-
Petty business (retail sector)	3	43	1	5	1	3
Artisanal works	-	-	4	18	3	8
Traditional healing	-	-	-	-	-	-
Upland village						
None apart from crop production	-	-	27	54	5	62
Herding/stockman	-	-	11	22	3	38
Salaried employment	-	-	-	-	-	-
Petty business (retail sector)	-	-	3	6	-	-
Artisanal works	-	-	9	18	-	-
Traditional healing	-	-	-	-	-	-

After assessing the livelihood portfolio based on subjective definition of poverty it was as well important to view the livelihood options in another sphere of relative absolute poverty. Table 46 shows that throughout the study villages, crop production was the widely dependable source of livelihood for both the relatively absolute poor and non-poor households. Non-poor households who depended on crop production were 52%, 58% and 71% of all respondent households in the lowland, midland and upland villages respectively. Corresponding to decreasing off-farm livelihood opportunities, reliance on crop production by the absolute poor, increased with increasing remoteness from the highway and the district capital. Contrary to subjective poverty based on societal welfare rating criteria, the relatively non-poor based on expenditure measure tended to have more diversified livelihood portfolios than the poor. In the lowland village, the absolutely non-poor were involved in all 6 livelihood options (100%) while the poor were involved in 4 out of 6 (67%). In the midland village, the non-poor earned their livelihoods through 5 out of 6 (83%) while the poor did through 4 out of 5 (80%) livelihood options. Furthermore, in the upland village, the non-poor demonstrated to survive on 4 out of 6 (67%) livelihood options while the poor depended on 2 out of 6 (33%).

In regard to Africa, the tendency of the relatively poor to diversify more in terms of livelihood options as a strategy which reduces vulnerability, is widely recognized in livelihood literature (Ellis, 2000; Ellis and Allison, 2004). Diversification can assist households to insulate themselves from environmental and economic shocks, trends and seasonality and make them less vulnerable. However, the comparative results of livelihood diversification under the two definitions of poverty, that is subjective and relative absolute, provoke a debate on which typology of the poor tends to have more diversified livelihood portfolio - the subjectively poor or the absolutely poor?

Table 46: Major livelihood options by relative absolute poverty

Location/Livelihood options	Poor		Non-poor	
	n	%	n	%
Lowland village				
None apart from crop production	9	52	22	36
Herding/stockman	3	18	18	30
Salaried employment	2	12	4	7
Petty business (retail sector)	-	-	8	13
Artisanal works	3	18	4	7
Traditional healing	-	-	4	7
Midland village				
None apart from crop production	11	58	22	48
Herding/stockman	5	26	12	26
Salaried employment	1	5	2	4
Petty business (retail sector)	-	-	5	11
Artisanal works	2	11	5	11
Traditional healing	-	-	-	-
Upland village				
None apart from crop production	10	71	22	50
Herding/stockman	4	29	10	23
Salaried employment	-	-	-	-
Petty business (retail sector)	-	-	3	7
Artisanal works	-	-	9	20
Traditional healing	-	-	-	-

Table 47 reveals that most of female-headed households in the lowland village relied on crop enterprise (64%) followed by livestock and petty business (18%), while three widespread livelihood options for male-headed households were crop production (36%), livestock (29%) and artisanal work (11%). In the midland village, 80% of female-headed households dependent on crop production and the remaining 20% on livestock, whereas the percentage of male-headed household dependent on crop production and livestock was 46%. In the upland village, all female-headed households (100%) survived solely on crop production as opposed to male-headed households which had a diversity of other livelihood means and options. From the results, it is evident that male-headed households had broader set of livelihood options than female-headed ones. Acknowledging the role of diversification in increasing livelihood security and capacity to absorb shock, the survey affirmed a high degree of vulnerability among female-headed households than male-headed ones.

Table 47: Major livelihood options by sex of household head

Location/Livelihood options	Male		Female	
	n	%	n	%
Lowland village:				
None apart from crop production	24	36	7	64
Herding/stockman	19	29	2	18
Salaried employment	6	9	-	-
Petty business (retail sector)	6	9	2	18
Artisanal works	7	11	-	-
Traditional healing	7	6	-	-
Midland village:				
None apart from crop production	25	46	8	80
Herding/stockman	15	27	2	20
Salaried employment	3	6	-	-
Petty business (retail sector)	5	9	-	-
Artisanal works	7	13	-	-
Traditional healing	-	-	-	-
Upland village:				
None apart from crop production	27	51	5	100
Herding/stockman	14	26	-	-
Salaried employment	-	-	-	-
Petty business (retail sector)	3	6	-	-
Artisanal works	9	17	-	-
Traditional healing	-	-	-	-

The dependence ratio is the number of dependents defined as younger than 15, the sick, disabled and older than 48 over the rest with ability. The argument is that a household which comprises more dependents is more vulnerable than a comparable household which has fewer dependents relative to members with ability. Here, the 'term comparable household' connotes the condition that for the argument to hold true, the two households must be much related in other aspects except the dependence ratio. Table 43 shows that households in the rich wealth group in the lowland village had lower mean dependence ratio (0.37) than households in the middle and poor wealth groups (0.51 and 0.40 respectively). In the midland village, the dependence ratio increased gradually from rich (0.37), middle (0.58) to poor wealth (1.00) categories. In the upland village, the mean dependence ratio increased from 0.64 for households in the middle wealth group to approximately a unity (0.94) for those in the poor wealth group. With respect to relative absolute poverty, the mean dependence ratio between the poor and non-poor differed only by 0.04 points more, that is 0.42 versus 0.46 respectively. In the midland and upland villages, poorer households hosted more dependent than members with ability (0.96 versus 0.72 and 0.75 versus 0.65, respectively). It is therefore arguably true to generalize that households rated poorer based on societal criteria tended to comprise more dependent than members with ability. With respect to gender, ironically female-headed households were found to have higher dependence ratio (0.75) than male-headed households (0.40). The lowland village is more urbanized with more mobility and interactions of people compared to other villages. This situation may prompt HIV/AIDS related deaths among mobile husbands and many children born outside the wedlock among unmarried women and widows.

Table 48: Level of dependency in the households

Wealth/Gender	Lowland village		Midland village		Upland village	
	Mean dep. Ratio	SD	Mean dep. ratio	SD	Mean dep. ratio	SD
Wealth:						
Rich	0.37	0.492	0.37	0.374	-	-
Middle	0.51	0.769	0.58	0.824	0.64	0.715
Poor	0.40	0.855	1.00	1.245	0.94	1.012
Median poverty:						
Poor	0.42	0.49	0.96	1.07	0.75	0.81
Non-poor	0.46	0.83	0.72	1.07	0.65	0.75
Gender of head:						
Male	0.40	0.678	0.80	1.111	0.70	0.783
Female	0.75	1.155	0.72	0.839	0.42	0.373

Land is obviously the single most critical resource for the livelihood of rural poor in Africa. The two spheres of the broad concept of land tenure assessed here include land acquisition and access arrangements. Land acquisition and access were assessed with respect to accessibility to RWH. This is because RWH possibility underlies the value and quality of land in water-constrained drylands. Table 45 reveals that most of the households in the study villages acquired land through inheritance from parents regardless of accessibility to RWH. The percentage of respondents who acquired land with RWH possibility through purchase in the lowland village was 21% which is about 2 and 3 times (9% and 7%) more than those who did so in the midland and upland villages respectively. Farmers in the lowland village demonstrated a higher tendency of purchasing and renting in land which had access to RWH compared to typically rainfed land. Throughout the study villages, farmers strived to have more alternatives of acquiring land with access to RWH than they did for land without access to RWH.

Table 49: Tenure systems of land access by location

Tenure systems of land access	Lowland village		Midland village		Upland village	
	n	%	n	%	n	%
Land with access to RWH:						
Opened a new field	12	16	6	14	4	13
Given by the village government	5	7	6	14	2	7
Inherited from parents	28	38	25	58	18	60
Purchased	16	21	4	9	2	7
Given by blood relative	11	15	2	5	3	10
Rented in	2	3	-	-	1	3
Land without access to RWH:						
Opened a new field	1	33	3	13	6	22
Given by the village government	0	0	1	5	-	-
Inherited from parents	2	67	18	82	18	64
Purchased	-	-	-	-	-	-
Given by blood relative	-	-	-	-	4	14
Rented in	-	-	-	-	-	-

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