EFFECTS OF CLIMATE VARIABILITY ON WATER RESOURCES AND LIVELIHOODS AND STATE OF ADAPTIVE CAPACITY IN SEMI-ARID THARAKA DISTRICT, KENYA

By

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PROFESSIONAL QUOTE

"It's not that I'm so smart;
It's just that I stay with problems longer."
- **Albert Einstein**

DECLARATION

This thesis is my original work and has not been presented for a degree in any other university or any other award.

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DEDICATION

To the young and great minds that rose to the occasion when it mattered most to their country

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ABBREVIATIONS AND ACRONYMS

ACMAD: African Centre of Meteorological Application and Development

AEZ: Agro-Ecological Zones

ASAL: Arid and Semi-Arid Lands

DFID: Department for International Development

ENSO: El Niño Southern Oscillation

EU: European Union

FAO: Food and Agricultural Organization of the United Nations

FGD: Focus Group Discussions

ICPAC: Inter-Governmental Authority on Development (IGAD) Climate Prediction and Application Centre

IDRC: International Development Research Centre

ILRI: International Livestock Research Institute

IL5: Intermediate Lowland Zone 5

IL6: Intermediate Lowland Zone 6

IRI: International Research Institute for Climate and Society

ITCZ: Inter-Tropical Convergence Zone.

IPCC: Intergovernmental Panel on Climate Change

KARI: Kenya Agricultural Research Institute

KEFRI: Kenya Forest Research Institute

KMD: Kenya Meteorological Department

LM4: Lower Midland 4

LM5: Lower Midland5

MAM: March-April-May rainfall

MDGs: Millennium Development Goals

MKEPP: Mount Kenya East Pilot Project

NGO: Non-governmental Organizations

OND: October –November- December rainfall

START: SysTem for Analysis, Research and Training

UNDP: United Nations Development Programme

VAC: Vulnerability Assessment Committee

WFP: World Food Programme

WRUA: Water Resource Users Association

WRMA: Water Resource Management Authority

OPERATIONAL DEFINITIONS USED IN THE STUDY

Adaptive capacity: Is defined as the ability of people or a livelihood system to adjust to climate change (including climate variability & extreme events) to moderate potential damages, take advantage of opportunities, or cope with the consequences.

Climate variability: Climate variability refers to fluctuations in climate or deviation from the long-term meteorological average over a certain period of time. In this study, climate variability will invariably refer to rainfall variability since it's the main determinant of livelihood decision-making and the most measured climate variable.

Exposure: Nature and degree to which a system (e.g agriculture, livestock) is exposed to significant climate variations.

Impacts: Refer to the consequences of rainfall variability on natural and human systems.

Household: A household is defined as a composition of a person or group of persons residing together within the same compound and have the same cooking and 'investment' (same farm unit, livestock, business etc) arrangement. Wives of a polygamist served from one granary or have the same source of income will be considered a household.

Livelihoods: Is defined as assets and endowment and socio-economic strategies meant to promote or protect household's well-being (Finan, West, Austin & McGuire, 2002).

Risk: Risk in this study is considered as a function of rainfall variability (as a hazard) and vulnerability.

Seasonal climate forecast: Is probabilistic information usually issued in equi-probable categories of below normal, near normal and above normal for a specified season and geographic location. In this study, it is regarded as a tool of adaptation.

Sensitivity: Refer to a degree to which a system (biophysical attributes or livelihoods) is affected, either adversely or beneficially, by climate related stimuli.

Stressor: Will be used interchangeably with worry and stress to refer to threats to people and the things they value as defined in Tschakert (2008)

Tharaka District: Refer to one of the districts curved from the former Tharaka-Nithi district in 1999 (Rep. of Kenya, 2001).

Vulnerability: Is defined as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including variability and extreme events. Vulnerability is a function of character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity (Intergovernmental Panel on Climate Change, 2001)

ABSTRACT

This study adopted an integrated approach of vulnerability assessment to understand climate variability and its effects in Tharaka District Kenya. The specific objectives of the study were: (i) analyze the characteristics of rainfall variability; (ii) assess the effect of climate variability on water availability; (iii) determine the perceived impact of climate variability on livelihoods; (iv) Assess the conceptual understanding of climate variability in relation to other socio-economic stressors and; (v) Assess the availability and use of attributes and indicators of adaptive capacity. The study utilized four data sets: daily rainfall data (1969-2007), household survey (N=326), interviews with practitioners (N= 24) and Focus Group Discussion (N= 48). The study used cumulative departure index and rainfall anomaly index to establish rainfall trends for the period on record; and two sample *t*-test to establish the difference between March-May (MAM) and October-December (OND). Percentage cumulative mean was used to estimate mean dates of onset and cessation and INSTAT in disaggregation of daily rainfall data into pentads to analyze within-season characteristics. The study utilized X^2 to establish satisfaction levels of distance to water points, social amenities and rating of seasonal climate forecasts. Factor analysis was used establish the main effect of climate variability while participatory risk ranking and scoring to yield the lead stressors. In Tharaka, OND and annual rainfall are persistently below normal when compared to MAM. Rainfall has high inter-annual variability with occasions of positive anomalies such 1997 for OND and negative anomalies such 1984 for MAM. MAM and OND had a coefficient of variation exceeding 0.3 although the former was poorly distributed in April. The average dates of onset were 21-25 of March and October, while cessation dates were May 16-20 for and January 6-10 for October-January season. But onset dates showed high inter-annual variability than cessation dates. MAM and OND seasons in Lower Midlands 5 and Lower Midlands 4 are markedly different and therefore require different cropping systems. Although 58% of households engage in more than three livelihoods, income derived is very low. Results of factor analysis showed livestock (25%) and water & forest products (12%) as the most affected by climate variability. This perception was at variance with practitioners who said crops were the most affected. Water scarcity (1.2) and lack of money (1.2) had the highest severity index, ahead of irregular rains (1.7) and drought (1.5) as stressors. Awareness on the causes and impact of climate variability and the improved rating of climate forecasts should be harnessed into an opportunity to reduce vulnerability. Livelihood diversity, land availability, two growing seasons and cultivation of drought tolerant crops are the indicators of adaptive capacity in Tharaka. Adaptation to climate variability is hampered by lack of credit facilities, low literacy levels and limited use of climate forecasts. There were institutions in Tharaka supporting adaptation through seed distribution, food relief, irrigation and rainwater harvesting. It is recommended that farmers in IL5 and IL6 tap the full potential of MAM season and stakeholders address socio-economic concerns as a first step to strengthen adaptation. Future studies should quantify drought episodes and analyze the implications of rainfall variability on major crop yields in Tharaka.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The impacts of climate variability are manifested in floods, prolonged drought, unseasonal rains and extreme climatic events, and create enormous developmental challenges to communities. This is due to the dependence on climate sensitive sectors such as rain-fed agriculture, pastoralism, forestry and wetlands. The threat that climate variability poses to these sectors has necessitated the assessment of the potential impacts of climate at various scales on these sectors as a first step to reduce their vulnerability and thereby secure the livelihoods of those who depend on them. Understanding of climate impacts has mostly involved assessment of bio-physical and social vulnerabilities (Deressa, Hassan & Ringler, 2008; Fussel & Klein, 2006; Brooks, 2003). Bio-physical assessment has involved monitoring of El Niño Southern Oscillation (ENSO) and other oceanic and atmospheric predictors of rainfall (Yasunaka & Hawana, 2005; Hasternrath, Polzin & Camberlin, 2004; Goddard, Mason, Zebiak, Ropelewski, Basher & Cane, 2001; Mutai, Ward & Coleman, 1998). Bio-physical assessments have led to the understanding of interaction between the atmosphere and sea and land surfaces, advances in modeling the global climate system and substantial investment in monitoring the tropical oceans now provide a degree of predictability of climate variability (Hansen 2005, Goddard et al., 2001). Bio-physical studies have also involved sectoral assessment of impacts of climate change & variability and subsequently laying a foundation for adaptation (Kundezewicz, Mata, Arnel, Doll, Jimenez, Miller, Oki, Sen, Shiklomanov, 2008; Indeje, Ward, Davies, Ogallo, Dilley & Anyamba, 2004; Chipanshi, Chanda &Totolo, 2003; Phillips, 2003). Socio-economic approaches to climate impacts have entailed assessment of the adaptive capacity at community and national (and sometimes regional) levels. There are calls for the establishment of institutions (Vogel, Moser, Kasperson & Dabelko, 2007; Washington, Harrison, Conway, Black, Challinor, Grimes, Jones, Morse, Kay & Todd, 2006; Sivakumar, 1987) which provide climate services, including early warning systems. Others have called for active involvement of social aspects such as poverty, livelihoods, health and natural resource degradation in climate change studies (Shisanya & Khayesi, 2007; Tschakert, 2007; Wehbe, Seiler, Vinocur, Eakin, Santos, Civitaresi, 2005; Vasquez-Leon, West & Finan, 2003).

Unfortunately, current development policies, plans and programs are not well attuned to existing climate vulnerabilities. As reported in the *Global Climate Observing System Program in Africa* (International Research Institute - IRI, 2006), there exist gaps, particularly in integrating climate risk management into climate sensitive development processes. These studies have added little to the understanding and enhancements of adaptive capacity of the vulnerable members of society. This is because for most studies, they adopt a bio-physical or socio-economic approach in climate change and adaptation studies. This study identifies an alternative approach that embraces both climatic and non-climatic factors that contribute to community's vulnerability to climate shocks.

Adaptation to climate change and variability is a critical issue for Kenya, especially given her dependency on agriculture (Republic of Kenya, 2002a). The fact that agriculture is predominantly rain-fed makes the sector more susceptible to climate variability. Kenya's marginal areas comprise both the arid and semi-arid (ASAL) areas and cover approximately 88% of the country's total area (Shisanya, 1996), with livestock as the main livelihood. Tharaka District is classified as ASAL and is characterized by high rainfall variability, which causes wide fluctuations in water availability for agriculture, livestock keeping and domestic use (Republic of Kenya, 2002b). This has left 41.76% of the population relying on relief food and over 30,000 children under school feeding program (Republic of Kenya, 2001a). Water shortage has led to low resource utilization, poor yields, food insecurity and has accentuated poverty (Smucker & Wisner, 2008; Republic of Kenya, 2000).

There are local level initiatives by governments and Non-Governmental Organizations (NGOs) to help households cope and recover from disasters and improve their resilience in the phase of adverse climate events. These include food relief and assistance in form of seeds (Orindi & Ochieng, 2005). Recognizing the importance of institutions and policy, the Government of Kenya established or reformed institutions that are expected to pro-actively conserve and manage natural resources that are sensitive to climate change and variability. The Water Act 2002, the Forest Act 2005 (Republic of Kenya, 2005; Republic of Kenya, 2002c) and the National Climate Change Response Strategy are manifestations of these efforts. In addition, local and regional institutions, particularly Kenya Meteorological Department (KMD) and IGAD Climate Prediction and Application Centre (ICPAC) continue to play a central role in the prediction and dissemination of climate forecast in mitigating the impacts of climate variability (Oduor, Mutea & Karanja, 2002).

Despite the efforts to support adaptation of households, people of Tharaka District continue to suffer from food insecurity and poor living conditions due to unreliable rainfall and a weak adaptive capacity. An understanding of the magnitude of climate variability and district’s adaptive capacity to climate variability are key to vulnerability assessment. It is important to establish the effect of climate variability on water and livelihoods and the community’s conceptualization of the problem of climate variability as the foundation for strengthening adaptation.

1.2 Statement of the Problem

Climate adaptation research, while it has provided vital information in understanding climate change and variability, has had its focus on determinants of climate change and variability, climate change scenarios and sectoral assessment. These studies have provided an understanding of the link between rainfall and ENSO, and also the impact of climate variability on various sectors of our economies. Few studies have provided information on the much needed character of within-season rainfall variability and its implication on water resources and livelihoods. There are still those that have advocated for recognition of the role played by socio-economic factors such as poverty, institutions, health education and resource degradation in addressing climate change and adaptation challenges. Yet an assessment of both bio-physical and socio-economic vulnerabilities to climate variability is critical in enhancing adaptation to climate change. This study identified an alternative approach that embraces both climatic and non-climatic factors that contribute to society's vulnerability to climate shocks.

Tharaka District has a diversity in agro-ecological zones (AEZs) that gives it a variety of livelihood zones; rainfed cropping, mixed farming and marginal mixed farming. This is in addition to the many permanent rivers that traverse the district. Despite these, the people of Tharaka District remain poor and dependent of food relief - usually attributed to erratic rainfall. It is against this background that the present study sought to characterize rainfall variability (onset, cessation, within season distribution and dry spells) and establish the role of non-climatic variables (such as livelihoods, assets, access to resources and information, institutional framework, education, gender and poverty) in accentuating poverty. This is seen as a first step towards understanding vulnerability and subsequently refining the adaptive capacity of communities. Study findings aim at mainstreaming current and future climate vulnerabilities into development as an urgent prerequisite for drought mitigation in semi-arid zones.

1.3 Objectives of the Study

The broad objective of the study was to quantify climate variability and assess its effects on water resources and livelihoods in semi-arid Tharaka District across the four (4) main agro-ecological zones. The specific objectives are:

(i) Analyze the characteristics of rainfall variability in the major agro-ecological zones of Tharaka District.

(ii) Assess the effect of climate variability on water availability in Tharaka District.

(iii) Determine the perceived impact of climate variability on livelihoods among households in Tharaka District.

(iv) Assess the conceptual understanding of climate variability as a problem in relation to other socio-economic stressors at household and community levels Tharaka District.

(v) Assess the availability and use of attributes and indicators of adaptive capacity to climate variability by the local community in Tharaka District.

1.4 Research Questions

(i) How significant is rainfall variability in the major agro-ecological zones in Tharaka District?

(ii) To what extent does climate variability affect water availability in Tharaka District?

(iii) Which household livelihood strategies are affected most by climate variability in Tharaka District?

(iv) How is the problem of climate variability perceived in relation to other socio-economic stressors?

(v) Which local-level interventions and adaptive capacities are used to counter the effects of climate variability in Tharaka District?

1.5 Hypotheses

(i) There are no variations in seasonal rainfall in the main agro-ecological zones of Tharaka District.

(ii) Climate variability has no effect on water availability at household level in Tharaka District.

(iii) Climate variability has no significant perceived impact on livelihoods among households in Tharaka District.

(iv) The concern for climate variability is at par with other socio-economic stressors in Tharaka District.

1.6 Significance and Justification of Study

Africa is in need of urgent effective development actions that are resilient to current and increasing climate variability. It is necessary to strengthen systems for coping with climate variability and reduce vulnerability. Efforts in this direction have been spearheaded by the Government of Kenya (GoK), IGAD Climate Prediction and Application Centre (ICPAC), Department for International Development (DFID), International Research Institute for Climate and Society (IRI), SysTem for Analysis, Research and Training (START), European Union (EU), International Development Research Centre (IDRC) among others. The present study compliments efforts of these organizations in understanding climatic impacts on livelihoods and water availability in Tharaka District and evaluates ongoing adaptation initiatives.

Tharaka District is susceptible to rainfall variability and most of the households depend on marginal mixed farming (Smucker and Wisner, 2008; Republic of Kenya, 2002b). Crop failure is recurrent and 41% of the population depends on relief food (Republic of Kenya, 2001a). Further, Tharaka people predominantly rely on stream flows (54.8%) and borehole (24%). This leaves the majority of the population vulnerable to water scarcity and limited livelihood options in times of extreme climatic events. Given the effect of climate variability on water resource and livelihood, the study sought to characterize rainfall variability and its effect on water resources and livelihoods. Characterization of rainfall variability provides a bio-physical vulnerability assessment in the District which offers much scope in developing strategies for efficient water resource management and livelihood planning in the district.

Vulnerability is not predominantly a climate-based condition but rather derives its significance from the interaction of climate and society. Previous adaptation studies have emphasized statistical modeling and sectoral adaptive responses to climate variability. Little attention has been given to qualitative analysis of the social context within which local communities have to adapt to climate variations. It is on this premise that the study sought to make a contribution by identifying the place of climate variability in relation to other socio-economic stressors (Tschakert, 2007). As a result, the study contributes towards insights on the role played by non-climatic factors in adaptation to climate variability.

Current understanding of the interaction between the atmosphere and its underlying surfaces, and advances in modeling the global climate system have allowed scientists to issue seasonal climate forecast with a degree of predictability (Goddard et al., 2001).

Studies by Hansen (2005) and IRI (2006) illustrate obstacles to using early warning information in reducing adverse impact. Among the obstacles is failure to integrate climate into practice at the scale of communication and capacity building. There is also need to explore other tools and options for adaptation in ASAL areas. It is against this background that the present study sought to explore existing adaptive capacity at the institutional, community and household level. The study builds on current coping strategies and seeks to identify good-practice adaptation options that are cognizant of science-practitioner communication (Vogel et al., 2007) in the context of policy-making and management.

Overall, characterization of rainfall and understanding the role of socio-economic factors is expected to contribute to vulnerability assessment in semi-arid Tharaka District.

1.7 Scope and Limitations of Study

The study is aware that climate variability encompasses variables such as rainfall, temperature, evaporation, evapo-transpiration, humidity, sunshine and wind among others. The present study however considers rainfall as the critical element that influences livelihoods and exploitation of natural resources such as water and land. Thus the significance of climate variability in this is limited to the understanding of rainfall variability. The specific variables of analysis are onset, cessation, dry spells, within-season distribution and trends. Furthermore, rainfall is used since it is the most important hydrological variable and generally the most measured in remote semi-arid areas such as Tharaka.

The study was also conscious of the expansive nature of Tharaka Districts. The study based its rainfall data analysis on three stations found in agro-ecological zones

Lower Midland (LM)4, Lower Midland (LM)5 and Intermediate Lowland Zone (IL)5 and (Jaetzold, Schmidt, Hornetz, & Shisanya, 2007). Rainfall analysis for Intermediate Lowland Zone (IL) 6 was not done for lack of adequate data for a climatologic analysis. However, data on socio-economic factors was collected in all the four agro-ecological zones, including IL 6.

For the three rainfall stations used in the study, each had a different period of data; 1973-2007 (Tunyai), 1974-1999 (Chiakariga) and 1969-1997). The variation arose as a result of lack of data update by the Kenya Meteorological Department (KMD). This is a limitation to an analysis that gives the current state of rainfall variability. Despite the data lacking currency, the stations used had data of more than 25 years - sufficient for a climatological analysis (Atheru, 1999) relevant to the present study.

It is possible that questionnaire response may have been influenced by the recent climatic events and immediate socio-economic concerns, perhaps even with expectations of immediate benefits through projects. In spite of these potential shortcomings, the integrated nature of the study (questionnaire, interview, FGD and analysis of rainfall variability), provides checks and balances to lead to more informed responses and reduce subjectivity.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This section reviews literature along five main themes. The first part interrogates relevant studies in climate change & variability. The second part discusses implications of climate change and variability on water resources and livelihoods. This is followed by a review of literature on adaptation to climate change and variability. The final part of the chapter presents a conceptual framework for this study.

2.2 Climate Change and Variability

Climate change is already exerting control over development programs, including efforts to address food security and poverty alleviation in Sub-Saharan Africa (Jones & Thornton, 2003; Sokona & Denton, 2001). On many occasions, extreme climate change events leave vulnerable people in Africa and indeed in other regions of the world, totally unprepared and unable to cope. The adverse impact of climate change affects natural resources such as water, vegetation, land and wildlife. These resources are threatened by poor and unsustainable resources management on the one hand, and the impact of climate change on the other. This challenge calls for a pro-active approach in addressing the challenges.

There are concerted efforts in Africa to address climate related challenges. In part, this has been through the establishment and strengthening of institutions (Vogel et al., 2007; Washington et al., 2006; Sivakumar, 1987) which provide climate services, including early warning systems. These include national meteorological services, ICPAC (Eastern Africa), Vulnerability Assessment Committee - VAC (Southern Africa), African Centre of Meteorological Application and Development (ACMAD)

(West Africa). These institutions need quantified information on the magnitude of rainfall variability at local level. Examples of published studies that have analyzed the magnitude of rainfall variability in SSA include Tadross, Suarez, Lotsch, Hachigonta, Mdoka, Unganai, Lucio, Kamdonyo & Muchinda (2009) Camberlin & Okoola (2003), Nicholson, Some & Kone, (2000), Mamoudou, Frouin & Nicholson (1995), Nicholson (1993) Nicholls & Wong (1990). More often than not, rainfall evaluation has in the past focused on annual averages and less on seasonal; an issue this study seeks to address.

The El Niňo - Southern Oscillation (ENSO) (Yasunaka & Hanawa, 2005; Odingo et al., 2002; Cane & Arkin, 2000) NINO3 (Phillips & McIntyre, 2000) and generally the Indian, Atlantic and Pacific Oceans' Sea Surface Temperatures (SSTs) (Paeth & Hense, 2004; Hasternrath, Polzin & Camberlin, 2004; Mutai et al., 1998) have been found to account for much of the inter-annual variability of climate in Africa. The link between rainfall and ENSO has contributed to the understanding of the interaction between the atmosphere, land and sea and significantly contributed to the improvement of seasonal forecasts (Hansen, 2005; Phillips, 2003). Improved seasonal climate forecasts are critical in strengthening the adaptive capacities of communities. This study seeks to establish the extent to which climate forecasts are part of the decision-making processes in supporting adaptation.

There is interest in understanding seasonal patterns of rainfall by investigating variables such as amount, rainy days, length of growing seasons and frequency of dry spells. For instance, Tilahun (2006), Seleshi & Zanke (2004), and Sivakumar (1987, 1991) characterized annual and seasonal rainfall totals and rain days in Ethiopia and the Sudano-Sahelian regions respectively, and both cases have exhibited high variability. Camberlin & Okoola (2003) and Mugalavai, Kipkorir, Raes & Rao (2008) analyzed onset and cessation of rainfall in Kenya and linked their variation to atmospheric, oceanic and local conditions. Previous studies have also investigated within-season dry spell and their impact on planting dates and crop yield (Mzezewa, Misi & Rensburg, 2010; Barron, Rockstrom, Gichuki & Hatibu, 2003; Tumwesigye & Musiitwa 2001; Kasei & Afuakwa, 1991). The main findings of these studies include variations in the dates of onset, small proportion of rain days supplying high proportion of rainfall and occurrence of dry spells that disrupt crop development and lower yield in SSA. This study identifies with these studies with a view of providing local level (by AEZ) information on the character of rainfall variability in Tharaka District. Knowledge of the statistical properties of rainfall variability can be applied in farm-management and management of natural resources.

2.3. Impacts of Climate Variability on Water Resources and Livelihoods

Sub-Saharan Africa experiences inter-annual and inter-decadal climate variability. Floods, droughts, and other weather extremes are common in several African countries, and they have harsh and damaging effects on agriculture, livestock, wildlife, tourism, health, water resources, hydroelectric power generation, and the many other socio-economic sectors that form the core of the society's basic livelihood survival. In this sub-section, a review of literature on impacts of climate variability on water resources and livelihoods is undertaken.

2.3.1 Impacts of Climate Variability on Water resources

Studies by Ngigi (2009) and Conway et al. (2009) show that many sub-Saharan river basins have high levels of inter-annual variability, diminishing runoff and increased evaporation due to climate variability. The situation is made worse by the fact that most African basins traverse ASALs. Extreme events such as floods overwhelm water and sanitation infrastructure, management and operation. Climate change scenarios show that the Eastern region of Africa is likely to have heavy precipitation events (Conway et al., 2009; van Steeg, Herrero, Kinyangi, Thornton, Rao, Stern & Cooper, 2009; ILRI, 2006) and this will most likely increase pathogen load in areas without good water supply and sanitation infrastructure (Kundezewicz et al., 2008). A report by LVBC and WWF-ESARPO (2010) observed that during a drought year, reserve flows are not met in the upper and middle reaches of the Mara River of Kenya and Tanzania. This is seen as evidence of a trend towards unacceptable alterations of the Mara River flow regime through mainly poorly managed water abstraction. These studies illustrated the impact of rainfall variability on water quality and quantity. The studies were however conducted on a larger spatial scale. The present study seeks to investigate impacts of climate variability on water at a household level in semi-arid Tharaka District.

A study by Kaur, Getnet, Shimelis, Tesfaye, Syoum & Atnafu (2010) show that climate change has impacted on rangelands and livestock watering points, changed patterns of crop production and led to a decrease in spring discharge in Ethiopia. In the Tana Basin, Agwata (2006) observed that water resources are constraint by high demand for farm and other land use activities, leading to conflict among communities. A similar position is echoed by Hoff, Noel & Droogers (2007) who observe that all water users in the Tana basin have un-met water demands. Overall, Chao & Peiwang (2005) identified five challenges to water resources in many countries: (i) increasing and competing water demands, (ii) uncertainty caused by unpredictable climates, (iii) co-ordination of trans-boundary water resource management, (iv) continuing water scarcity in water-short areas, especially in arid and semi-arid lands and (v) absence of proper management of water resources, leading to conflict. In the study by Chao &

Peiwang (2005), it was observed that climate change, land-use activities and water management practices affect water availability. To address water related challenges, it is important for the present study to establish the extent to which communities have prioritized climate variability as a challenge.

There have been a number of initiatives to address water related challenges. World leaders through the Millennium Development Goals (MDGs) agreed to ensure environmental sustainability - Goal number 7 (UN, 2005). In this goal, leaders committed themselves to increase access to safe drinking water. In Kenya, the Kenyan government through the Water Act 2002 introduced reforms in the water sector. The Act provided a legal framework for the reform process and established new institutions and their responsibilities in water resources management (Republic of Kenya, 2002c). Among the institutions established were Water Services and Regulatory Board, Water Resource Management Authority (WRMA) and Water Resource Users Association (WRUAs) (WRMA, 2007). WRMA seeks to monitor water resources and administer water resource regulations while WRUAs are to ensure that users participate in decision-making concerning management of water resources in their sub-catchments. The importance of institutions in enhancing water resource management in light of climate change and variability is underscored by Vogel et al. (2007) and Crabbe & Robin (2006). For instance, institutions can play a role in illustrating to people how climate change relates to water resources. Institutions can also put in place policy interventions directed towards large scale water management projects as was the case in Ceara`- Brazil (Lemos, Finan, Fox, Nelson & Tucker, 2002). Kundzewicz et al. (2008) observed that climate change will affect water management practices and the operations of existing water infrastructures and institutions. They have called for incorporation of current climate variability into water management to make adaptation to climate change easier. WRMA (2007) identified accessibility one of the key issues in the sub-catchment of Tharaka. WRMA in the same report categorizes some rivers in Tharaka to have a resource status of *alarm,* indicating a strain on water availability.

From the afore-mentioned literature review, it is apparent that climate variability affects water quality and quantity, and that institutional capacity is critical in water resource management. The present study complements these studies by investigating household access to water in light of climate variability; and examines institution-led adaptation strategies to impacts of climate variability on water.

2.3.2 Impacts of Climate Variability on Rural Livelihoods

To understand the impact of climate variability, one needs to go beyond the physical characteristics (rainfall) but also material assets such as access to land, other natural resources, financial capital and credit, tools and inputs into productive activities and others. Climate-induced changes to resource flows can fundamentally affect the viability of the livelihoods of the poor. Premised on this, this sub-section reviews literature on the impact of climate variability on food production and livelihoods.

According to Mall, Ranjeet, Gupta, Srinivasa & Rathore (2006) summer monsoon rainfall is responsible for 50% of variability in the total food production anomalies in India. While comparing the impact of climate change on production by seasons, Mall et al. (2006) observed that the impact would be small on *Khalif* (summer) crops than on *rabi* (winter) crops which are relatively more risky to projections of large increase in temperature. Similarly, Sultan, Baron, Dingkuhn, Sarr & Janicot (2004), using crop model SARRAH, found that large scale inter-annual variability of West African monsoon rainfall had a strong correlation with sorghum yield. Vinocur, Seiler & Mearns (2001) (as cited in Wehbe et al., 2005, p 10) demonstrated how changes in temperature and rainfall affected simulated yields of peanut crop in Argentina. Jones & Thornton (2003), using models CERES-Maize and MarkSim, found that by 2055, rain-fed maize production in Latin America and Africa would decrease by 10%. Although maize breeding and technological interventions are expected to offset this shortage, it is observed that in some rural areas, there may be considerable disruption to rural life. Other simulated results in Botswana show that maize and sorghum production would decline and the length of growing season become shorter (Chipanshi et al., 2003). According to Chipanshi et al. (2003), the decline is not limited to lack of rain but also socio-economic constraints. Amissah-Arthur, Jagtap & Rosenzweig (2003) observed that although it is inconclusive as to why El Niño years are associated with positive or negative changes in maize yields, an annual maize yield trend for the period 1979-1998 show that the highest yielding years were non-El Niño years. This implies that high rainfall leads to widespread losses of crops and nutrients applied. In Uganda, Phillips & McIntyre (2000) observed that in unimodal zones, El Niño events are likely to lead to lengthening of seasons and potentially provide an opportunity for growing late maturing crops. In bimodal zones however, November rainfall is enhanced in El Niño years and depressed in La Niña years; a scenario that calls for making decisions on crop choice, timing of planting based on ENSO forecasts (Phillips & McIntyre, 2000).

The emerging theme from these studies is that rainfall variability will have adverse impacts on food production, especially on sub-Saharan staples such as maize and sorghum. This calls for a local-level and national-level adaptation strategies that could ensure high production. It also raises the need to re-evaluate current cropping systems in light of a highly variable climate. Against this background, the present study sought to evaluate the magnitude of rainfall variability for MAM and OND, and assess the sustainability current adaptation in light of a variable rainfall pattern in Tharaka District.

Livestock are particularly important for increasing the resilience of vulnerable people. Yet indications are that climate change will have specific livestock impacts. Among these include changes in feed resources (Thornton, Herrero, Freeman & Mwai, 2007). Barrow & Mogaka (2007) observed that drought leads to reduced forage availability, degradation of the environment and an increase in destitution. They opine that in Kenya, drought proceeds famine, a scenario that relates to under and misguided development. Omolo (2010) discussed how resource competition, arising from climate related stress leads to conflict between the Turkana community and her neighbours. Since the Turkana are predominantly pastoralists, climate change is likely to provoke the drivers of conflict in many livelihoods, including livestock production. An outcome of these conflicts was variations in gender coping strategies. Livestock is a key livelihood in semi-arid Tharaka District. An investigation on the role of livestock keeping as a livelihood and the arising impacts of climate variability are important in understanding on-going adaptation efforts.

Climate variability is also known to have an impact on market, access to inputs and food availability. A study by Brown, Pinzon & Prince (2006) show that growing-season vegetation production is related to the price of millet at the annual and the seasonal timescales in Sahelian countries. Thus, a growing season characterized by erratic, sparse rainfall resulted in higher prices, and well-distributed abundant rainfall resulted in lower prices. A study by Misselhorn (2005) identified climate and environmental stressors as the leading direct drivers of food insecurity in Southern Africa. The study cautioned that understanding future determinants of food security in southern Africa lie primarily outside the domain of agricultural production. This calls for an investigation into the role economic and socio-political factors have in increasing vulnerability and social instability of communities. FAO (2010) identified twenty-two countries in which a significant proportion of the population is acutely vulnerable to death, disease and disruption of livelihoods over prolonged period of time. Food insecurity is seen as the most common manifestation of protracted crises. Countries in protracted crises are characterized by natural disasters, human-induced disasters and a combination of natural and human-induced disasters. FAO (2010) observes that between 1996 and 2010, Kenya had a total of 9 natural disasters and 3 combined natural and human-induced disasters. FAO identified conflict, weak governance, unsustainable livelihood systems and a break-down of local institutions as the main cause of food insecurity. It is safe to conclude that extreme climatic events, especially drought in the Horn of Africa, exacerbate food insecurity in the region. In the case of Tharaka District, the present study sought to investigate the effect of climate variability, socio-economic factors and institutional capacity on livelihood systems.

2.4 Adaptation to Climate Change and Variability

As observed in Osman-Elasha (2007), Africa is especially vulnerable to climatic changes and variability. This vulnerability is due to the fact that a large share of its economies depends on climate-sensitive sectors (mainly rain-fed agriculture), widespread poverty, poor infrastructure, high illiteracy rates, over-exploitation of natural resources and tribal conflicts. All these factors, in addition to limited institutional and technological capabilities, have contributed to its low adaptive capacity. In spite of the low adaptive capacity of Africa, communities and governments have developed adaptation strategies to cope with climate variability and extreme events. Rural households have been practicing coping strategies and other tactics, especially in places where droughts recur, and have developed their own ways of assessing the prospects for favourable household or village seasonal food production.

Bradley & Grainger (2004) in a study on social resilience in Senegal, observed that the Peul, a pastoralists community, has a higher social resilience, with more flexible decision-making process, greater mobility, a more extensive action space, a reference mode attuned to high anticipation and recognition of stress. They also exhibit more continuous performance–survival switching. On the other hand, the Wolof, mainly croppers, make a radical change from cropping to labour migration and reliance on external support, making them more vulnerable to climatic shocks. Nielsen & Reenberg (2010) explored adaptation strategies by focusing on livelihood diversification in the face of the most recent of recurrent droughts in the Sahel among two communities: Fulbe and Rimaiibe of Burkina Faso. In the study culture is seen to play an important role in the adaptation to climate change. Thus, Rimaiibe have taken advantage of the arrival of development projects, the labour power of women and the wells in the gardens and increased their labour migration in order to better cope with the biophysical uncertainty caused by the most recent Sahelian droughts. The Fulbe on the other hand, are reluctant to embrace these livelihoods diversification on account of personal integrity and worthiness (Nielsen & Reenberg, 2010). What emerges in the Nielsen & Reenberg (2010) and Bradley & Grainger (2004) is that culture, particularly the livelihood system a community engages in, determines its resilience to climatic shock. The present study sought to investigate the livelihood support system in Tharaka. The livelihood support systems will be examined in view of diversification, access to resources (land, information technology, water) and availability of institutions and physical infrastructure.

Tschakert (2007) carried out a study in Senegal where understanding of the vulnerable was at the centre of the analysis. Using a participatory risk ranking and scoring among smallholder farmers, the research characterized the understanding of climate variability and change in the context of multiple livelihood risks. Research findings underline the importance of tackling both climatic and non-climatic conditions in enhancing adaptation. These views are also expressed in Shisanya & Khayesi (2007) who examined the perception of climate change in relation to other socio-economic environmental problems among Nairobi residents. According to Shisanya & Khayesi (2007), residents of Nairobi do not perceive climate change as being a significant problem when compared to corruption, unemployment, crime, garbage and poverty. Misselhorn (2005), in a study on drivers of food insecurity in southern Africa, observes that although climate and environment is a major stressor, solutions to poverty, land tenure and unemployment will go along away to enhancing food production and subsequently adaptive capacity of households. These studies underscore the importance of investigating and providing solutions to non-climatic factors that inhibit adaptation to climate change and variability. The present study sought to investigate how communities perceive climate variability as a problem in relation to other socio-economic factors and evaluate their conceptual understanding of the concept.

Vogel et al. (2007) discussed the importance of science-practitioner communication and the role of regional institutions and policy in addressing vulnerability in southern Africa. These views are also echoed by Crabbe` & Robin (2006) (Ontario- Canada), Vasquez-Leon et al. (2003) (US and Mexico) and Lemos et al. (2002) (in Brazil). In the Great Horn of Africa, ICPAC in partnership with international and national level institutions, regularly generate and disseminate climate forecasts on a seasonal basis through Climate Outlook Forums (COFs). Despite the effort, seasonal climate forecasts are rarely objectively integrated in application models to help the end user decision- making process (Coelho & Costa, 2010; Patt & Gwata, 2002) in spite of recent advances in prediction skill (Hansen, 2005; Goddard et al., 2002) and potential benefits (Hansen 2002) as demonstrated through pilot projects in health, agricultural and water resources applications. Against this background, the present study seeks to establish the extent to which households and institutions factor seasonal forecasts as a tool for enhancing adaptive capacity.

Orindi & Ochieng (2005) discussed seed fair as a drought recovery strategy in semi arid Kenya districts within the Tana Basin. The study considered seed distribution as a strategy to coping with drought and shift from the current approach by government of distributing food relief. Smucker & Wisner (2008) studied how people in Tharaka cope with drought in the face of major macro-level transformations, which include privatization of land ownership, population growth, political decentralization, increased conflict over natural resources and environmental shift. The study shows increased use of drought responses that are incompatible with long-term agrarian livelihoods and calls for a shift in government policy to address the challenges of drought. Wehbe et al. (2005) found that although farmers of the Cordoba Province, Argentina, increased their adaptive capacity through diversification of the agricultural system and a broadened resource base, they remained vulnerable due to unstable income caused by climatic and market impacts. Vasquez-Leon et al. (2003) discussed how economic disparities between two communities in the same biophysical environment can influence the ability to respond to extreme climatic events in Sonora – Mexico and Arizona-USA. The present study considers investigation of the type and number of livelihood options by agro-ecological zones of Tharaka District as an essential in understanding their viability in the context of climate variability.

In agriculture, technological research and development are advocated as strategies for climate adaptation. Over time, technological innovations have provided farmers with the means to respond to climatic limits and possibilities. Smithers & Blay-Palmer (2001) identified two basic types of technological options – mechanical and biological. Mechanical technologies have included irrigation technologies, conservation tillage and integrated drainage system; mostly aimed at delivering the needed water for plants in moisture deficient zones or excess moisture during the growing season. With regard to biological innovation, there has been development of hybrid for many major field crops. Studies by Signh, Ajeigbe, Tarawali, Fernadez-Rivera, Abubakar (2003), Shisanya (2002), Hornetz Shisanya & Gitonga (2001) and Shisanya (1998) have provided insights on adaptation of crop cultivars in semi-arid environment by linking phenology and yield to climate. These studies are particularly important when evaluating the suitability of cropping systems in light of a variable climate. The present study sought to establish current cropping system in semi-arid Tharaka and relate it to annual yield and seasonal rainfall amount.

In conclusion, literature suggests that adaptation to climate change and variability require an understanding of both climatic and non-climatic factors that leave communities vulnerable to climate change. A community's adaptation is determined by cultural factors, institutional capacity, economic status and utilization of technology. But adaptation will also depend on understanding the magnitude of extreme climatic events. Knowledge of within-season characteristics of rainfall patterns, frequency of drought coupled with climate sensitive policies can help buffer households and communities from the vagaries of extreme climate events - issues the present study sought to address.

2.5 Conceptual Framework

Understanding the impact of climate on society and the environment has mostly involved an assessment of bio-physical and social vulnerabilities (Brooks, 2003; Kelly & Adger, 2000). According to Kelly & Adger (2000) vulnerability is defined and addressed in three perspectives: *end* point, *starting* point and *focal* point. Assessment of vulnerability as the *end* point is seen as a sequence of analysis beginning with projection of future emissions trends, moving to climate scenarios (climate change and variability), thence to biophysical impact studies and the identification of adaptive options. Vulnerability as a *starting* point is seen as the capacity to anticipate, cope with, resist and recover from the impact(s) of a natural hazard. In this approach, vulnerability is a characteristic or state generated by environmental and social processes but exacerbated by climate change and variability (O'Brien, Eriksen, Schjolden & Nygaard, 2004). Vulnerability is also seen as an overarching concept, a *focal* point. Implying it is a meeting point of the impact of natural hazards on one hand and socio-economic factors (e.g economic resources, technology, information & skills, institutions and equity) on the other hand.

The present study adopted an integrated approach; arguing that vulnerability assessment should be premised on both biophysical and social vulnerability assessment. Vulnerability is considered in this study as *focal* point; a convergence between climate variability as a biophysical attribute and non-climatic factors as social attribute. For the purpose of this thesis, an understanding of climate variability and non-climatic factors should yield ground for sound vulnerability assessment. The study adopted the prototype conceptual framework of Fussel & Klein (2006), albeit with modification as shown in Fig 2.1.

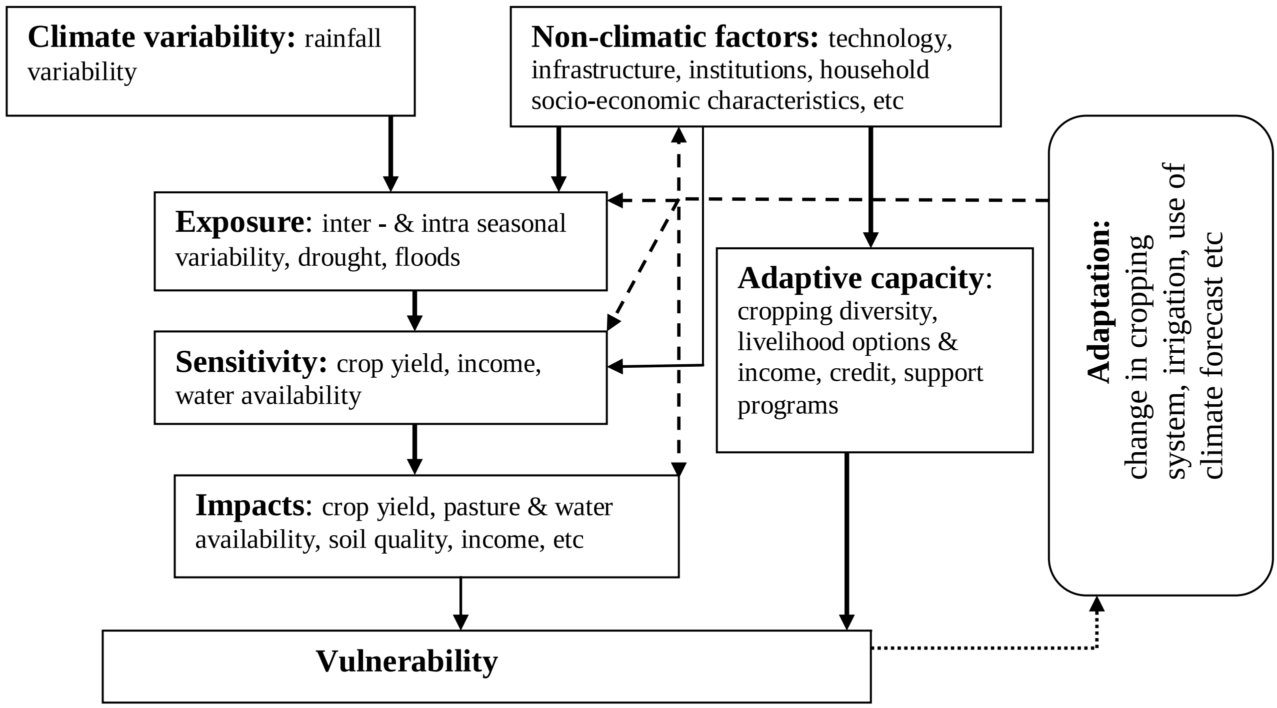


Figure 2.1: Conceptual framework for assessing climate vulnerability

Source: Author and modified after Fussel & Klein, 2006; Deressa et al, 2008

In this study, climate variability (specifically rainfall), a consequence of climate change, is at par with non-climatic factors (households socio-economic characteristics, resources, technology, infrastructure, institutions and information & skills). The two variables determine the degree of exposure of a system to climatic stimuli, affecting sensitivity. The study considers persistence & frequency of droughts, floods and intra & inter-seasonal variability of rainfall as indicators of exposure, while livelihood outcomes (e.g crop yield, income, livestock, water resources) as indicators of sensitivity. Non-climatic factors such as access to information and skills, infrastructure, institutions, socio-economic conditions jointly interact with climate variability to yield total vulnerability of a household, community or a region. Non-climatic factors can also affect sensitivity of a system. For instance, in a farming community characterized by prolonged dry spells within a growing season, a well-of farmer would decide to apply supplementary irrigation, reducing his/her sensitivity.

Potential impacts envisaged are both biophysical (crop yield, water & pasture availability, soil quality and cover) and socio-economic (changes in income and livelihoods). It is important to note that impacts do not cause vulnerability and this is denoted by a relatively thinner arrow from impacts to vulnerability. Vulnerability is caused by multiple factors that go beyond impacts of extreme climatic events. Total vulnerability of the district can be examined in the broader context; not only of the impact of climate variability and non-climate factors, but also of current adaptive capacity. The study envisaged three attributes of adaptive capacity: flexibility, access to resources and stability (Wehbe et al., 2005). Flexibility encompasses diversification of agricultural system, income diversity, and resource endowments. These attributes reflects the capacity of a household or community to continue functioning after the hazard.

Adaptive capacity is also determined by access to resources (access to credit, participation in social & support programs), which are critical to preparing and recovering from climate events. Stability on the other hand includes frequency of both climatic and non-climatic shocks and the degree of uncertainty affecting decision-making. Knowledge of the causes, structure and shape of vulnerability should trigger policy responses for adaptation at the respective administrative units as shown by the dotted line from the Vulnerability box. Community or household adaptation can influence four elements in the conceptual framework as shown by the dashed line. For instance, distribution of drought resistant crops would reduce sensitivity and at the same time reduce the impact of climate variability to a resource limited household (non-climatic factor). Provision of early warning information to a flood prone area would prepare evacuation and reduce exposure.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

This section describes the research design of the study. The section provides details of the study area, variables and categories of analysis, sampling technique and size, tools of research and procedures for data collection and analysis.

3.2 Research Design

Research design generally refers to methods and procedures employed to carry-out scientific research. It is the structure of an enquiry (www.nyu.edu/classes/bkg/methods/005847ch1.pdf). Different types of research design have been widely documented. This study adopts a descriptive approach that will involve analysis of rainfall data, household survey, interviews and FGDs. A description of rainfall variability and state of adaptive capacity are to guide policy formulation at the district level in strengthening adaptation to climate variability in Tharaka District. In using descriptive research, both qualitative and quantitative data were used. Quantitative data used in this study was daily rainfall data and household survey data – with the aim of providing the status of the variables under study. On the other hand, qualitative data (interviews, FGDs and observations) were used with the aim of deepening understanding the variables under study. The specific variables and categories of analysis are presented in Table 3.1. These are presented in tabular, graphical, and numerical methods in describing essential features of the sample population.

Table 3.1: A summary of data requirements, measurable variables and methods of analysis by objective.

Objective	Data required and source	Measurable variables	Method of collection, analysis and tools
1.0 Analyze the characteristics of rainfall variability in the major agro-ecological zones of Tharaka District.	*Requirements:* daily Rainfall *Source:* KMD	- Trends: MAM, OND & annual -monthly rainfall variability --seasonal rainy days & amount - dry spells -onset and cessation	*Collection:* collect data from representative rainfall stations. *Analysis:* Rainfall anomaly index, cumulative departure index, percentage cumulative mean *Tools: Ms Excel,* INSTAT
2.0 Assess the effect of climate variability on water availability in Tharaka District.	*Requirements:* sources, distance covered to fetch water by seasons *Source:* household survey.	-Sources of water, -access to safe drinking water - distance covered by site and season	*Collection*: household survey *Analysis:* descriptive method, X^2 test *Tools:* SPSS, *Ms Excel*
3.0 Determine the perceived impact of climate variability on livelihoods among households in Tharaka District	*Requirements:* identify livelihoods; rank effect of livelihoods. *Source:* literature review, household survey, interview with practitioners	Crop farming, livestock, wage employment, irrigation, forest and non-forest products etc.	*Collection*: literature review, household survey, *Analysis:* descriptive, factor analysis. *Tools:* SPSS, *Ms Excel*
4.0 Assess the conceptual understanding of climate variability in relation to other socio-economic stressors among households	*Requirements*: - rank stressors: deforestation, poor soil, conflict, livestock diseases, lack of pasture, water scarcity, social amenities, drought, employment, agricultural inputs etc - evaluate conceptual understanding of climate change and variability terms *Source:* FGD, literature review	-Rank stressors -Calculate incidence index, severity index, risk index -Community level understanding of terms	*Collection:* Literature review, FGDs *Analysis:* Participatory ranking *Tools:* SPSS, *Ms Excel*
5.0 Assess the availability and use of attributes and indicators of adaptive capacity to climate variability by the local community in Tharaka District.	*Requirements*: <u>Flexibility</u>: diversity of livelihood, water resource, income, resource base <u>stability</u>: degree of variability and exposure <u>resource access:</u> financial, participation in social & support programs *Source:* household data, interviews with devpt agencies and CIGs, FGD	*Diversity of livelihoods*: No. of crops, types of livestock, Diversity of water sources, *Income:* diversity of sources, *Resource base:* water supply & adequacy, soil quality, land tenure, terrain, material equipment *Stability:* impact on production and resource availability & quality. *Resource access:* credit, technology transfer, technical assistance	*Collection:* household survey, interview with practitioners, FGD *Analysis:* descriptive analysis, Tools: SPSS, Ms Excel

3.3 Study Area

Tharaka District is one of the districts found in Eastern Kenya that was established in 1999 together with Meru South as administrative districts. The two districts were curved out of the erstwhile Tharaka Nithi district (Republic of Kenya, 2001a) and today constitute Tharaka Nithi County (Constitution of Kenya, 2010). This study was however limited to Tharaka District which covers an area of 1569.5km^2 and a population of 175, 905 (Republic of Kenya, 2010). Generally, the western part of Tharaka is densely populated than the rest (Republic of Kenya, 2010). This can be attributed to the favourable farming conditions in region. Tharaka District is predominantly inhabited by a Tharaka - a subgroup of the larger Meru ethnic group, which includes the neighbouring highland subgroups of Chuka, Igembe, Igoji, Imenti, Mwimbi and Tigania (Smucker, 2003).

The district has four agro-ecological zones (AEZs), namely; Lower Midland (LM)4, Lower Midland (LM)5, Intermediate Lowland Zone (IL)5 and Intermediate Lowland Zone (IL)6 (Jaetzold et al., 2007). IL5 and LM4 are the main AEZs given their expansiveness in the district, making understanding the link between climate variability and livelihoods & water resources vital. Derived from these AEZs are three main livelihood zones, namely; rain-fed cropping, mixed farming and marginal mixed farming (http://www.aridland.go.ke/bullentins/2011/september/tharaka.pdf). Livestock rearing is the main economic activity. Households keep indigenous breeds of cattle, goats, sheep and chicken. They also practice crop farming where green grams, millet, cow peas, sorghum, pigeon peas, beans and maize are cultivated. Tharaka District comprises of low, hilly and sandy marginal lowlands (Fig. 3.1). The hills in the district have forest covers while the low lands are characterized by bush and shrubs. According to Otuoma (2004), current policies that have ignored pastoral communities and promoted agriculture and the movement of farming communities into Kenyan rangelands have led to a reduction vegetation cover.

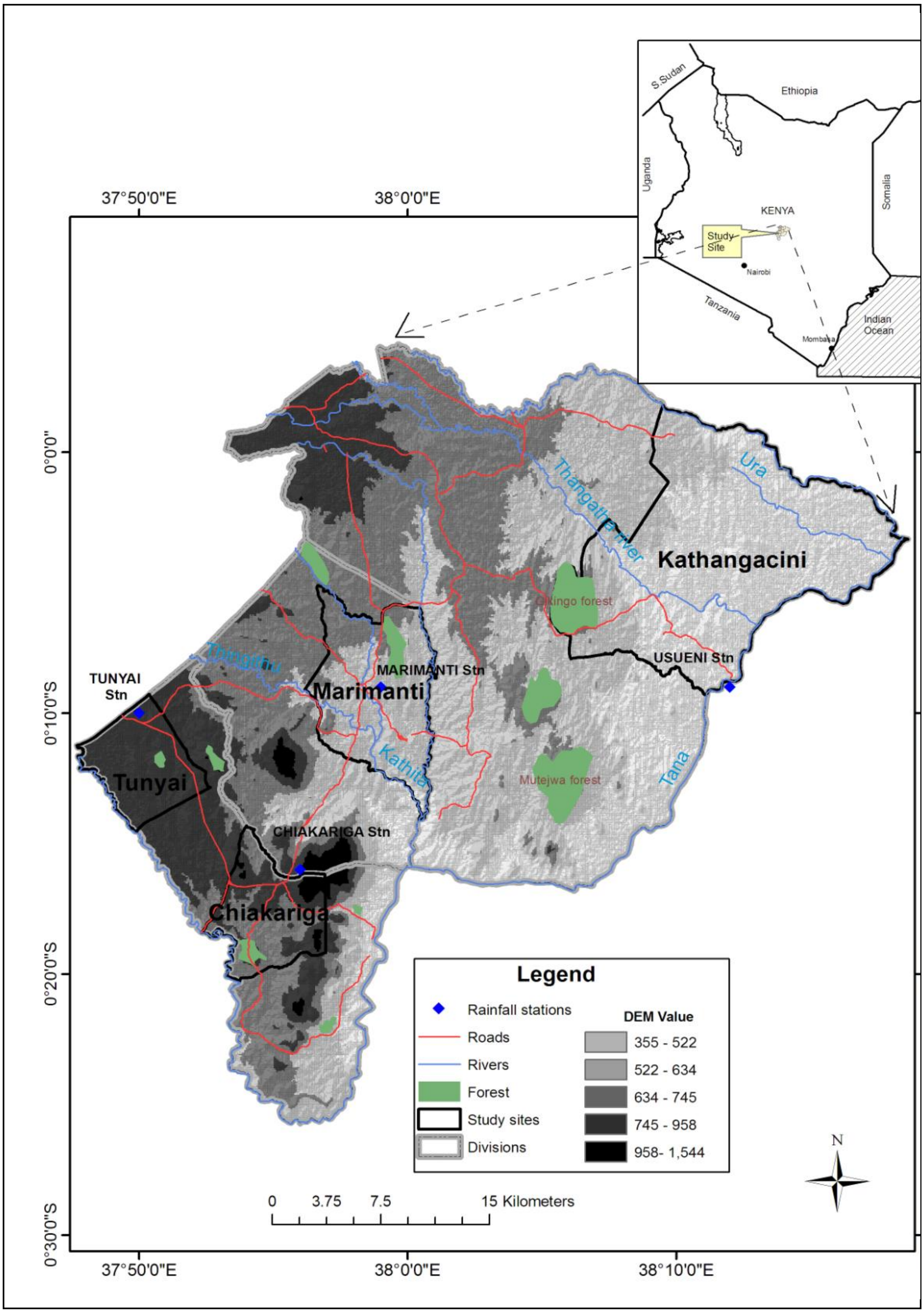


Figure 3.1: Tharaka District: Physiography, study sites and rainfall stations

Source: Author, 2013

Tharaka District is located on the Eastern side of Mount Kenya, a feature that combines with latitude, presence of Inter tropical convergence Zone (ITCZ), ENSO, sea surface temperatures among others (Odingo et al., 2002) to influence rainfall variability. The district is characterized by inland rainfall regime, found at a distance of more than 100km from the coast of Kenya (Shisanya, 1996). Tharaka has a bi-modal rainfall, namely: MAM 'long rains' and OND 'short rains' with March/April and November/December as the main rainy months. A large segment of the population in Eastern Kenya depends on OND rains which are considered reliable and can be predicted with a reasonable degree of accuracy (Cooper, Dimes, Rao, Shapiro, Shiferaw & Twomlow, 2008; Hansen & Indeje, 2004). As a semi-arid district, rainfall is expected to be highly variable, causing wide fluctuations in agricultural production and has profound impacts on the ecology, economy and social welfare of the people.

Tharaka District has a network of many rivers and eight of them are permanent (Republic of Kenya, 2002b). The rivers originate from both Mt. Kenya and Nyambene Hills and traverse eastward as tributaries of river Tana. Some of the main rivers include Mutonga, Thingithu, Kathita, Kithima and Ura Gate (Fig 3.1). Despite the existence of permanent rivers, the district remains food insecure and dependent on rain-fed agriculture. It is possible that the rivers are under-utilized due to socio-economic and institutional factors. The choice of the district was based on an understanding that as a semi-arid area, seasonal variations of rainfall usually undermines the long-term viability of development initiatives. Hence the need to characterize rainfall variability and assess it's impacts on water resources and livelihoods in the district.

3.4 Sampling Techniques and Sample Size

3.4.1 Rainfall Data.

The choice of rainfall stations for this study was informed by agro-ecological zones (Jaetzold et al., 2007) and percentage of missing data (less than 10% for any given year as required by the World Meteorological Organization). Thus, the selected rainfall stations were Marimanti (IL5), Tunyai (LM4) and Chiakariga (LM5) (Fig. 3.1) and each had a data set of over 20 years (Table 3.2). There was no rainfall station in AEZ IL6 within Tharaka District. The only available station was Usueni which was in the neighboring Mwingi District. Although use of Usueni would have been representative of AEZ IL6 in Tharaka, it had 24% of its data missing, making it unsuitable for a climatological analysis.

Table 3.2: Rainfall stations used in the study and status of rainfall data.

No.	**Station ID**	**Rainfall station**	**Data availability (period)**	**Altitude**	**Agro-ecological zone**	**Status of data after observation**
1	9037184	Tunyai	1993-2007	884	LM4	9.2% missing. Used in analysis
2	9037187	Chiakariga	1974-1999	823	LM5	8.6% missing. Used in analysis
3	9037160	Marimanti	1969-1997	587	IL5	9.5% missing. Used in analysis
8	9038020	Usueni	1974-1988	411	IL6	24% missing

Source: Kenya Meteorological Department, 2009

3.4.2 Household, Focus Group Discussion and Practitioners Populations

The study utilized three sets of data, household survey, focus group discussion and interview schedules. This was in an effort to establish the role of socio-economic factors in communities' vulnerability to climate variability. The first category was households drawn from across the four main agro-ecological zones in Tharaka District: LM4, LM5, IL5 and IL6. These represented Tunyai, Chiakariga, Marimanti and

Kathangacini respectively. A total of 326 respondents were interviewed across the four study sites as shown in Table 3.3(also see Fig 3.1). The selection of respondents was informed by household population by sub-location level. This information was acquired from the District Development Officer at Marimanti, the district headquarters. In each study site, 5% of the households were selected for interview which explains the difference in totals in the four sites. Their participation during the interviews was however based on random sampling. Household survey collected information on farm assets, income flows, livelihood activities and access to information.

Table 3.3: Sample population by study sites and gender

Location	***Sub-location***	***Male***	***Female***	***Sub-total***	**Total**
Kathangacini	Kathangacini	27	24	51	58
	Rwanthanju	4	3	7	
Marimanti	Marimanti	20	20	40	92
	Kithigiri	26	26	52	
Tunyai	Tunyai	24	13	37	78
	Tubui	30	11	41	
Chiakariga	Materi	23	6	29	98
	Chiakariga	51	18	69	
Total		**205**	**121**		**326**

Source: Field data, 2009.

The second set of data was collected through focus group discussions (FGDs) which were carried out in four of the study sites (Fig 3.1). From each of the sites, twelve respondents were sampled based on their level of economic status (‘poor’, ‘fair’ and ‘well off’) as classified by the Department of Arid Lands -Marimanti. Thus a total of forty-eight (48) respondents participated in the FGD. The FGDs were carried out with the assistance of Field Monitors working for the Department of Arid Lands who were involved in monthly assessment of households’ livelihood status. The main aim of the FGDs was to collect data that would assist in evaluating the perception of climate change and variability as a stressor in relation to other socio-economic variables.

The third category comprised of officials of institutions with activities in Tharaka District and from diverse areas of interest as shown in Table 3.4. The development agencies targeted for interview were from both the public and private sectors. The target sample population was drawn from Provincial administration, officials of the Ministries of State for Special Programs, Local Government, Water and Irrigation, Agriculture, Livestock, Health and Water Resource Management Authority. Officials of the Ministry of Provincial Administration and Internal Security were targeted at the sub-locational, locational and divisional levels. These included Assistant Chiefs/Chiefs and District Officers. In the private sector, target institutions were the Plan International, the Dioceses of Meru, Christian Children Fund and Ngiuru Gakirwe Water Project. During the reconnaissance, these institutions were found to be facilitating or implementing development programmes in Tharaka District hence reason for their selection. A total of twenty-four official were interviewed; nineteen from the government and the five from private sector. Interviews with the public and the private sectors sought information on current efforts towards enhancing community’s adaptive capacity to climate variability.

Table 3.4: Sample population of institutional respondents used in the study

Field of interest	*Frequency*	*Percent*
Food security	4	16.7
Agriculture	3	12.5
Livestock	1	4.2
Water	3	12.5
Administration	8	33.3
Support programs	3	12.5
Public health	2	8.3
Total	**24**	**100.0**

Source: Field data, 2009

3.5 Research Instruments and Pilot Study

Three research instruments were used to collect data: a questionnaire, interview guide and FGDs guide (Appendix I). All the three tools were pre-tested before administration to the respective target respondents. The questionnaire sought to collect information on socio-economic characteristics which included current adaptive capacity to climate variability. The FGD collected information on perception to climate change and variability in relation to other socio-economic variables. The socio-economic variables envisaged include health, age, lack of money, education, infrastructure, water scarcity, food insecurity among others (Table 3.1). On the other hand, an interview guide collected in-depth interviews with institutions and Community Based Organizations (CBOs) within Tharaka District. The aim of interviews was to assess the role of institutions in enhancing adaptive capacity to climate variability. Besides a questionnaire, FGD guide and interview guide, the study relied on secondary data (literature) to investigate the existing policy or operational framework of these institutions that seeks to address challenges arising from climate variability and determine livelihoods in Tharaka District . A digital camera was further used to document some of the livelihood practices at household level that enhance or/and weaken adaptation to climate variability.

A reconnaissance and pilot study were prerequisites to the study. A reconnaissance was used to identify existing institutions and determine the number of rainfall stations. It also provided an understanding of the administrative unit of the district at the lowest level, the general physiography and communication network of the district. This provided critical information on planning for data collection. The pilot study was useful in the adjustment or clarification of some questions that were not clear.

3.6 Validity and Reliability

Rainfall data for eleven stations in and around Tharaka was acquired from the Kenya Meteorological Department – Nairobi. These data was subjected to scrutiny - to check for missing data as well as errors in the data. The search identified three rainfall stations that were representative of the agro-ecological zones in Tharaka. INSTAT software was used to calculate missing data percentage and therefore determine reliability of data. Thus, only Chiakariga, Tunyai and Marimanti had acceptable data for analysis. This was on the basis of length of period (over 20 years) and percentage of missing data. These stations were also representative of the main agro-ecological zones.

To fill in the missing daily data, the study used multiple imputations which created several copies of the data sets and imputed each copy with different plausible estimates of the missing values. The multiple imputation method was preferred to single imputation and regression imputation methods. According to Ender (2010), multiple imputations do not suffer from the problem of underestimating the sampling error because it appropriately adjusts the standard error for missing data. This is in addition to the fact that it yields complete data set for analysis. The single imputation was found undesirable as it would imply generating a single value for all the missing data and this would significantly alter the coefficient of variance. Although many other studies have recommended regression imputation, its requirement to use complete variables to fill incomplete variables (Ender, 2010) made it difficult in this study given the scant nature of data in the neighbouring stations. In addition, regression imputation was discarded for lack of adequate stations to allow for generation of a regression equation.

3.7 Data Collection

The study utilized four sets of data: daily rainfall data, household survey, focus group discussions and interview schedules. This was in an effort to establish the role of bio-physical and socioeconomic factors in communities' vulnerability to climate variability.

Daily rainfall data was collected for three stations: Tunyai, Marimanti and Chiakariga to represent agro-ecological zones LM4, LM5 and IL5 respectively. Rainfall data was used to analyze trends in rainfall and within-season characteristics, onset and cessation.

Questionnaire administration and interview guides were collected with the assistance of research assistants. The target population sites were Tunyai (LM4), Chiakariga (LM5), Marimanti(IL5) and Kathangacini (IL6) divisions. Research assistants were recruited from the local community with the assistance of the local administration. Household survey aimed at collecting information on socio-economic characteristics, effects of climate variability and current adaptation strategies.

FGDs are exploratory research tool whose purpose is to explore peoples' thoughts and feelings and obtaining detailed information about a particular topic or issue. The purpose of FGD in this study was to generate qualitative and quantitative data that provide information on how communities perceive the problem of climate change and variability in relation to other socio-economic challenges. The results of the FGDs were compared to those generated from household surveys, interview schedules and literature review.

Selection of FGD participants was based on perceived socio-economic status as determined by the Arid Lands Department. FGDs were conducted in four sites, just like household survey: Tunyai, Chiakariga, Marimanti and Kathangacini. After an extensive research, a list of stressors/worries were identified and listed on the FGDs tool. With the assistance of Field Monitors, participants were asked to rank these stressors in order of severity, give reasons for each ranking, and describe strategies undertaken to reduce climate impacts. Participants were also engaged in a discussion to explain their understanding of key terms and concepts in climate change and variability.

The role of both private and public actors in enhancing the adaptive capacity of local communities was assessed through interview schedules and a critique of literature or policies governing their day-to-day activities. Participants in the interview schedule were selected as illustrated in Table 3.4. Photographs were also taken and used to give a visual understanding of climate impacts and household's adaptive capacity to climate variability.

3.8 Data Analysis and Tools.

Data analysis was guided by the objectives and hypotheses of the study as described below.

3.8.1 Rainfall Data

To determine the significance of rainfall variability, daily rainfall data was used. There was no need for entering daily rainfall data, since the data was acquired in digital form. However, the dataset was organized into months to yield analysis of seasonal variation. Parameter analyzed using rainfall data were annual and seasonal rainfall variability, monthly rainfall distribution, estimation of onset and cessation of seasonal rainfall and dry spells. Analysis of these variables yields an understanding of the character of rainfall variability in each of the AEZs.

To characterize seasonal rainfall variability in Tharaka, rainfall amount, number of rain days and dates of onset & cessation were analyzed for both MAM and OND growing seasons. Cumulative departure index and rainfall anomaly index (RAI) were used to analyze long-term trends of annual and seasonal variability (Tilahun, 2006). Cumulative departure index was derived from normalized rainfall values and was plotted to achieve long term trends for annual and seasonal rainfall. Cumulative departure index was derived from the arithmetic mean of seasonal and annual rainfall for the period of record. Thus the arithmetic means of seasonal and annual rainfall were normalized as follows:

$$(r- R)/ S \tag{1}$$

Where r is the actual rainfall (seasonal) of a given year,

R is the mean rainfall of the total length of period,

S is the standard deviation of the total length of period.

Results of the values were cumulatively added to each other for the period of record and plotted to achieve long-term trends of annual and seasonal rainfall. RAI was plotted to illustrate inter-seasonal rainfall variations and calculated as follows for positive anomalies:

$$RAI = +3 \left(\frac{RF - M_{RF}}{M_{H10} - M_{RF}} \right) \tag{2}$$

and for negative anomalies

$$RAI = -3 \left(\frac{RF - M_{RF}}{M_{L10} - M_{RF}} \right) \tag{3}$$

Where:

RAI is seasonal Rainfall Anomaly Index,

RF is the actual rainfall for a given year,

M_{RF} is mean of the total length of record,

M_{H10} is mean of the 10 highest values of rainfall on record,

M_{L10} is the 10 lowest values of rainfall on record.

According to van Rooy (1965), RAI is a very effective index for detecting persistence of drought periods (as cited in Tilahun, 2006). Whereas Tilahun (2006) used RAI to analyze annual rainfall variability, the present study analyzed seasonal rainfall variability. *INSTAT* software, designed to support analysis of climatic data (www.ssc.rdg.ac.uk/software/**instat/climatic**.pdf), was used to calculate mean rainfall for every five days (pentads) starting from the first to the last day of the two seasons. Analysis of rainfall by pentads helped in detecting the distribution of rainfall amount within seasons.

A coefficient of variation (CV), defined as the ratio of standard deviation to the mean, was calculated for rainfall amount and rain days for each station. Coefficient of variation for annual rainfall was used by Mzezewa et al. (2010), Shisanya (1990) and Sivakumar (1987); while Barron et al. (2003) and Seleshi & Zanke (2004) used it for seasonal rainfall. A paired sample *t-test* was used to test the significant difference of means (at the significant probability level of 0.05) of OND and MAM seasons for each of the three stations. The premise to use *t-test* hinged on understanding that the sample population (rainfall data) was drawn from different environment (seasons) (Shaw & Wheeler, 1985).

Mean onset and cessation dates of seasonal rainfall was estimated using percentage cumulative mean rainfall approach as described by Odekunle (2006). In using the percentage mean cumulative rainfall approach, the first step was to derive the mean seasonal rainfall amount and mean rain days that occur during each 5-day interval (pentad) of the season using *INSTAT*. Thus, pentads were calculated for the period 1st March to May 31 and October 1 to December 31 (January 31 in the estimation of cessation) for MAM and OND respectively. This was followed by computing the percentage of the mean seasonal rainfall amount and rain days for each of the pentads. The third step involved cumulating the percentages of the pentad rainfall amount and rain days. The cumulative percentages (of pentads' rainfall amount and rain days) were plotted against time for each season. When the cumulative percentage is plotted against time through the season, first point of maximum positive curvature of the graph corresponds to the time of rainfall onset, while the last point of maximum negative curvature corresponds to the rainfall cessation. Percentage cumulative means for rainfall amount and rain days are expected to converge to give the same mean dates of onset and cessation. *INSTAT* was used to determine inter-annual variability of onset and cessation for comparison with mean. A significant departure in the use of percentage mean cumulative rainfall is that while Odekunle (2006) plotted the percentage cumulative mean against time through the year, the present study plotted it against time through the two seasons. In this case the first day of MAM and OND seasons were considered as March 1st and October 1st respectively. The last day of MAM season is May 31st while the last day of ONDJ season is considered January 31. Even though most of the rain is received during the OND season, there is usually a spillover effect into January (Shisanya, 1996), meriting the inclusion of January in the determination of cessation dates.

The results of the percentage mean cumulative rainfall were complimented by computing *INSTAT* generated dates of onset and cessation. The threshold for a rain day was put at 0.85mm as defined by the Kenya Meteorological Department (Shisanya, 1996). This threshold was also adopted by Odekunle (2006) in a study of rain season onset and retreat in Nigeria. Onset of growing period has been defined differently in such studies as Marteau, Sultan, Moron, Alhassane, Baron & Traore (2011), Dodd & Jolliffe (2001), Omotosho, Balogun & Ogunjobi (2000), Sivakumar (1988). The present study adopted and modified the onset criteria by Sivakumar (1988). Thus, onset was defined as the day after March 1 and October 1 that received at least 20mm of rainfall totaled over two days with a dry spell not exceeding seven days in thirty days. The considered date of onset is informed by the general understanding that MAM and OND rains start in March and October respectively and that seeds for cereals take approximately seven days to germinate. In addition, sowing by most farmers in arid areas mostly take place during and just after a two-day wet spell receiving at least 10mm (Marteau et al., 2011). Similarly, cessation has been defined differently (Tadross et al., 2009; Kasei & Afuakwa 1991). In this study, cessation was defined as the date after May 1st and December 1st for MAM and OND respectively when the soil water supply becomes null and after which no rain falls for the next 10 days. The soil water holding capacity was fixed at 60mm. In this study, a dry spell was considered as a dry day (with <0.85mm) which occur after onset of a rainy season. A dry spell was estimated within the first 31 days after onset. This is because sowing usually start after onset and therefore a prolonged dry spell in the first 30 day implies crop failure.

To test the difference between means of the two seasons- MAM and OND, *t*-test was used as outlined in Shaw & Wheeler, 1985) using the equation:

$$t = \frac{\bar{x}1 - \bar{x}2}{\sigma d} \qquad (4)$$

Where;

t= t-test,

$\bar{x}_1$ and $\bar{x}_2$ refer to mean rainfall of MAM and OND respectively.

σd^2 refer to variance of the difference between the two means of MAM & OND.

The variance of the two means is calculated as;

$$\sigma_d{}^2 = \frac{\sigma_1{}^2}{n_1} + \frac{\sigma_2{}^2}{n_2} \qquad (5)$$

Where:

σd^2 is the variance of the difference between the means of MAM & OND,

$\sigma_1{}^2$ is the variance of MAM,

$\sigma_2{}^2$ is the variance of OND,

n_1 and n_2 are total number of years on record for MAM & OND respectively.

The standard error, σd is then calculated by finding the square root of σd^2. The null hypothesis, H_0 states there is no difference between MAM and OND was tested at the significance level p= 0.05. In using *t*-test, if the calculated *t*-value exceeds the tabulated (critical) value then the means are significantly different at the level of probability.

For both datasets, F-test was used to test homogeneity of data. Tool of analysis for rainfall data was INSTAT version 3.36 (Stern & Knock, 1998); while *MS Excel* was used in the analyses of central measures of tendency and presentation of results.

3.8.2 Household Survey, Focus Group Discussion and Interview Schedules Data

Household survey data sought information on household assets, income flow, effects of climate variability on livelihoods & water, and state adaptive capacity in Tharaka District. Households' intervention strategies were examined and among the variables analyzed were flexibility, stability and access to resources and information.

Households' access to water was examined and this included sources of water and distance from water points. On assumption that rainfall varies by agro-ecological zones, the study correlated the main source of water and return distance from the main source of water. In addition, a chi-square test was used to test a significant association in the rating of satisfaction levels of accessibility to water during the dry and wet season. Respondents were asked to state the level of satisfaction in accessing water during the dry and wet seasons. These results were then computed and their significance tested using chi-square. Chi-square is a non-parametric test used to test the independence of attributes. To apply chi-square, requirements were observed as discussed by Shaw & Wheeler (1985) and Kothari (1996).

Calculated chi-square, X^2, was attained by the formula:

$$X^2 = \sum \frac{(O-E)^2}{E} \quad (6)$$

Where X^2 is chi-square, Σ is summation,

O is observed frequency,

E is expected frequency.

The calculated X^2 is then compared with the critical table X^2 at the required degree of freedom (d.f) and probability. If the calculated X^2 is less than the critical table value at a given level of significance (in this case 5%) for a given degree of freedom, it is concluded that the null hypothesis, H_0, is true and therefore no difference between the variables. But if the calculated table chi-square value is greater than the tabular X^2

value, its then concluded that the H_0 does not hold, giving way to acceptance of the alternative hypothesis, H_1, and a confirmation that there exist a difference between the variables under investigation. Besides satisfaction levels to access to water, X^2 was used to test satisfaction levels of social amenities such as health facilities, market centres, administrative centres and educational institutions and rating of seasonal climate forecast.

Factor analysis was used to detect any underlying structure in the identified rainfall variability impacts on identified livelihoods and resources. A total of twenty-five perceived impacts of climate variability were listed and respondents asked to rate the severity of rainfall variability on each of them. These impacts were then awarded severity scores as most severe (7), moderately severe (4) and not severe (1). Using the principal component analysis (rotated method, varimax), the variables were reduced to identify any underlying structure in the way respondents perceived the impact of climate variability. There are two methods of selecting relevant factors based on the eigenvalue: the Kaiser criterion and scree test as put forward by Kaiser (1960) and Cattel (1966) respectively (http://www.statsoft.com/textbook/principal-components-factor-analysis/). This study utilized the Kaiser criterion where factors with eigenvalue greater than 1 were retained. In each factor, variables with high loading (of a correlation matrix > 0.5) were identified and their similarity established before a name (for the factor) was assigned. Statistical Package for Social Scientists – SPPS version 11.5 was used. In addition, a descriptive analysis of these impacts was done and presented. Application of factor analysis has been used by Shisanya & Khayesi (2007) to assess how climate change is perceived in relation to other socio-economic and environmental threats.

Using a participatory risk ranking and scoring method (Tschakert 2007; Quinn, Huby, Kiwasila & Lovett, 2003) data from the FGDs was used to rank stressors at an individual and community level. The data was also used to evaluate how community members perceived the term climate change and variability. The procedure to rank stressors was carried out as discussed in Tschakert (2007). However, there were differences in sampling procedure and composition between Tschakert (2007) and the present study. In this study, the sample population consisted of household representatives only while Tschakert (2007) included extension officers. Instead, practitioners were asked separately to identify constraints in resource exploitation in Tharaka. In terms of procedure, the present study utilized Field Monitors who assisted illiterate respondents to rank stressors. This is unlike Tschakert (2007) who used pebbles in assisting respondents to rank stressors. Data collected from the FGDs' participatory ranking was used to calculate incidence index (I), risk index (R) and severity index (S) of stressors as discussed in Quinn et al. (2003). Incidence index (I) was calculated as the measure of proportion of respondents identifying each particular stressor. Thus;

$$I = s/T \qquad (7)$$

Where:

s was the total number of respondents who mentioned a stressor,

T is the total number of respondents in the FGD.

The severity index measured the severity of risk of each problem on a scale from 1 (most severe) to 2 (least severe). Severity index (S) was calculated using the equation:

$$S_j = 1+(r-1)/ (n-1) \qquad (8)$$

Where:

S_j is the severity index value of a problem,

r is its rank based on the order in which it was mentioned by the respondent,

n is the total number of problems identified by that respondent.

Lastly, for each problem, a risk index (R) was calculated to indicate the most acute risk and was calculated as:

$$R_j = I_j/S_j \qquad (9)$$

Where:

I_j is the incidence index,

S_j is the severity index calculated above.

Risk index ranges from 0 to 1. It is instructive to note that higher values for I_j indicate higher incidences and lower values for S_j indicate more severity. Thus R_j increases with the overall risk associated with each type of problem.

Household survey data and parts of the FGDs and interview schedule data were coded, entered and analyzed using the Statistical Package for Social Scientists (SPSS). The incidence index was calculated by running a frequency table (in SPSS) to determine the total number of respondents who mentioned a particularly stressor. S and R values for each respondent were computed using the above equations in the SPSS software. Thereafter, the risk incidence index was plotted against the severity to produce a risk map. For most part, many other variables were analyzed and presented as frequencies, crosstabulation and means.

CHAPTER FOUR

4.0 CHARACTERIZATION OF RAINFALL VARIABILITY AND ACCESS TO WATER IN THARAKA DISTRICT

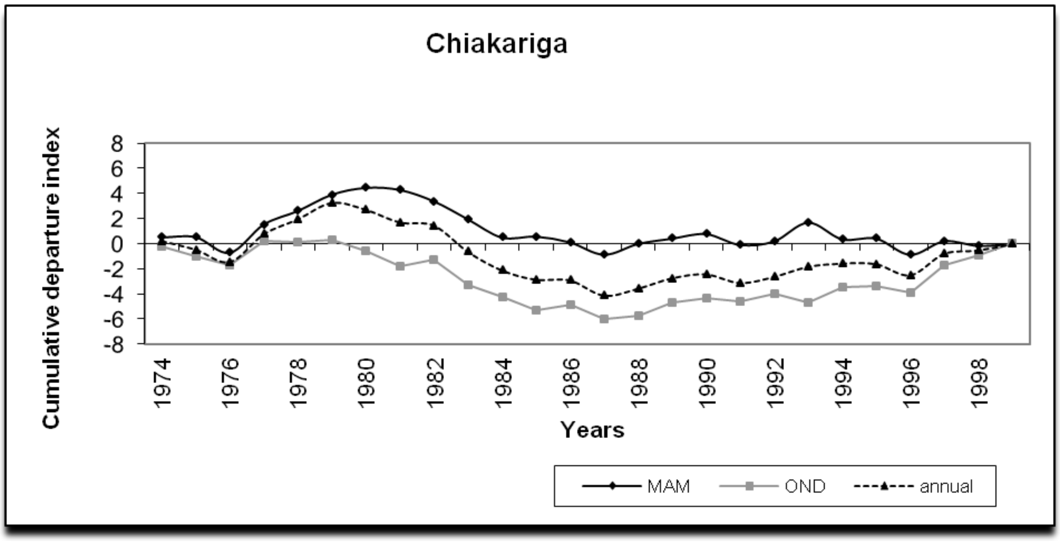
4.1 Introduction

This chapter presents results and discussion of quantified rainfall variability and access to water. In the first part, results and discussion of trends in seasonal rainfall variability, seasonal rainfall amount, within-season distribution of rainfall, dry spells, onset and cessation are presented. In the second part, results and discussion of water sources, distance covered and institutional capacity are presented.

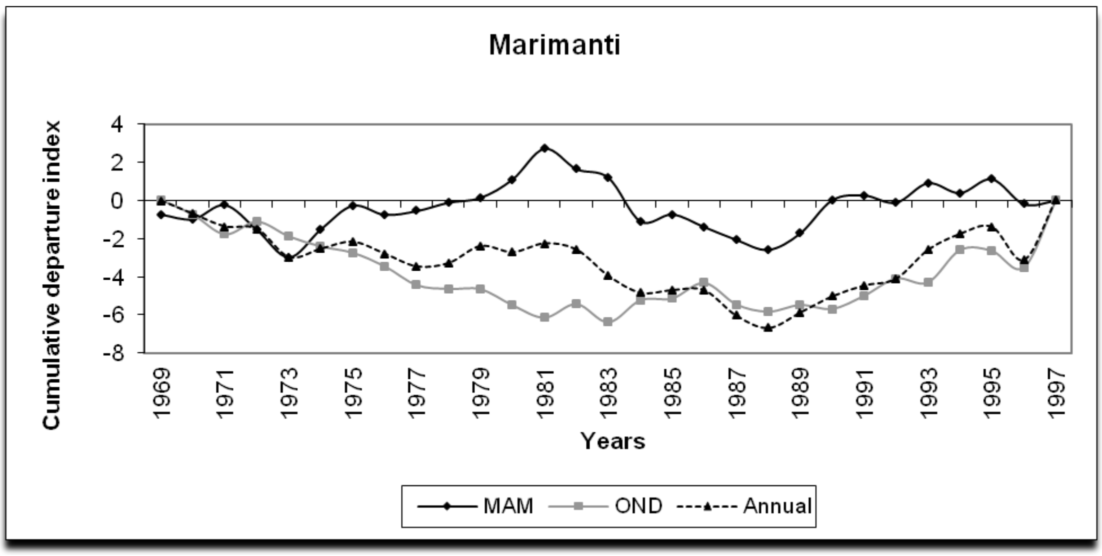
4.2 Characterization of Rainfall Variability

4.2.1 Trend Analysis of Annual and Seasonal Rainfall

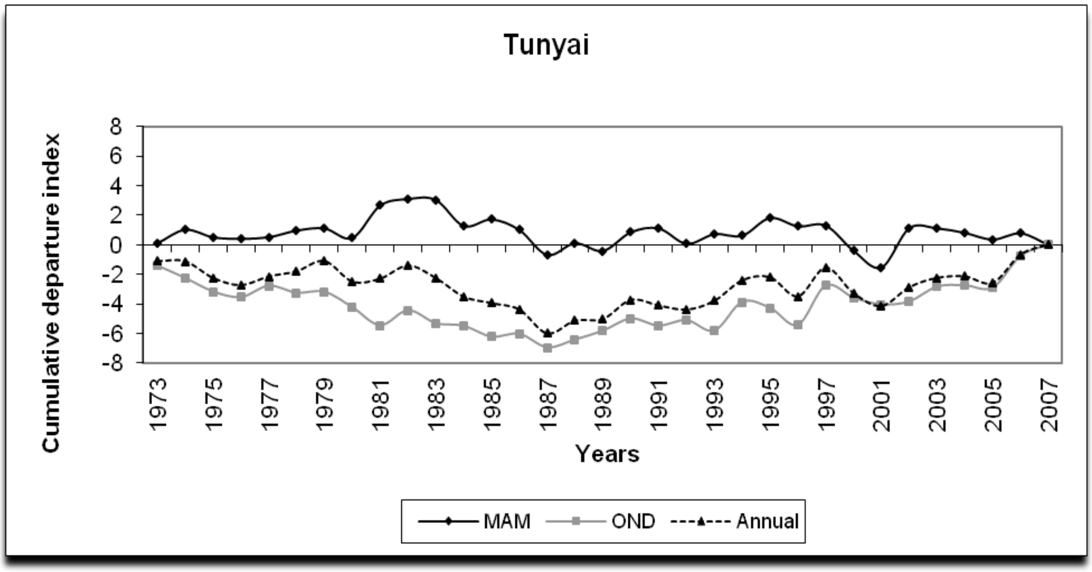
The upward and downward movement of the cumulative departure index graphs corresponds respectively to above and below average rainfall (Fig 4.1a-4.1c). At Chiakariga, the period 1974-1976 experienced near average rainfall (for annual, MAM & OND) while the period 1977-1983 had above average MAM and annual rainfall but with a decreasing trend. The 1980s and 1990s experienced near average MAM rainfall and below average OND and annual rainfall. During the 1970s, Marimanti received below average rainfall in all seasons. At Tunyai during the same period, MAM rainfall was nearly average but OND and annual rainfall assumed a trend of below average – just like Marimanti. The findings illustrate that the 1970s desiccation of annual rainfall established by Dai, Lamb, Trenberth, Hulme, Jones & Xie (2004), Hulme (2001) and Nicholson (1993) in Sahelian region also affected parts of the Great Horn of Africa. The desiccation could be attributed to a decrease in OND rainfall since MAM rainfall varied minimally from the mean during the 1970s. At Chiakariga and Tunyai, MAM rainfall ranged from average to above average over the period of study. This was unlike the MAM pattern at Marimanti which had periods of above average (1980-1983), average (1990-1997) and below average (1969-1977, 1984-1989). On the other hand, the periods 1970s and 1980s show OND rainfall with a declining trend across the three stations, an almost similar pattern as annual rainfall. But the 1990s show OND and annual rainfall with an increasing trend towards normal rainfall.



(a)



(b)



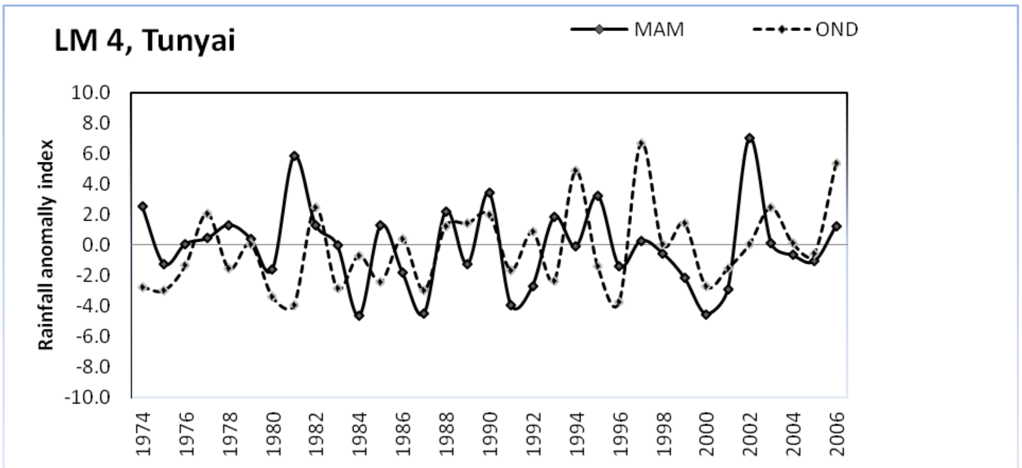
(c)

Figure 4.1 Cumulative departure index time-series plot of annual, MAM and OND from the mean rainfall at (a) Chiakariga, (b) Marimanti and (c) Tunyai

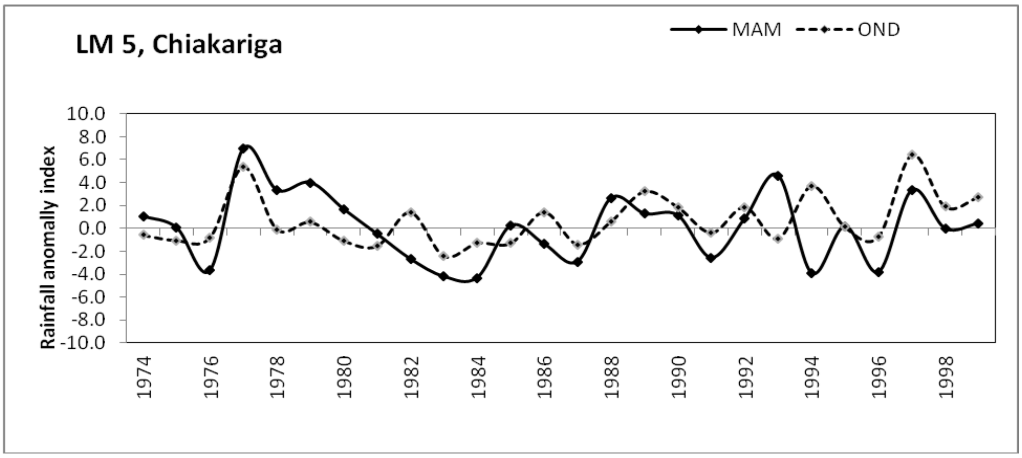
The rainfall trend established in Tharaka District is similar to the findings of Tilahun (2006), Anyamba & Tucker (2005) and Ovuka & Lindqvist (2000). For instance, Ovuka & Lindqvist (2000) observed a decreasing annual rainfall trend for the period 1963-1976 in Murang'a, District, Central Kenya. Using cumulative departure index, Tilahun (2006) illustrated that parts of Central and Northern Ethiopia persistently received below average rainfall for the period 1970-1995 and 1975-1990 respectively. The pattern observed between OND and annual rainfall suggests that OND rainfall is a significant determinant of annual rainfall variability in Tharaka District. The below normal rainfall trend of OND rainfall is a cause for concern as it signals a reduction in rainfall amount over the years. Hansen & Indeje (2004) and Amissah-Arthur et al. (2002) allude that OND rainfall constitute the main growing season in Eastern Kenya on which annual crops such as maize, sorghum, green grams and finger millet are dependent. Thus, its decline has implications on agricultural production (cropping systems) and related livelihoods. Smucker & Winser (2008) noted a substantial decline in crop productivity in Tharaka District and have attributed this to land degradation and erratic rainfall. Trends of below normal rainfall for OND, the main growing season, call for an evaluation of the current cropping system (crop cultivars) to determine their viability in the current rainfall pattern.

In the analysis of Sahelian vegetation dynamics using normalized difference vegetation index (NDVI), Anyamba & Tucker (2005) established that 1982-1993 was characterized by below average NDVI and persistent drought; and the period 1994-2003 was marked by a trend towards wetter conditions. Dai et al. (2004) echoed similar sentiment in which they observed that Sahel rainfall had recovered by 2003. In this study, results of cumulative departure index suggest that OND and annual rainfall in Tharaka is recovering. A clearer picture however can be given if data up-to the most recent period is analyzed.

Fig 4.2a-c shows patterns of inter-seasonal rainfall variability in Tunyai, Marimanti and Chiakariga. During the MAM season, the highest positive anomalies were recorded at Tunyai (+7.0) in the year 2002 and Chiakariga (+7.0) in 1977. At Marimanti, 1990 was the wettest year with a positive anomaly of +5.0. 1984 recorded the highest negative anomaly during the MAM season across the three stations: Marimanti- -6.6, Tunyai- -4.6 and Chiakariga- -4.3. For the study period, 1997 recorded the highest positive anomalies for OND at all stations: Marimanti- +9.1, Tunyai- +6.7 and Chiakariga- +6.4. OND recorded the highest negative anomalies of -3.9 (Tunyai), -4.0 (Marimanti) and -2.4 (Chiakariga). The three stations have a commonality in 1984 and 1997. The year 1984 recorded the driest MAM season and 1997 the wettest OND season.



(a)



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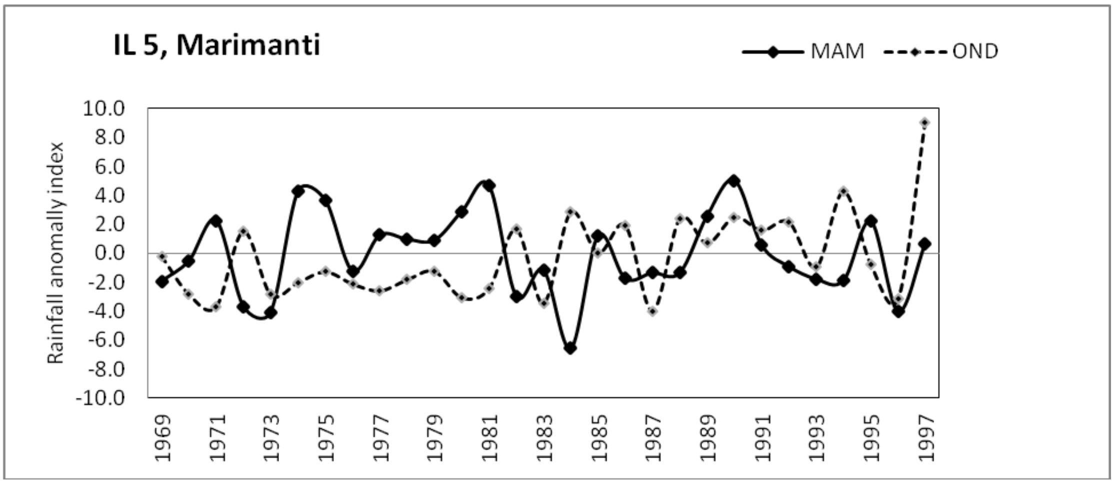


(c)

Figure 4.2 A time series of seasonal rainfall anomaly index at (a) Tunyai, (b) Chiakariga and (c) Marimanti stations in Tharaka District, Kenya.

The 1984 drought, caused by widespread failure of the MAM rains is documented (Hutchison 1996; Shisanya 1990; Cohen & Lewis 1987). During this period, the Republic of Kenya recorded low production of staple cereals prompting the then President of Kenya to launch a National Food Relief Fund among other responses (Shisanya, 1990). In fact, at Tunyai and Chiakariga, the year 1984 experienced failure of both the MAM and OND rains. Shisanya (1990) argues that the La Niña event of 1982-1984 might have contributed significantly to the drought which affected the whole country. The high positive anomalies of 1997 OND rainfall is attributed to the 1997/98 El Niño rains that characterized the OND season in Eastern Africa (Amissah et al., 2002; Anyamba, Tucker & Eastman, 2001).

Observation of MAM and OND inter-annual rainfall variability show that the latter's deviation from mean is greater. The results of cumulative departure index and rainfall anomaly index highlight the inter-annual and inter-decadal rainfall variability that characterizes sub-Saharan climatology. Inter-annual variability of seasonal rains results from complex interactions of forced and free atmospheric variations. Mutai et al. (1998) observed that OND variability is stronger than MAM while Phillips & McIntyre (2000) observed that the low inter-annual variability of MAM rainfall in East Africa can be attributed to its insignificant relationship with ENSO. ENSO is the most dominant perturbation responsible for inter-annual climate variability, especially OND over eastern and southern Africa. Studies by Ogallo (1988), Farmer (1988), Phillips & McIntyre (2000) and Hutchinson (1990) have found OND rainfall to be in phase with ENSO.

In general, seasonal rainfall in Tharaka District varies a lot around the mean, with occasions of subsequent below average rainfall. Persistence of below normal rainfall risk peoples livelihood and majority in Tharaka are left vulnerable to hunger and famine. As a result, farmers have learnt to farm in ways that partially adjusts to such variations by making adjustments in labour requirements, dig ridges to trap water, and plant & replant due to 'false' start of season with a view of reducing their risk (Wisner, 1977). Whether these adjustments are still viable in the current climate pattern is a matter that needs to be investigated.

4.2.2 Within-season Characteristics of Seasonal rainfall

Tharaka District is largely a semi-arid area which receives less than 1200mm of annual rainfall. Chiakariga, Marimanti and Tunyai stations receive 950mm, 805mm and 1138mm of annual rainfall respectively. Seasonal rainfall accounts for over 90% of the annual rainfall and OND season receives more rain than MAM season except at Marimanti (Table 4.1). In a related study, Mzezewa et al. (2010) found that in Ecotope – South Africa, 80% of annual rainfall is usually received between October and March. The emerging point in Mzezewa et al. (2010) and the current study is that a comparatively small proportion of rain days supplies most of the annual rainfall. Since rainfall in sub-Saharan Africa is largely seasonal, it is therefore important that a meaningful analysis of the impact of rainfall on crop yield be based on seasonal and not annual rainfall. In Tharaka therefore, analysis of rainfall impact on such crops as maize, millets, green grams, and sorghum (Smucker & Wisner 2008) should be based on MAM and OND growing seasons and not annual rainfall to avoid the high covariance arising from the dry spell periods during the year.

Table 4.1 Rainfall amount (mm) and coefficient of variation (CV) (%) for annual, MAM and OND seasons in the selected stations

Station	**MAM**				**OND**			
	Rain (mm)	CV	Rain days	CV	Rain (mm)	CV	Rain days	CV
Chiakariga	409	0.34	19	0.39	527	0.41	27	0.48
Marimanti	408	0.33	22	0.35	386	0.43	26	0.33
Tunyai	503	0.34	28	0.27	606	0.44	36	0.31

Source: Field data, 2009

Agro-ecological zone LM4 (Tunyai) is the wettest with an average of 503mm and 606mm of rainfall, and 28 and 36 rain days during MAM and OND rainfall respectively. During MAM season, Chiakariga (LM5) and Marimanti (IL5) receive nearly the same amount of rainfall. During the OND season, Chiakariga receive 527mm while Marimanti receive 386mm. Despite the remarkable difference in rainfall amount during OND, the difference in the number of rain days is one day, suggesting that the distribution and amount received per day at Chiakariga is better than at Marimanti. The relatively higher rainfall amount and rain days at Tunyai suggest the agro-ecological zone can support crop varieties with relatively longer growing period than at Marimanti and Chiakariga. Nonetheless, support for crop development is subject to within-season rainfall characteristics and soil's water retention capacity. Compared to others seasons such as the ones in Sahelian and Guinean region (Sivakumar, 1987; Kasei & Afuakwa, 1991), Southern Africa (Tadross et al., 2009) or even Eastern Africa for March-September (Shisanya, 1996; Phillips & McIntyre, 2000), the two rainfall seasons in Tharaka District have a short growing period. In neighbouring Ethiopia, Araya & Stoosnijder (2011) established that short growing periods were among the causes of crop failure. This makes breeding of short season crops and development of drought mitigation strategies such as supplementary irrigation and rainwater harvesting important in Tharaka.

Results of coefficient of variation (CV) for seasonal rainfall (amount and rain days) show that both OND and MAM have a CV exceeding 0.30. According to Araya & Stroosnijder (2011), a CV> 30% is an indicator of large rainfall variability. When the CV of rainfall amount is compared to that of rain days, it is observed that rain days have higher CV values than rainfall amount. Analysis of seasonal rainfall shows that Chiakariga (LM5) and Tunyai (LM4) receive more rainfall during OND than MAM. Marimanti on the other hand receives slightly more rainfall during MAM than OND season. A paired sample *t*-test was used to test the significant difference of means (at the probability level of 0.05) of OND and MAM seasons. The *t*-test results show that the difference between MAM and OND at Chiakariga (t-value = 2.3) to be significant, implying the two seasons are markedly different and farmers need to adopt different cropping system and farm management strategies. At Marimanti (IL5) (t-value = 0.54) and Tunyai (LM4) (t-value = 1.88) however, it would appear that variations in rainfall amount of the two seasons is not significant. Despite *t*-test results showing that MAM & OND are not significantly different at Tunyai, the relatively high difference in rainfall amount and rain days; and the proximity of calculated *t-value* (1.88) and tabulated *t-value* (1.96) may qualify OND rainfall to be more useful for crop farming than MAM. Studies by Barron et al. (2003) and Amissah-Arthur et al. (2002) demonstrate that parts of Eastern Kenya receive more OND than MAM rainfall amount. With the perception that OND is the main season, it is possible that farmers in Tharaka reduce area under farming and number of cultivars during MAM. Such a decision implies a missed opportunity for farmers in agro-ecological zone IL5 (Marimanti) who may benefit from MAM just as much as they would for OND. An assessment of the two seasons needs to consider within-season distribution and the contribution of each season to yield in each of the agro-ecological zones.

Table 4.2 shows the distribution of monthly rainfall amount and rain days in the three sites of study. Nearly one fourth of the total rainfall in the three stations is received during the onset months (March and October). Although April and November are the wettest months of the two seasons, their contribution to the seasonal rainfall varies for their respective seasons.

Table 4.2: Monthly rainfall amount (RA) and rain days (RD) and their respective coefficient of variations (CV) by station

Station		Mar	Apr	May	Oct	Nov	Dec
Chiakariga	RA(mm)	101	255	52	127	260	134
	RA-CV	0.76	0.40	1.18	0.73	0.55	0.69
	RD	5	11	3	7	13	7
	RD-CV	0.81	0.42	0.65	0.72	0.45	0.81
Marimanti	RA(mm)	80	262	66	78	217	106
	RA-CV	0.83	0.42	0.76	0.83	0.39	0.73
	RD	5	11	6	6	13	7
	RD-CV	0.94	0.43	0.70	0.83	0.40	0.45
Tunyai	RA(mm)	126	293	83	148	324	134
	RA-CV	0.74	0.38	0.70	0.73	0.45	0.63
	RD	7	14	7	9	17	10
	RD-CV	0.68	0.30	0.57	0.47	0.28	0.55

Source: Field data, 2009

Thus, rainfall received in April accounts for nearly 60% of the total MAM rainfall while November rainfall accounts for about 50% of the total OND rainfall in the three stations (Table 4.3). May, the cessation month of MAM rainfall, accounts for less than 20% of the total rainfall while December, the cessation month of OND rainfall, accounts for about 25% of the total rainfall. Another notable feature about MAM rainfall is that in April, more rainfall is received in less days and this difference is largest in Marimanti and Tunyai (Table 4.2 & Table 4.3). In November however, the difference between rainfall amount and rain days is less. The results imply that OND rainfall amount and rain days are fairly spread through the season, potentially reducing the impact of within-season variability. The rainfall received in May is little and might not be sufficient to buffer crops from agricultural drought, especially in Tharaka where soils are predominantly sandy-loam and shallow (Jaetzold, Schmidt, Hornetz & Shisanya, 2007). A planting date is important, especially during the MAM season. It is important that sowing takes place prior to or upon onset, failure to which a significant amount of rainfall will be missed and therefore affect crop performance.

Table 4.3: Percentage rainfall distribution for March – May (MAM) and October – December (OND) seasons (derived from averages of data on record).

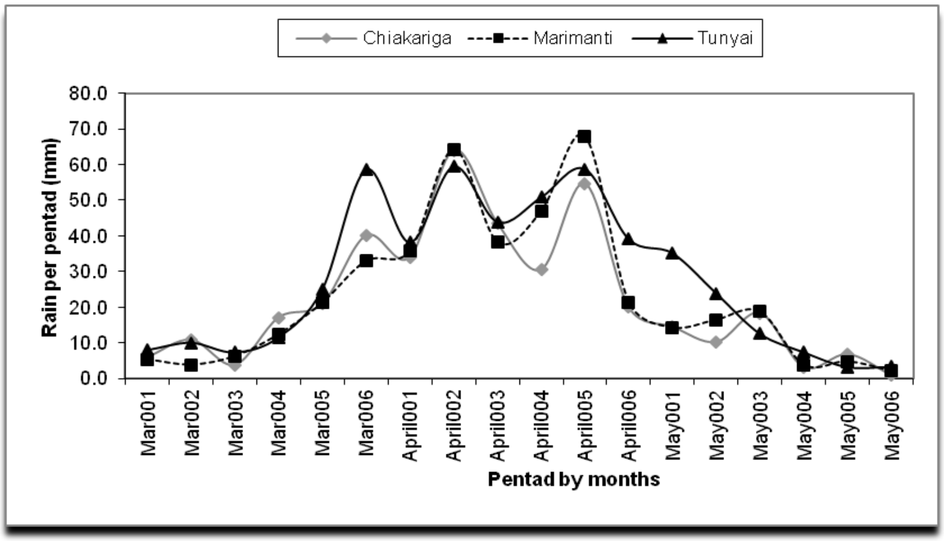
Site	Rainfall % by months					
	MAM season			***OND season***		
	March	**April**	**May**	**October**	**November**	**December**
	Rainfall amount					
Chiakariga	25	63	13	24	50	26
Marimanti	20	64	16	19	54	26
Tunyai	25	58	17	24	53	22
	Rain days					
Chiakariga	26	58	16	25	54	21
Marimanti	23	50	27	23	50	27
Tunyai	25	50	25	25	47	28

Source: Field data, 2009

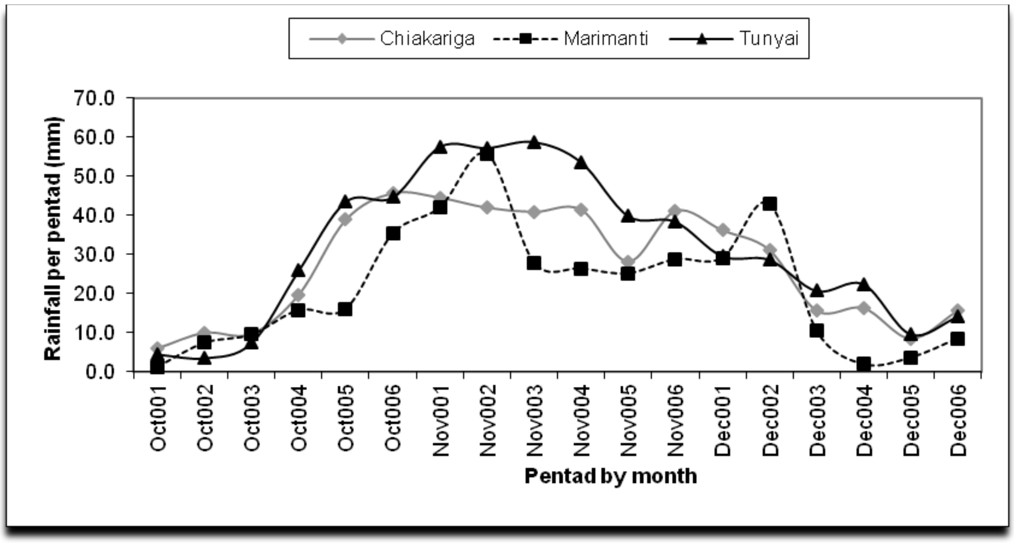
Analysis of rain days by months shows that the first and last months (of both seasons) are characterized by high CV for rainfall amount and rain days. Similar findings are reported in Sivakumar (1987) in which onset (May) and cessation (October) months in Sudano-Sahelian zone are characterized by variations of over 100%. When the month of January is added to OND (to become ONDJ), the average number of rain days changed to 29, 29 and 40 while average seasonal rainfall amount changed to 563mm, 420mm and 653mm at Chiakariga, Marimanti and Tunyai respectively. This indicates a slight increase in mean number of rain days and rainfall amount. This also had a minimal increase on CV for both rain days and rainfall amount in the three stations when compared to OND. For instance, ONDJ recorded a CV for rainfall amount of 0.42, 0.42 and 0.44; and rain days of 0.51, 0.33, and 0.32 for

Chiakariga, Marimanti and Tunyai respectively. The results suggest that the contribution of January to the increase in variability of ONDJ season is less. The minimum influence of January on the CV especially on rain days, suggest that January rainfall is critical to the overall seasonal performance and may be vital to the maturation of crops. Mzezewa et al. (2010) also reported high co-efficient of variation for annual (315%) and monthly (50-114%) rainfall in semi-arid Ecotope, north-east of South Africa. Findings of Seleshi & Zanke (2004) show that annual and seasonal rainfall (*Kiremt* and *Belg*) in Ethiopia are also highly variable (with CV values ranging between 0.1 and 0.5). Sivakumar (1987) found that annual rainfall in the Sudano-Sahelian zone of West Africa was less variable than monthly rainfall. In Tharaka District in East Africa, seasonal rainfall is less variable than monthly rainfall

Figure 4.3a show that April rainfall amount is characterized by within-season variation. This is unlike in March and May rainfall which shows increasing and decreasing trends respectively. During the month of March, all stations receive less than 20mm per pentad with an average of one rain day per pentad. Rainfall amount increases in April, with an average of two rain days per pentad but the month is characterized by suppressed rainfall. For instance, rainfall amount increases in the 2nd pentad of April to over 60mm then decreases to less than 50mm in the 3rd and 4th pentads. The rains then increase to over 60mm in the 5th pentad before assuming a declining trend. Over 80% of the May rainfall amount is received between the 1st and 3rd pentads in the three station of study. The average rainfall amount per pentad in May is 9mm, 10mm and 14mm at Chiakariga, Marimanti and Tunyai respectively. The last rain days for the MAM season are in the 3rd pentad (Chiakariga) and 4th pentad (Marimati and Tunyai).



(a) MAM



(b) OND

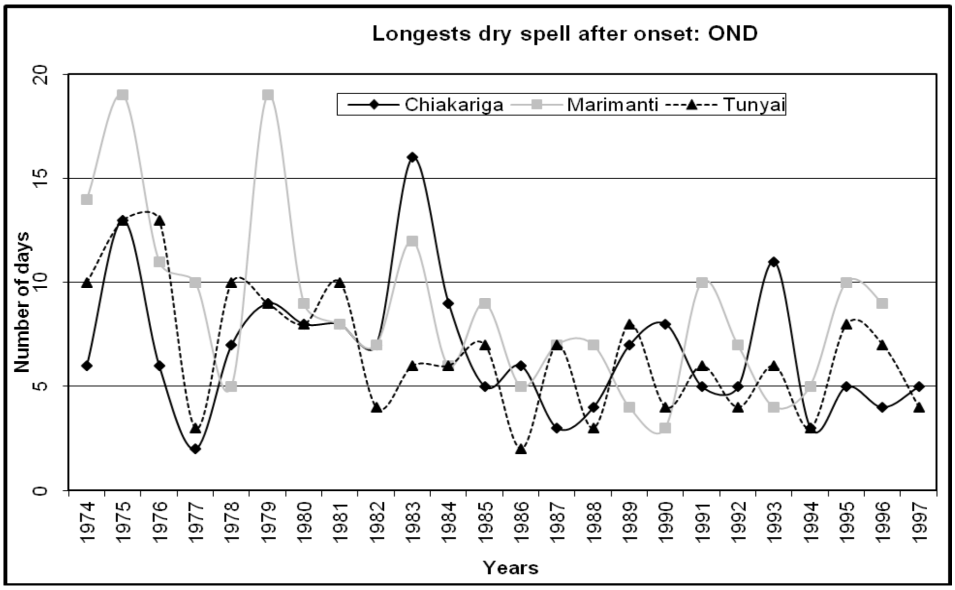
Figure 4.3 Mean rainfall amount received for the period March-May (MAM) (a) and October – December) (OND) (b) by pentads.

Figure 4.3b illustrates that all stations have an increasing trend in rainfall amount in October up to the 1st pentad of November before assuming a declining trend thereafter. Although November is the peak month in rainfall amount, there are significant differences in the distribution pattern. At Tunyai, rainfall peaks between the 1st and the 4th pentads of November with an average of over 55mm per pentad before assuming a declining trend. At Chiakariga, rainfall peaks between the 6th pentad of

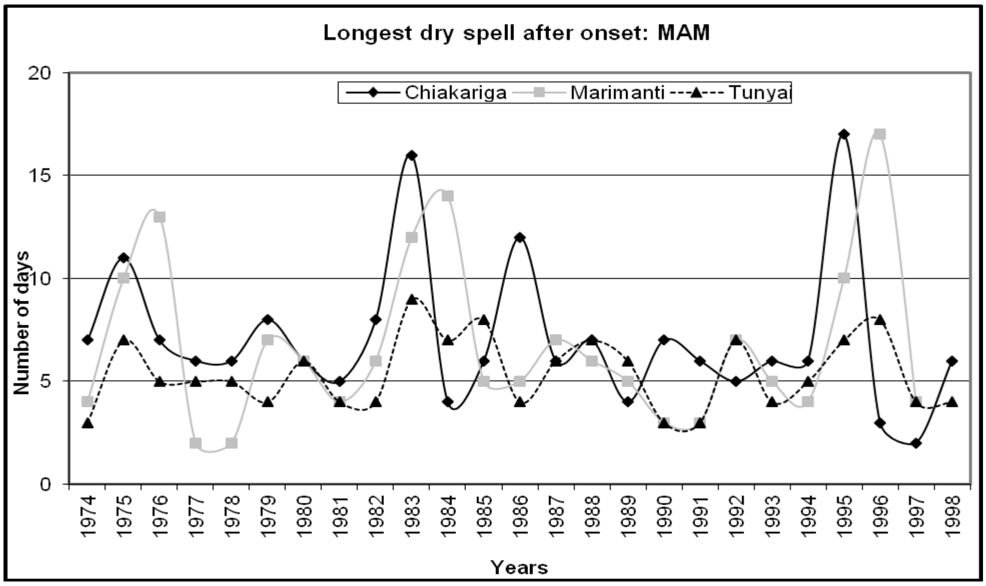
October and the 4th pentad of November, with a pentad average of slightly above 40mm. However, Marimanti presents a different pattern from the two other stations. OND rainfall assumes an increasing trend from onset up to the 2nd pentad of November when the peak is reached – 56mm. The rains then decline in the 3rd pentad of November to less than 30mm – a pattern maintained until the 2nd pentad of December. A notable feature of OND rainfall is that its distribution from onset to retreat dates is fairly constant in the three stations when compared to MAM rainfall. With rainfall peaking in early November, it is important for farmers to plant early in the three agro-ecological zones if crops have to optimize rainfall received at the early stages of the season. As stated by Hansen & Indeje (2004), the findings are particularly useful in crop production and management decisions which depend more on distribution of rainfall within the season than the seasonal average. According to Barron et al. (2003), the uneven seasonal distribution of rainfall, such as the one depicted by MAM, may expose crops to a range of mild to severe intra-seasonal dry spells, which may subsequently affect the yield adversely.

Analyses of dry spells show that rarely do we have a dry spell exceeding 15 days after onset for both MAM and OND season (Fig 4.4a-b). In fact at Tunyai, very rarely was a dry spell of over 10 days recorded for both MAM and OND season for the period under study. Marimanti and Chiakariga however recorded few cases of dry spells exceeding 15 days. For the OND season, Marimanti appear to have recorded prolonged dry spells in 1975 & 1979 (19 days), and Chiakariga in 1983 (16 days). Analyses of dry spells during MAM season show Marimanti to have had prolonged dry spells in 1976 (13 days), 1984 (14days) and 1996 (17days). In the same season of MAM, Chiakariga had prolonged dry spells in 1983 (16 days) and 1995 (17 days).

According to Sivakumar (1991) a dry spell is a period of at least 15 consecutive days and none of which has received 1mm or more. The severity of dry spells depends on their frequency and duration, amount of rainfall received, type of soil and on the crop stage during which they occur. A study by Barron et al. (2003) show that a maize crop on sandy soil in Machakos Kenya was affected by dry spells of longer than 15 days in all development stages for both OND and MAM season. The implication is that drought tolerant maize cultivars stand a chance of survival in Tunyai. In Marimanti and Chiakariga however, maize farming may be a risky venture. A study by Marteau et al. (2011) established that a dry spell lasting 7 days was associated with re-sowing. For the period on record, all stations experienced dry spells after onset at least 9 out of 24 years. The implications are a loss of seeds and an increase of labour devoted to re-sowing. Since wet events at the start of the season are not always followed by the full installation of the season, it is possible that dry spells could still occur afterward, leading to a seasonal crop failure. A visual glance of Figure 4.4 shows that the number of dry spells, particularly for OND season is on the decline. This suggests that OND rainfall in Tharaka District show sign of recovery (Fig 4.1). Information regarding occurrence of dry spells in agro-ecological is valuable in selecting crops and their varieties and also to obtain the required level of drought tolerance.



(a) OND



(b) MAM

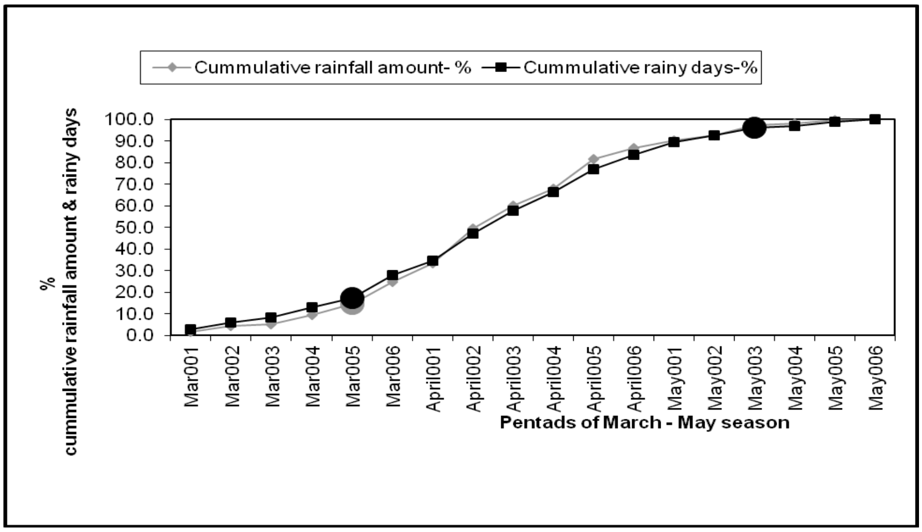
Figure 4.4: Longest dry spell in the first 31 days after onset of (a) OND and (b) MAM rainfall seasons

Changes in frequency and size of rainfall events may alter water availability in the sandy-loam soil of Tharaka District (Jaetzold et al., 2007) and consequently produce differential patterns in the depth and duration of soil wetting. The results compliment previous studies (Kasei & Afuakwa, 1991; Sivakumar, 1987) which have tied the length of a rain season to rainfall amount. For instance, Tunyai records the highest number of rain days and also receives the highest amount of rainfall. A combination of these results would therefore lead to the conclusion that optimum planting time for seasonal crops to meet crop water requirements could start in the 4th pentads of March. However this should be done in consideration of the existing agro-meteorological advisories. Kasei & Afuakwa (1991) recommend early planting in areas with relatively longer growing seasons (such as Tunyai) to allow for maximum crop production. It is important to note that analysis of dry spells alone may not be useful for assessing whether the crop water demand will be met, for the three reasons outlined by Araya & Stroosnijder (2011): (i) it does not consider the evaporative demand of the atmosphere; (ii) a day of rainfall with little agronomic effect may be counted as a wet day and (iii) effective rainfall is not considered. In Tharaka therefore, an understanding of within-season variability and dry spell frequency & duration impacts on crop development and yield is critical in designing a cropping system and farm management. Studies of dry spells in Tharaka also need to be complimented by estimation of drought episodes – taking into account the different types of drought (World Meteorological Organization, 2006)

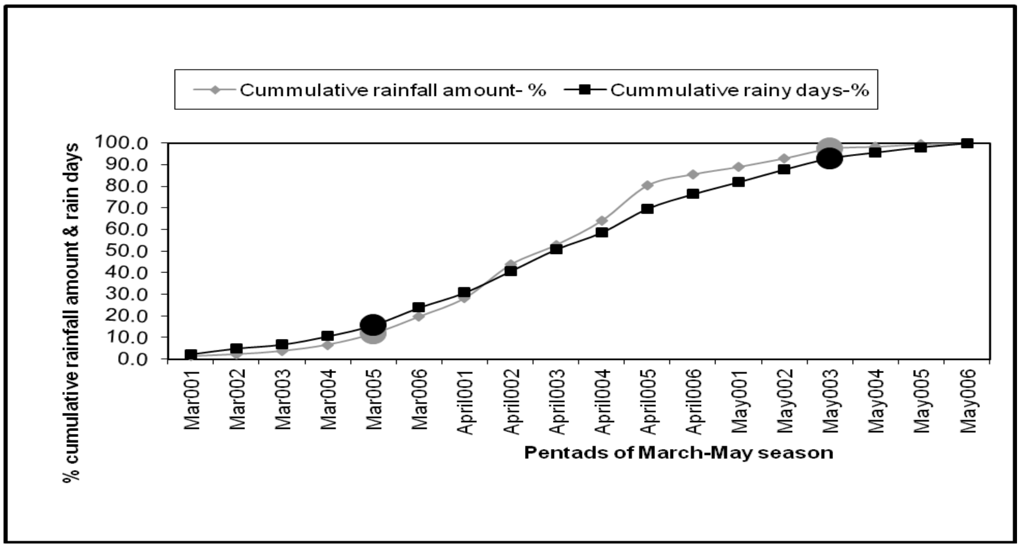
4.2.3 Onset and Cessation of Seasonal Rainfall

Figures 4.5a-c and 4.6a-c show the cumulative percentage mean of rainfall amount and rain days for MAM and OND season. Based on both cumulative rainfall amount and rain days, onset for MAM and OND is in the fifth pentads of March and October respectively which translates to between 21st and 25th of March and October.

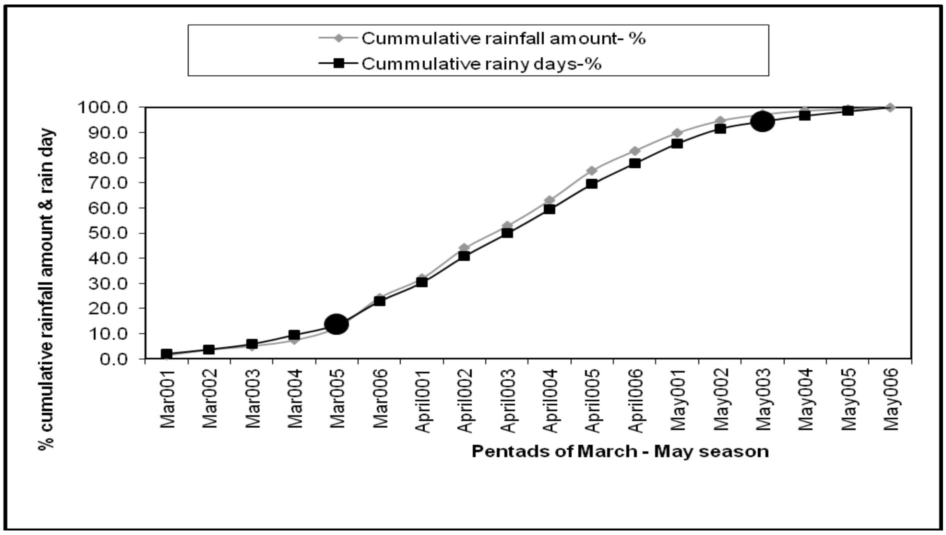
Cumulative rainfall amount and rain day curves show that during MAM, rainfall amount signal an earlier onset than rain days. Thus, there are differences in the specific dates (day) when the two variables are used separately to determine onset. During OND, there is concurrence on the date of onset when rainfall amount and rainy days are used. The concurrence of rain days and rainfall amounts on dates of onset would partly explain the high skill of prediction associated with OND rainfall (Cooper et al., 2008). It is important to note that by the 5th pentad of March and October, all the stations record between 11-16% of the total rainfall amount and 14-17% of the total rain days. For an area with a highly variable rainfall, it would therefore imply that in a normal season, seeds are sown during this period when the rains have stabilized and are on the increase. Planting later than the 5th pentad of March and October is likely to hamper crop development and potentially lower yields or lead to crop failure, depending on the maturity length of the cultivar.



(a)



(b)

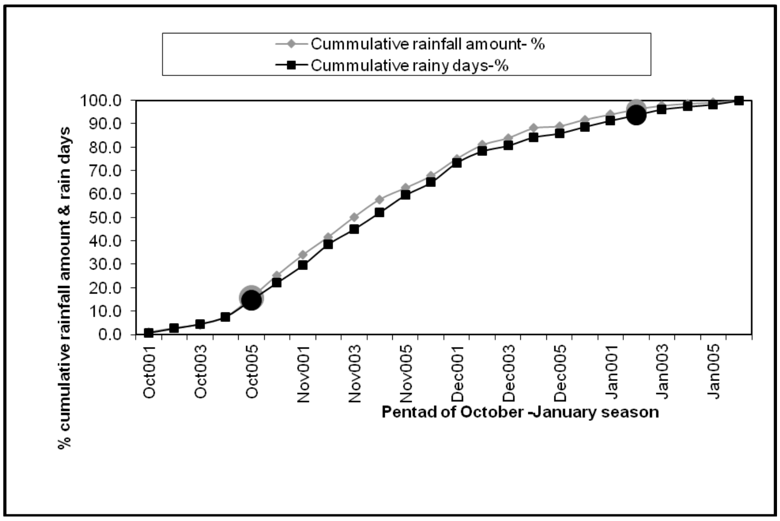


(c)

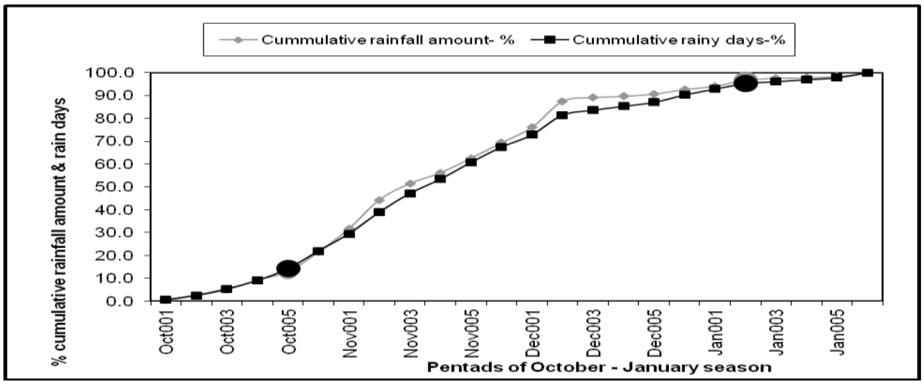
Figure 4.5: Mean rainfall onset and cessation dates for (a) Chiakariga, (b) Marimanti and (c) Tunyai for MAM season.

Cumulative percentage mean shows that MAM rains retreat in the 4th pentad of May (May 16-20th) and ONDJ rains in the 2nd pentad of January. There is also relative uniformity in the amount of rainfall received by the date of cessation. By the date of MAM retreat, Chiakariga, Marimanti and Tunyai received 97%, 98% and 97% of the rainfall amount and 96%, 93%, and 95% of the rain days respectively. Marimanti and Tunyai had received 97% of the rainfall amount and 95% of the rain days by the date of cessation for ONDJ rainfall season. At Chiakariga the mean retreat date is reached after 96% of rainfall amount and 95% of rain days.

From these results, it is observed that although mean rainfall amount and rain days converge to give mean onset and cessation; there are differences in the cumulative values. For instance, in all the three stations, the percentage rainfall amount received is less than the percentage number of rain days by the date of onset for both OND and MAM season; though the difference is bigger for the later. It therefore implies that determination of onset based on rainfall amount alone signal an early onset while rain dates a late onset. There is no concurrence for cumulative rainfall amount and cumulative rain days at the maximum positive curvature for MAM when compared to ONDJ. This suggests that onset and cessation are steadier in terms of rainfall amount and rain days for ONDJ than for MAM. By the dates of cessation, all the stations had recorded more rainfall amount than rain days. The case at Marimanti is of particular interest where the difference between rainfall amount and rain day cumulative percentage is the largest. In Marimanti, use of rain days would signal an early cessation.



(a)



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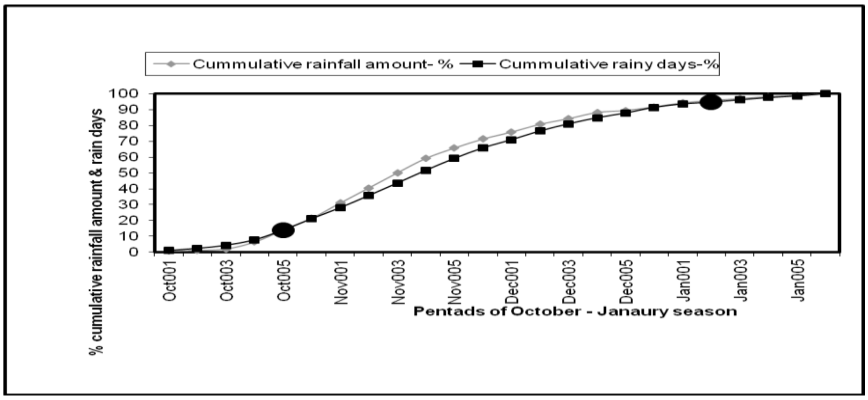


(c)

Figure 4.6: Mean rainfall onset and cessation dates for (a) Chiakariga, (b) Marimanti and (c) Tunyai for ONDJ season

Although mean dates of onset and cessation appear to be uniform for the period on record, results of individual years show high inter-annual variability for both MAM and OND season (Fig. 4.7a- b). For instance, onset for 1983 was as late as the 8th pentad (April 5-10) at Chiakariga and Tunyai and 11th pentad (April 15-20) at Marimanti during the MAM season. Other years of late onset for MAM are 1979, 1987, 1992 and 1993. Early onsets for the same season were realized in 1977, 1981 and 1990. The latest onset (after November) during OND for the period under study was in 1981, 1987 and 1996. While 1982, 1991 and 1994 recorded early OND onsets for the period on record. Figure 4.7a-b also shows the general trend of onset dates for MAM and OND for the period of study. The MAM at Marimanti shows a constant onset trend within the first week of April (Pentad 7). Chiakariga and Tunyai record mixed fortunes of increasing and decreasing trends respectively for MAM. Onset for OND depicts a declining trend at Marimanti and Tunyai and a constant trend at Chiakariga. What emerges from these results is that whereas there is uniformity on pentads of onset using the percentage cumulative mean across the three stations, there are several instances when onset varied from station to station. Trend lines show that onset for OND season is moving towards the mean dates of onset (October 21-25). Onset dates for MAM at Chiakariga appear to be progressing towards the 1st pentad of April from the 6th pentad of March.

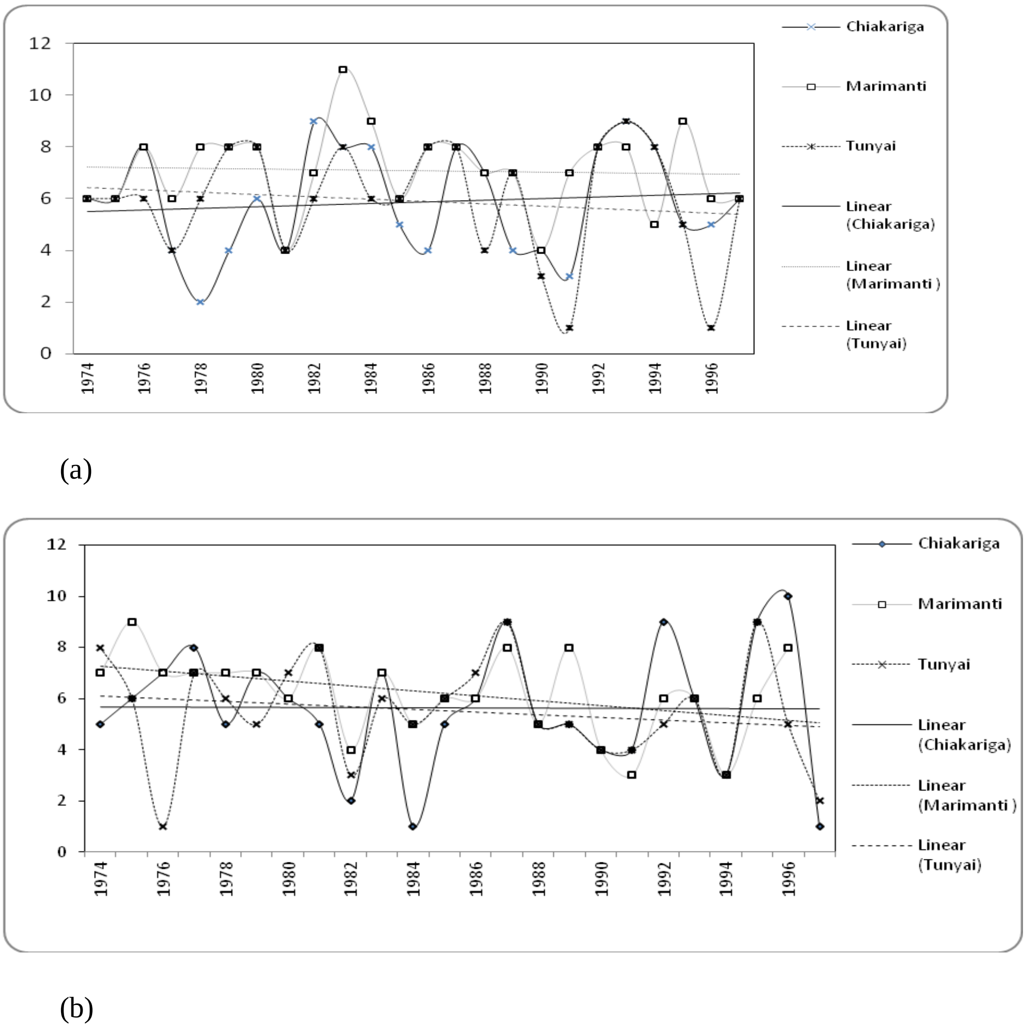
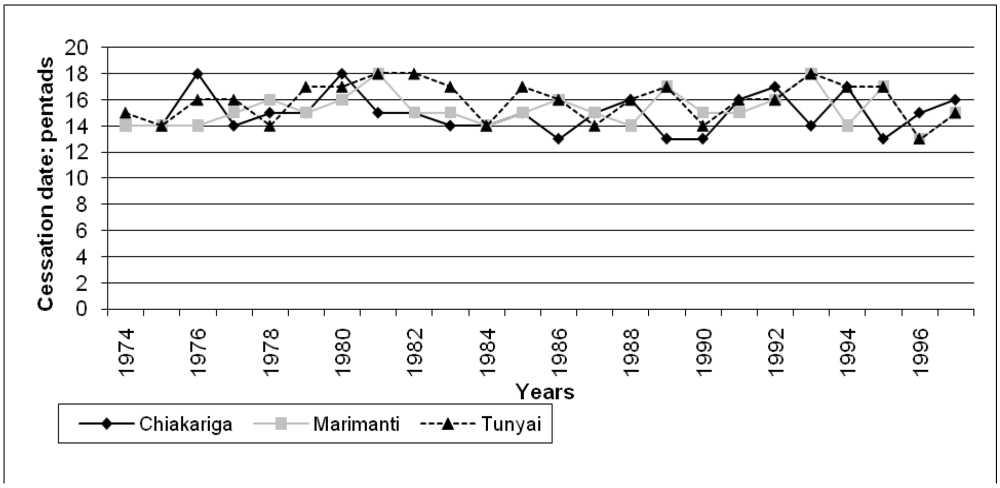
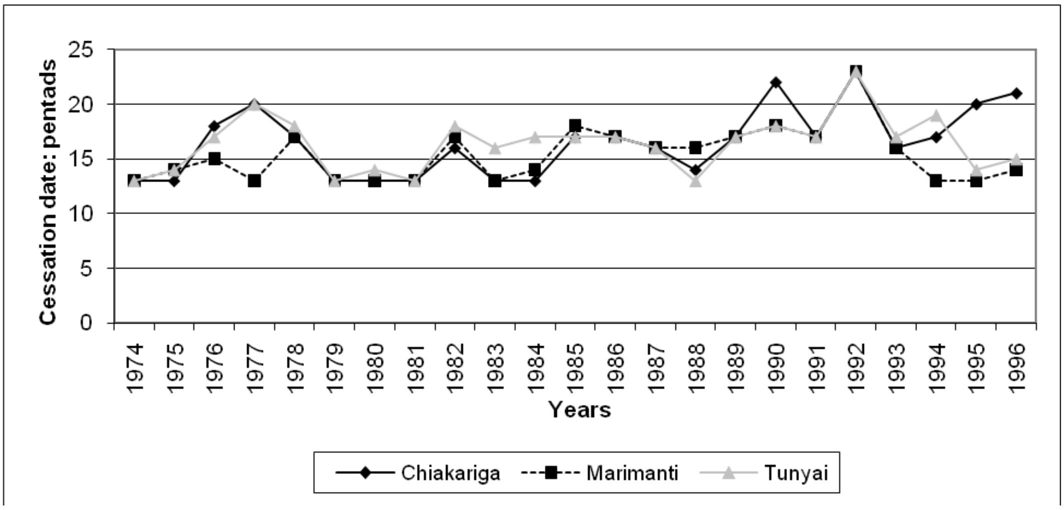


Figure 4.7: Estimated dates of onset by pentads (y-axis) for (a) MAM and (b) OND for the period on record in years (x-axis).

Dates of rainfall cessation are less variable when compared to onset (Fig 4.8a-b). During MAM season, cessation is expected between the 14 pentad (May 6-10) and 16th (May 16-20th). Although cessation can start as early as the 14th pentad (December 6-10) during OND, it stretches to the 1st week of January (Pentad 19 and 20). A notable feature of this is that although dates of cessation vary from year-to-year just like onset, the amplitude of variation is not as high compared to onset.



(a)



(b)

Figure 4.8: Estimated dates of cessation for (a) MAM and (b) OND

These findings vindicate those of Camberlin & Okoola (2003) who observed that inter annual variability of the onset is larger than the withdrawal in eastern Africa. The study further established that in Eastern Kenya, the average onset for MAM occur on March 25 and cessation on May 21. The results however contradict those of Araya & Stroosnijder (2011) who established that in northern Ethiopia, onset of rain over the study area was less variable than cessation. Mugalavai et al. (2008) has illustrated the role of atmospheric winds (NE & SE monsoon) and localized effects (escarpments and Lake Victoria) in the determination of onset and cessation for the long rains (March-September) and short rains (October – December) in the humid region of western Kenya. Odekunle (2006) observed that onset is first realized in the south of Nigeria by end of March and progress northward where northern stations such as Kano realizing onset in June. In Nigeria, onset and cessation are associated with south-westerly winds and *Harmattan* winds respectively.

Inter-annual variations of onset and cessation in Tharaka could be attributed to local factors and position of sites in relation to the amplitude of Inter Tropical Convergence Zone, a critical determinant of onset and cessation. The presence of hills and protected forest cover (Smucker & Wisner, 2008) in the south of Tharaka are potential determinants of onset and cessations. The high variations that characterize rainfall onset in Tharaka make agricultural planning difficult for farmers. But farmers can find hope in the improved skill of seasonal climate forecast in Eastern Africa (Cooper et al., 2008). Effective use of climate forecast information (on date of onset and rainfall amount) can significantly optimize rainfall and lead to improved yields. An early onset of the rains give a longer growing season and a delayed onset may mean a short growing season as documented by Sivakumar (1987) and Kasei & Afuakwa (1991). On the efficiency of the methods in determining mean onset and cessation, results corroborate those of Odekunle (2006) who found that use of rainfall amount and rainy days do not have major differences in determining mean onset and cessation. The study however recommends that in cases of significant variations, percentage mean cumulative rainfall amount be used. The conclusion is informed by the percentage of rainfall amount received by the dates of onset and cessation.

4.3 Effect of Climate Variability on Water Availability

Figure 4.9 shows that rivers/streams (80%), wells (10%), springs (8%) and boreholes (3%) are the main sources of water for domestic use. Wells and springs were almost exclusively mentioned in Chiakariga while boreholes in Tunyai. All the respondents of Kathangacini (IL6) mentioned stream and rivers as their main source of water. Respondents were then asked if this was the only source of water.

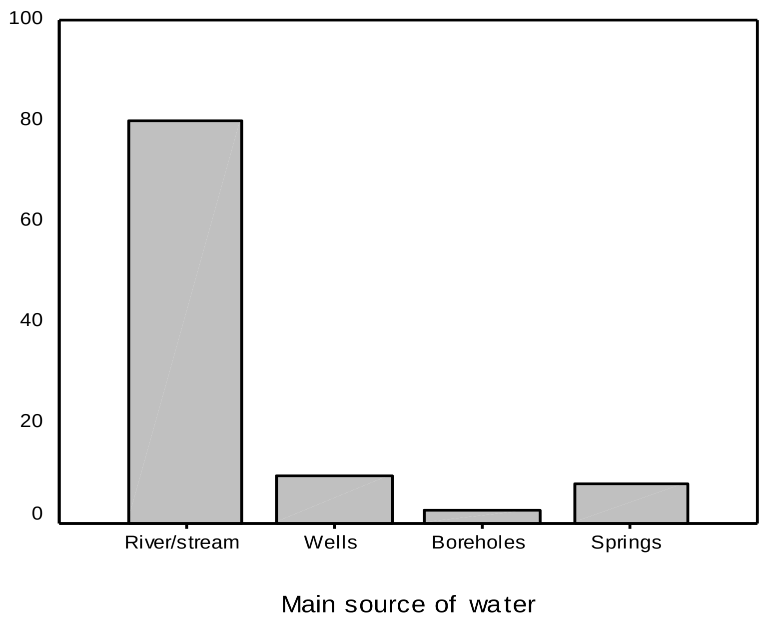


Figure 4.9: The main sources of water in Tharaka.
Source: Field data, 2009

Results in Table 4.4 show that a majority of respondents in Marimanti (IL5) and Kathangacini (IL6) did not have alternative sources of water. According to the survey, only 23% of the respondents had alternative sources of water. The main alternative sources of water were boreholes at Tunyai (25%), rivers at Chiakariga (20%) and wells in Kathangacini (12%). It would imply that some rivers, wells and springs dry up during the dry season – usually June-September and January -February, compelling households depending on them to opt for river/stream water that are far away.

Table 4.4: Response on alternative sources of water

		Site (N)				Total
		Kathangacini	Marimanti	Tunyai	Chiakariga	
Is this the only source for the whole year?	No	8	7	33	28	76
	Yes	50	85	45	70	250
Total		58	92	78	98	326

Source: Field data, 2009

Fourty-two percent of the respondents walk for a distance of less than one kilometre to the main source of water for domestic use, while the rest (58%) said they cover more than one kilometre to reach the main source of water. When the distance was analyzed by study sites, Tunyai had the highest number of respondents (76%) who walked for less than a kilometre to fetch water while Chiakariga had the highest number of respondents who walked long distances (over 5km) to access water (Fig 4.10). Return time from the main source of water was highest (more than 2hrs) among respondents at Kathangacini (38%), Chiakariga (37%) and Marimanti (26%). Respondents at Tunyai (76%) spent less than 30minutes to return from the main source of water.

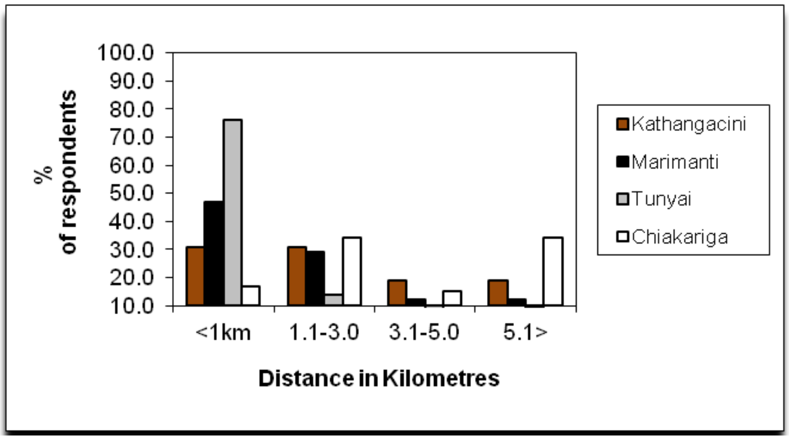


Figure 4.10: Percentage of respondents and the return distance (in Km) from the main source of water for domestic use.
Source: Field data, 2009

When asked the return distance to a watering point for animals, 58% of the respondents said it took them less than 1km to the livestock watering point. This was higher compared to 42% of the respondents who walked for less than 1km to a watering point for domestic use. This could be because the proximity of animals to watering point is dependent on spatial location of grazing field. Unlike water sources for domestic use that is determined by location of homestead. A majority of respondents (265 – 81%) reach watering points within a distance of less than 2km during the wet season (Table 4.5a). But this proportion reduced during the dry season when the number of households who had water points within a distance of 2km declined to 189 (Table 4.5b). Uneven distribution of rainfall during the wet season may still compel households to walk long distances to access water.

Table 4.5a: Distance to water point during the wet season

		Site (N)				
		Kathangacini	Marimanti	Tunyai	Chiakariga	Total
Distance water point: wet season	<2km	39	58	72	96	265
	2-5km	15	30	6	2	53
	5-10km	4	4	0	0	8
Total		**58**	**92**	**78**	**98**	**326**

Table 4.5b: Distance to water point during the dry season

		Site (N)				
		Kathangacini	Marimanti	Tunyai	Chiakariga	Total
Distance water point: dry season	<2km	21	54	60	54	189
	2-5km	26	33	15	27	101
	5-10km	8	5	3	17	33
	10-20km	2	0	0	0	2
	20+km	1	0	0	0	1
Total		**58**	**92**	**78**	**98**	**326**

Source: Field data, 2009

The percentage of respondents who covered long distance to watering points during both the wet and dry season was highest in Marimanti. The increase was most noticeable at Kathangacini and Chiakariga where 64% and 44% of the sampled population covered more than 2km to reach water points during the dry season. The problem is expected as most households depend on streams as sources of water, some of them seasonal. In Chiakariga, a section of the households depend on wells and springs which dry up during the dry season. The increase was less in Tunyai (from 6 to 15 households) and this can be attributed to the sinking of boreholes which provide a supplementary source of water. It would be helpful if similar efforts were directed in other parts of the district to make clean and safe water more accessible to people. It would also be much more helpful to invest in rainwater harvesting equipment which would make water available for use during the dry season.

The important question asked was to what extent are households satisfied with water availability for domestic use during both season? Results in Figure 4.11 show that during the wet season, 35%, 44% and 21% of the respondents were very satisfied, satisfied and not satisfied respectively with the distance covered to fetch water.

Analyzed by sites (AEZs), Tunyai had the highest proportion of respondents who were very satisfied (50%) and satisfied (41%). Marimanti (41%) and Kathangacini (29%) had the highest proportion of respondents who were not satisfied with access to water during the wet season. This correctly relates with the fact that Marimanti and Kathangacini receive the least amount of rainfall in a year which has implications on stream flow – the main source of water. The number of respondents not satisfied with the distance to watering points during the dry season shot to 49% (from 21%) (Fig4.11). Rise in dissatisfaction was more remarkable at Chiakariga (67%) and Kathangacini (55%). Whereas the dissatisfaction at Kathangacini (IL6) may be attributed to aridity, dissatisfaction at Chiakariga (despite being LM5) may be attributed to the drying up of springs during the dry season. The level of satisfaction was apparently constant in Marimanti during the dry and wet season, an indication of the minimum impact of seasonal rainfall on water availability.

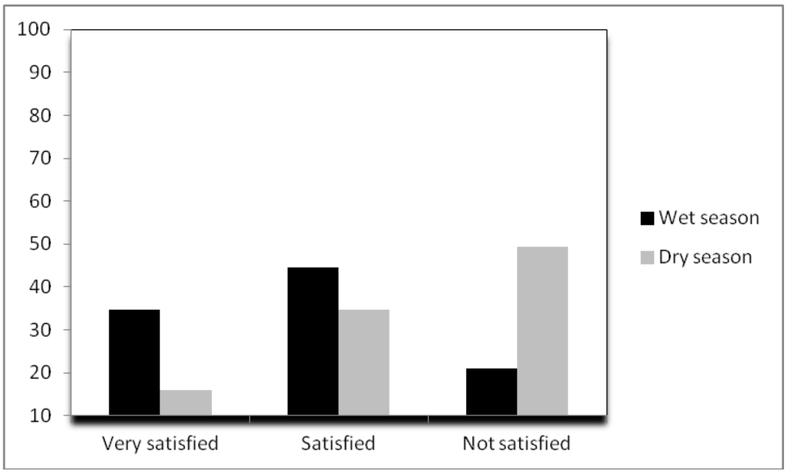


Figure 4.11: Satisfaction level (in %) to water access during the wet and dry seasons.
Source: Field data, 2009

Sixty-two percent of the respondents in the study opined that rainfall variability had a ‘most severe’ impact on water accessibility for domestic use in the past five years (Fig 4.12). Analyzed by sites, the impact of rainfall variability on water accessibility in the last five years was most severe (82%) at Chiakariga. At Kathangacini, 62% and 24%

rated accessibility as most severe and moderately severe. Marimanti had the least percentage of respondents (44%) who thought the impact of rainfall variability on accessibility was severe. Despite the apparent high satisfaction level, 56% and 32% of the respondents at Tunyai thought the impact of rainfall variability on accessibility was 'most severe' and 'moderately severe.'

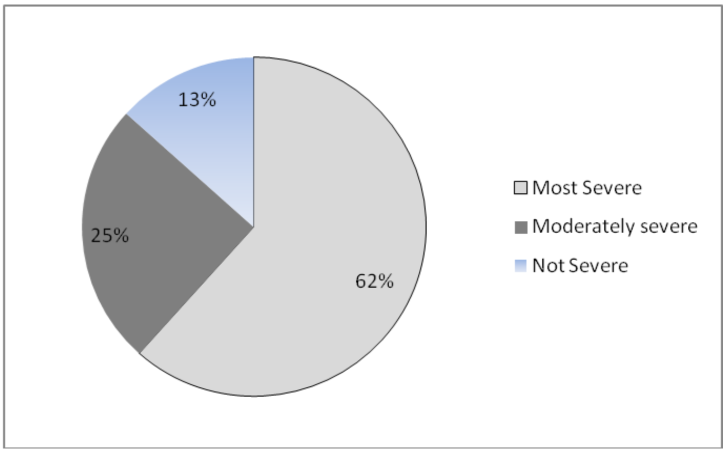


Figure 4.12: Perceived impact of rainfall variability on water accessibility for domestic use
Source: Field data, 2009

When respondents were asked to rate the reliability of water for domestic use, 35% and 44% rated it as good and fair (Table 4.6). The rating of good and fair is replicated in most of the stations. Significant to note was that a majority of the respondents in Tunyai rated water reliability as 'good'. While nearly half (46/98) of the respondents at Chiakariga rated water reliability as poor (the highest). Interestingly, a significant proportion of the respondents at Kathangacini (IL6) rated reliability as 'fair' and 'good'. The positive rating of water availability can be attributed to a number of rivers that traverse the district. Thus, despite Tharaka being ASAL, communities still get the water from rivers. It is significant to note that these rivers originate from Mt. Kenya and Nyambene Hills – areas that receive fairly high amounts of annual rainfall.

Table 4.6: Status of water reliability in Tharaka

	Site (N)				Total
	Kathangacini	Marimanti	Tunyai	Chiakariga	
Very good	0	2	8	0	10
Good	21	39	50	3	113
Fair	28	49	19	49	145
Poor	9	2	1	46	58
Total	**58**	**92**	**78**	**98**	**326**

Source: Field data, 2009

Checking that none of the cells had less than five counts, a chi-square test was carried to establish if there is a significant relationship between satisfaction level in distance to watering point and study site. Chi-square results show that there was a significant ($p < 0.05$) difference between the expected and observed results when satisfaction levels are compared by sites during the wet and dry season. Correlation results show that study site had a significant relationship with the main source of water (0.45, $p<0.01$) and return distance from main source of water (0.14, $p<0.05$). These results are a statement on why majority of households in Chiakariga and Kathangacini walk for long distances than their counterparts in Tunyai and to some extent, Marimanti. It is possible that people at Chiakariga, some who depend on wells and springs, are more vulnerable during the dry season which leads to drying up of these sources. The sinking of boreholes in Tunyai has in away helped reduce households' vulnerability to water scarcity. The overall rating of water reliability as good and fair can be attributed to the presence of permanent rivers which traverse most parts of Tharaka District. It is possible that when a stream dries up during the dry season, households opt for the permanent river which may be far away. There was no significant relationship between income levels and main source of water and return distance from main source of water, suggesting access to water points in Tharaka is not influenced by income. This is because most households rely on rivers, wells and springs which are either natural resources or government projects. Where boreholes are used, these are usually sunk by either government or developing agencies and are for public use. In Tharaka, interviews with residents indicated that Diocese of Meru (based in Chuka), the Plan International and the Government of Kenya are involved in the sinking of boreholes.

Rainfall variability results in decreased spring discharge and stream water volume. With households in Tharaka relying on springs, wells and stream, this explains why the number of respondents not satisfied with accessibility to water shot up during the dry season in most of the study sites. Households cope with water scarcity by resorting to alternative water sources – mostly streams that are far away. Over reliance on streams as a local coping strategy does not reduce households' exposure to climate variability and induced impact. Stream volume decreases due to rainfall variability and upstream uses (especially in Meru – upper Tana) and this does not only affect accessibility to water, but usually has a ripple effect on livelihoods. Indeed Hoff et al. (2007) observes that in the Tana Basin, all users have substantial un-met water demands. Efforts to dig boreholes and install rainwater harvesting storage facilities- initiatives of government and development agencies has the potential to reduce vulnerability to water accessibility. These efforts are necessary to save water in times of water surplus for use in times of water shortage as observed by Bouwer (2003).

The reformed water sector through the Water Act 2002 can equally play a pivotal role in enhancing community adaptation to climate change. Thus, WRMA and the private Water Supply Companies can work towards an effective adaptation strategy as is the case in Eastern Ontario – Canada (Crabbe & Robbin, 2006). The role of strengthened institutions in enhancing water accessibility is equally underscored by Kundzewicz et al. (2008) although the monetary cost of these adaptations is expected to be large. In Tharaka, all stakeholders in the domestic water supply should collaboratively develop the main sources of water (springs, wells and streams) and consequently consider pricing water from these sources as a way of encouraging water and watershed conservation and raise funds for coverage expansion as suggested by Shisanya (2005). Similar views are expressed by Cullis, Strzepek, Tadross, Sami, Havenga, Gildenhuys & Smith (2011) who called for water conservation and demand management and a need to develop additional storage facilities in Polokwane – South Africa.

Construction of additional water storage facilities would assist residents of Tharaka by reducing the distance covered and time taken in search of water during the dry season. Even with the enhanced role of institutions and promotion of water-use efficient technologies in managing water resources, science-policy interface must be seen as a feature of integrated water resource management (IWRM). Scientist are more obliged to take a more active role in sensitively managing the advice-to-policy process in order to improve management of water within river basins (Vogel et al., 2007; Lankford, Koppen, Franks & Mahoo, 2004), particularly in the context of a variable climate, increasing human population and competing water interests within catchments. In Tharaka, planning and management of water resources should be informed by upstream (upper Tana catchment) water uses and impact of rainfall variability.

4.4 Chapter Summary

This chapter presented results of rainfall variability and perceived impact of rainfall variability on water access. The study found that rainfall variability is persistent in Tharaka District. The early 1970s were characterized by below normal rainfall, a trend similar to that observed in the Sahel. Results of cumulative departure index show that MAM rainfall season has varied less from the mean across the three stations. OND rainfall is a major determinant of annual rainfall as demonstrated by the below normal pattern they both display. Results of rainfall anomaly index show that seasonal rainfall in Tharaka is highly variable from year-to-year. With the exception of LM4 (Tunyai), agro-ecological zones LM5 and IL5 receive less than 1000mm annual rainfall. A comparison of rainfall amount and rain days shows that OND is a longer season than MAM. This is with the exception of Marimanti which receives nearly the same amount of rainfall during the MAM and OND seasons. *t*-test results show that the difference between OND and MAM at Chiakariga is significant, suggesting the two seasons merit different cropping systems. MAM rainfall season shows signs of within-season variability than OND; especially so when the rainiest months (April and November) are considered. Results of cumulative percentage mean show that 21-25 of March and October are the mean onset dates for MAM and OND respectively. While May 16-20th and January 1-5th are the mean cessation dates for MAM and ONDJ respectively. Despite these mean dates, onset dates are highly variable than cessation dates. Estimation of dry spells after onset show that there can be as high as 15days of dry spell after onset at Marimanti and Chiakariga.

People of Tharaka are dependent on rainfall sensitive water sources; namely: rivers, wells and springs. To many respondents (81%), water points were within a distance of 1 kilometer during the wet season. But this reduced to 58% during the dry season. The increase in distance covered during the dry season correspondent with the increase in respondents not satisfied during the same period. To improve water availability and reduce household vulnerability, science-policy interface need to be recognized as an essential of IWRM where development of water saving technologies and institutional capacity are at the centre.

In conclusion, the people of Tharaka are vulnerable to rainfall variability. This is illustrated by the persistently below normal OND seasonal rainfall – the main growing season; the within season variability (in terms of dates of onset, cessation and dry spells). Variation in rainfall amount during the year affects accessibility to water for domestic use. Although these variations in water accessibility can partly be attributed to rainfall variability, there is a possibility that the level of development too affects access and availability. The next chapter examines the cropping systems by seasons and some of the existing measures that enhance households' adaptive capacity to impacts of rainfall variability on water availability and livelihoods.

CHAPTER FIVE

5.0 CLIMATE VARIABILITY IMPACTS AND ITS UNDERSTANDING AS A PROBLEM.

5.1 Introduction

This chapter presents results of the perceived impacts of climate variability on livelihoods and assesses community's conceptual understanding of climate change and variability as a problem. The first part of the chapter presents existing livelihood strategies and sources of income. The second part presents results of the perceived impact of climate variability on crop yield, natural resources and other livelihoods. A culmination of the sub-section will be the results of factor analysis to determine any structure in the many variables perceived to be impacted by climate variability. The third part of the chapter presents results of participatory risk ranking and scoring among the Focus Group Discussants, providing insights on the understanding of climate variability as a problem in relation to other socio-economic problems and environmental concerns.

5.2 Livelihoods and Income Diversity

Households were asked to mention livelihood support strategies they engaged in during the past 12 months and the results are presented in Table 5.1. Sale of livestock (55%), sale of crops (15%), forest and non-wood forest products (8%) were the main sources of income in Tharaka District. Sale of goats, cattle and poultry, were the main sources of income from livestock. The sale of livestock is common in the period preceding the onset of rainfall as many households seek to purchase farm inputs and food for their families. Prices at such a time are said to be low because supply far much outstrip demand. In most African societies, livestock is seen as a symbol of wealth, especially among the agro-pastoralist of the semi-arid. Thus, in many households, sale of livestock is seen as ‘a last resort’.

Table 5.1: Household livelihood support strategies by study sites

Livelihood	**Kathangacini (IL6)**	**Marimanti (IL5)**	**Tunyai (LM4)**	**Chiakariga (LM5)**	**Total**
Rent land	4	6	7	1	18 (5.5%)
Sale of Sorghum	2	2	3	1	8 (2%)
Green grams	2	2	11	4	19 (5.8%)
Cowpeas	-	1	18	5	24 (7.4%)
Crop sale	**6**	**5**	**27**	**10**	**48 (15%)**
Cattle	17	9	21	36	83 (25%)
Goats/sheep	35	18	17	42	112 (34%)
Poultry	13	13	11	23	60 (18%)
Livestock sale	**44**	**37**	**36**	**62**	**179 (55%)**
Sale of handicrafts	3	3	2	6	14 (4%)
Sale of Charcoal	3	6	5	-	14 (4%0
Forest and non-wood forest products	**6**	**8**	**6**	**7**	**27 (8%)**
Sale of household assets	-	4	4	3	11 (3%)
Off-farm employment	13	9	7	31	60 (18.4%)
Join social program	12	7	2	5	26 (8%)

Source: Field data, 2009

Cowpeas and green grams were the most sold of the harvested crops at household level. When compared to livestock, very few households sale crop yields. This could be attributed to low yield they receive, leaving households with hardly enough for family consumption. Sale of livestock was common in Chiakariga and Marimanti and sale of crop sale crop yield.

A small section of the sampled households (N=27) engaged in sale of charcoal and handicrafts. Whereas sale of charcoal is widespread in the district, sale of handicrafts (baskets, marts and brooms) was common in Chiakariga. At least 18% (N= 60) of the respondents engaged in on-farm-wage employment, while about 8% joined social programs as a food security measure.

The result in Table 5.2 shows the total number of livelihoods households were engaged in. At least 18% claimed not to have undertaken any livelihood. It is not clear whether this group (with no livelihood) is the most stable and therefore no need to dispose some assets or engage in alternative sources of income. Nonetheless, diversity in livelihoods was an indication of stability and therefore less vulnerable to rainfall variability. A chi-square test (p= 0.05) to establish a relationship between number of livelihoods and study sites was found to be significant. The implication is that households in Tharaka have livelihood options but the high proportions of respondents without livelihoods at Marimanti should be of concern. The limited livelihoods at Marimanti can be related to erratic rainfall that characterizes IL5.

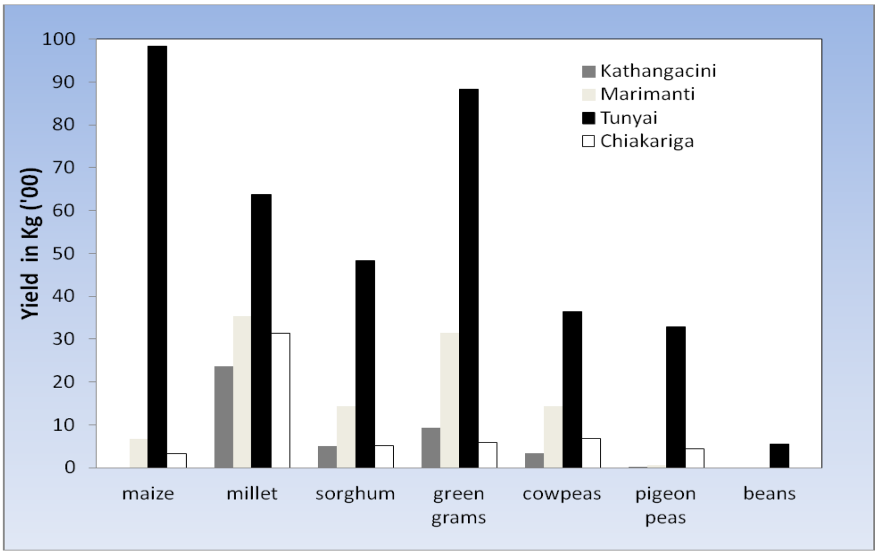
Table 5.2: Number of livelihoods at household level by study sites (N= 326)

No. of livelihoods	Site				Total
	Kathangacini	Marimanti	Tunyai	Chiakariga	
None	8 (14%)	31 (34%)	14 (18%)	5 (5%)	58 (18%)
1-2	11 (19%)	28 (30%)	16 (20.5%)	23 (23%)	78 (24%)
3-4	16 (28%)	22 (24%)	25 (32%)	34 (35%)	97 (30%)
5-6	14 (24%)	6 (7%)	16 (20.5%)	30 (31%)	66 (20%)
7-8	9 (15%)	5 (5%)	7 (9%)	6 (6%)	27 (8%)
Total (N)	**58**	**92**	**78**	**98**	**326 (100%)**

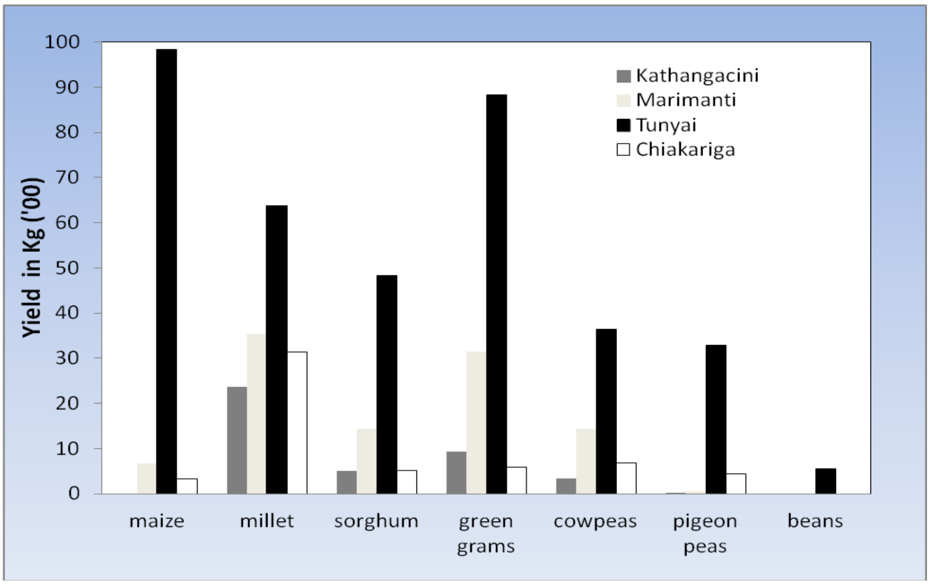
Source: Field data, 2009

Although households in Tharaka have more than one livelihood, their reliance on sale of livestock and crop harvests as sources of income, extreme events such as prolonged drought could spell doom. For instance, the highest income (in Ksh.) at Kathangacini, Marimanti and Chiakariga came from sale of livestock. At Tunyai, crop sale was the main source of income and livestock the second. Going by the number of people involved, there are more income opportunities at Tunyai with residents engaging in sale of livestock products, non-wood forest products and waged farm labour (in addition to crop and livestock sale). At Chiakariga and Marimanti, a number of households additionally engage in crop sale and forest product. Apart from sale of livestock, people of Kathangacini rely on sale of livestock products. However the income from these products is very low.

Engagement in these livelihood support activities was mainly between the months of June and November. The period June-October is the driest period in the study area. With low crop yields, households without alternative sources of income are compelled to sale their livestock, seek off-farm employment or join support programs, among others. The relative difference in coping strategies mirrors variation in degree of severity of climatic conditions in the district. For instance, analyses of total crop yield show that Tunyai – LM4 recorded the highest yield in all the crops during OND (Fig 5.1a). During OND, Marimanti (IL5) and Chiakariga (LM5) recorded slightly higher millet and green grams yields while Kathangacini (IL6) recorded the lowest yields in all crops.



(a) OND



(b) MAM

Figure 5.1: Total crop yield (all the respondents) for the main crops cultivated in Tharaka District during (a) OND and (b) MAM.
Source: Fieldwork, 2009

During MAM, Tunyai recorded the highest yields in maize, cowpeas and pigeon peas. Marimanti recorded the highest yield of sorghum and green grams and Kathangacini recorded the highest yield of millet during MAM (Fig 5.1b). Chiakariga recorded the lowest yield during MAM. Cultivation of millet and green grams was found appropriate in Tharaka District given their adaptation to arid and semi-arid environments.

A study by Ayanlade, Odekunle, Orinmogunje & Adeoye (2009) showed that millet is relatively tolerant to water deficits during vegetative and ripening periods, while annual rainfall variability has considerable effect on maize yield in the Guinea Savanna ecological zone of Nigeria. Hornetz et al. (2001) established that green grams are well adapted to semi-arid tropical lowlands as well as lower midlands due to low water requirements. The same study found *Kathika* beans (*phaseolus vulgaris L*) to be more susceptible to extreme climatic environment. Although Finkel & Darkoh (1991) found that farmers in ASAL were shifting towards maize farming instead of the traditional ASAL crops because of dietary preferences, this study illustrate that farmers in Tharaka still cultivate drought tolerant crops. With the increased awareness of climate change and variability, in addition to regular failure of high water demand crops such as maize, farmers may be opting for the more drought tolerant crops. In Namibia, Newsham & Thomas (2011) found that farmers in Ovambo embraced new and early maturing varieties such as pearl millet in the 1980s. This strengthened resilience to impacts associated with dry conditions in Namibia. It is also seen as a fruitful co-production of knowledge between farmers and extension workers.

Although this study did not establish the different varieties of crops grown in Tharaka, cultivation of non-native crops such as pearl millet (matures in 55 days) and N-26 green gram (matures in 45-50 days) varieties is a demonstration that farmers have mixed agricultural science with their knowledge of agro-ecological zones. Thus in terms of cropping systems, farmers are conscious of their environment and cultivate crops that are adapted to the environment. Secondly there are differences in yield by seasons. For instance, Kathangacini records higher yields during MAM than during OND. Similarly, Marimanti recorded relatively higher yields of sorghum, green grams and pigeon peas during MAM than during OND. This therefore calls for agricultural–based support programs that are agro-ecological zone and rainfall season specific. However, yields across agro-ecological zones remains very low. This is partly due to low utilization of farm inputs due to low income levels and a highly variable rainfall.

Taking these findings into consideration, it would therefore be prudent to prioritize building livelihoods that will enable farmers cope better with current climate variability as a first essential step to adapting to climate change in future. Among other factors, crop selection must conform to the climatic vagaries of the district. There is a need for diversification of livelihoods to reduce over-reliance on crops and livestock as sources of livelihood. In a feasibility study on gum arabic and gum resin resources, Gachathi, Wekesa, Somo & Maitha (2008) found Tharaka District to have high densities of gum Arabic producing species widely occurring in bush lands on individually owned farms. The district also has wild tamarind fruit tree in LM4 which is currently threatened by conversion of bushes into farm lands (Nyadoi, Okori, Okullo, Obua, Burg, Fuch, Magogo, Saleh, Kipruto, Temu & Jamnadas, 2009). Despite the abundance of these dry land resources, communities in Tharaka District remain vulnerable to rainfall variability due to over-reliance on cropping and livestock production system. Even though a section of the population depend on forest (especially charcoal) and non-wood forest (honey and handicrafts) products, there is lack of diversity in commercialization of other dry land resources such as gum arabic and gum resin (Chikamai, Ng'ethe & Quresh, 2005).

The study further inquired on why households engaged in livelihood strategies. This was with a view to establishing the extent to which rainfall variability affects the decision to engage in livelihood. Lack of food, prolonged drought and school fees were the main reasons for engagement in livelihoods. The most common food security measures adopted by households were reduction of number of meals per day, sale of goats & sheep, poultry and engagement in on-farm wage employment (Table 5.3). Similarly, engagement in these livelihoods was informed by prolonged drought. Given that farmers are mostly engaged in the cultivation of drought tolerant crop, use of farm inputs especially pesticides, use of seasonal climate and supplementary irrigation can go a long way to improve the food status in Tharaka.

Table 5.3: Reason for engaging in livelihood strategy (N= 326)

Livelihood	**Main reason for engagement**					
	Lack of food	Prolonged drought	Conflict	School fees	Medical care	Purchase farm inputs
Rent land	4	1	1	11	2	1
Sale cattle	31	12	1	32	6	1
Sale goat/sheep	50	20	-	28	7	3
Sale oxen	4	2	1	1	-	-
Sale poultry	44	4	-	6	-	1
Sale sorghum	5	-	-	6	2	1
Sale millet	3	2	-	5	1	2
Sale cowpeas	7	3	-	12	2	1
Sale of basketry	11	1	-	2	-	-
Sale of honey	3	2	-	-	-	-
Sale of household asset	4	-	-	3	3	-
Consume stored seeds	8	4	-	-	-	-
Off-farm employment	40	12	1	2	2	-
Withdraw children from school	8	3	-	19	-	-
Sent children to stay with relatives	5	4	2	3	-	-
Reduce number of meals	142	31	-	3	-	-
Consume wild food	5	1	-	-	-	-
Consume less preferred food	11	5	-	-	-	-
Join social group	15	6	-	-	2	-

Source: Field data, 2009

In summary, households in Tharaka engage in more than two livelihoods. Livestock (and livestock products) and crops are the main sources of income although a significant number rely on forests and non-wood forest products. Although livestock keeping and the current cropping system (choice of crop cultivars) have a higher resilience in semi-arid environment, the low income generated from them demonstrates that households can be vulnerable to extreme climatic events. The future of sustainable development of drylands also lies in the rational use of other resources. This entails recognizing and developing the potential that exists in the vegetation resources for production of economically valuable products. Mendelsohn (2006) has argued that development of markets can encourage efficient adaptation to climate change, particularly in sectors whose goods are traded such as agriculture, forest and non-wood forest products, and livestock. Brown, Pinzon & Prince (2006) observed that in Mali, Burkina Faso and Niger, if the growing season was characterized by erratic, sparse rainfall, it resulted in higher prices, and well-distributed, abundant rainfall resulted in lower prices. Thus, lower prices may mean cereal accessibility to majority of households, but it may also mean poor business to farmers! The point is motivated by self-interest - a developed market will see farmers switch livelihoods to avoid predicted damages from climate variability. With livelihood diversification as an adaptation strategy to reduce vulnerability to climate change impacts, an adaptation policy needs to focus on developing tools and policy instruments to facilitate diversification into higher value activities.

5.3 Perceived Impact of Climate Variability on Livelihoods

An overwhelming majority (98%) of the respondents opined that rainfall patterns had changed in the last twenty years. This response was strong across gender, age and agro-ecological zones. The main indicator of change in rainfall patterns was mainly attributed to increase in frequency of extreme events (specifically prolonged drought) and change in rainfall amount as shown in Figure 5.2.

When analyzed by sites, a higher number of the respondents at Kathangacini (43%) and Marimanti (48%) considered change in rainfall amount the main evidence of the change in rainfall patterns. While a higher number of respondents at Tunyai (48%) and Chiakariga (38%) regarded extreme events as the evidence to change in rainfall patterns. This was a little strange given that Tunyai – LM4 receives higher rainfall and therefore cases of prolonged drought would not be expected as compared to Kathangacini and Marimanti which are drier. Nonetheless the perception vindicates results of rainfall analysis by seasons which show that OND and annual rainfall have been persistently below normal. Interviews with practitioners and policy-makers show that erratic rainfall and drought are among the leading challenges to resource exploitation in Tharaka District. Out of the 24 respondents interviewed, 20 answered in the affirmative that rainfall variability was a constraint to resource-use. The question that followed was: which livelihoods and natural resources are most affected by variation in rainfall?

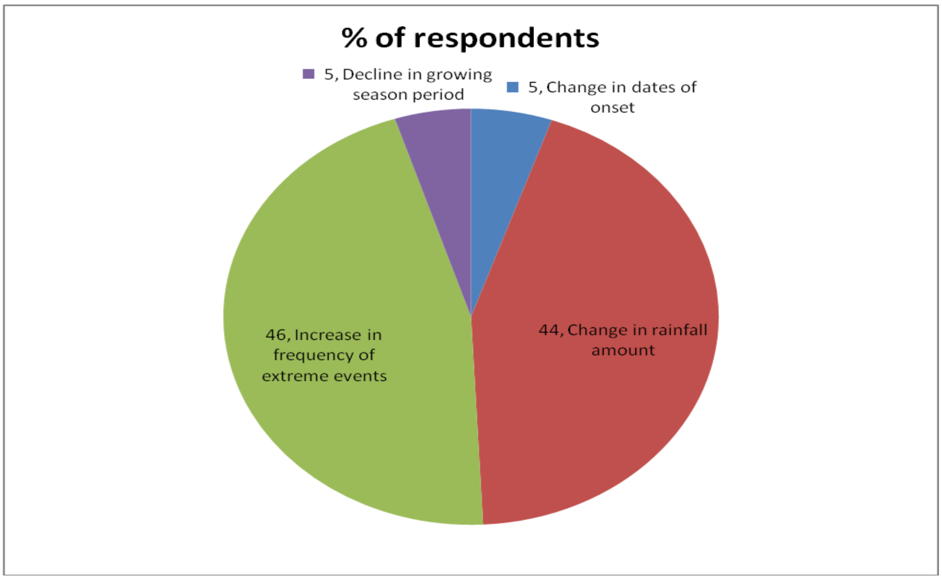


Figure 5.2: The main indicator of changed rainfall patterns in the last twenty years
Source: Field data, 2009

Respondents were asked to rank the severity of rainfall variability on varieties of livelihoods and natural resources. A total of twenty-five potential impacts of rainfall variability were listed and respondents were asked to rate the severity of rainfall variability on each of them. Frequency distribution results in Table 5.4 shows that crop failure (90.5%), increase in foodstuff prices (90.2), increase in farm input prices (79.1%), livestock death (78.5%), crop destruction (76.4%), low pasture productivity (72.7%), unexpected sale of livestock (70%) and reduction in water availability (73%) were the most severely affected by extreme climate events. The impact of rainfall variability on land degradation (42.3%), infestation of water by pathogens (39.9%), destruction of infrastructure (39.3%) were perceived to be moderately severe. The least affected with rainfall variability were remittances, reduction in sale of forest products and over exploitation of forest resources.

To detect any underlying structure in the relationship of these variables, factor analysis was used. Using Kaiser criterion, factor analysis classified variables into seven main factors – which explained 65.4% of the variance with an eingen-value of 16.4 (Table 5.4). In the Kaeser criterion, only variables with an egeinvalue exceeding 1 and high loading exceeding 0.5 were considered.

Factor 1, named livestock related impacts explained 25% of the variance with an eigenvalue of 6.2. These included death of livestock (0.84), unexpected sale of livestock (0.82), reduction in livestock products (i.e milk, skins and hides) (0.77), and low pasture production (0.71). Factor 2 was named water and forestry products which explained 12% of the variance. High loading for water and forestry products were reduction in irrigation water (0.71), infestation of water by pathogens (0.70), trek long distances in search of water (0.54), reduction in sale of forestry products (0.63) and overexploitation of forest resources (0.57). With the exception of increased post harvest losses, factor 3 were market and income related, accounting for 7.4% of the variance. In this category, variables with high loading were reduced access to market (0.72), reduction in remittances (0.57) and unexpected sale of household assets (0.80). It is possible that due to the poor state of roads in Tharaka, rainfall seasons are characterized by impassable roads. Prolonged drought reduces employment opportunities for those depending on on-farm wages and small businesses in the nearby trading centres. This therefore may reduce cash remittances especially for those in rural Tharaka. As a result, households resort to sale of household assets such as radio, bicycle or ox-plough; to raise income to meet household's basic requirements.

Variables with higher loading in factor 4 - accounting for 6.4% were: pests & diseases (0.58), loss of soil fertility (0.56), reduction in sources of credit (0.76) and increase in malnutrition (0.54). While variables with higher loadings in factor 5 were crop failure (0.74) and crop destruction (0.85) and they accounted for 5.4%. Although there was no discernible pattern (in terms of grouping) of variables of factors 4 and 5, it is implied that rainfall variability affects crop farming through pest & diseases and land degradation and this subsequently affects food security. Factor 6 and 7 accounted for 5.0% and 4.0% of variance respectively. Factor 6 had destruction of infrastructure as the only variable with a high loading (0.79) while factor 7 had increase in prices of seeds (0.75) and food (0.81) as the main variables. In Tharaka, all weather roads are usually impassable during the rainy season and a threat to human life as there are flooded with seasonal rivers. The district has a short stretch of tarmac road (less than 15km) that connect Kathwana (in Meru South) and Chiakariga. In most cases, there are no bridges and therefore during the rainy season, rivers flood and cut off roads - making movements within the district difficult and risks people's lives as they can be swept by the raging river as they attempt to cross over. Flooding roads make provision of support programs such as relief food and supply of farm inputs and household needs difficult.

Table 5.4: Rating of impact of climate variability on livelihoods and household resources

Impact	**Ranking of severity (%)**			**Factors loadings (F)**						
	Most severe	**Moderately Severe**	**Not severe**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
Crop failure/reduced yield	90.5	7.7	0.1	0.34	0.06	-0.08	0.23	**0.74**	-0.08	0.11
Crop destruction	76.4	21.5	1.5	0.10	0.06	0.05	-0.02	**0.85**	0.00	-0.04
Low pasture production	72.7	20.9	5.8	**0.71**	-0.03	0.02	0.13	0.27	-0.01	0.03
Pest & disease infestation	61.3	29.1	8.6	0.44	0.01	0.11	**0.58**	0.09	0.12	0.02
Loss of soil fertility/land degradation	46.3	42.3	10.4	-0.01	0.05	0.36	**0.56**	0.27	-0.33	0.02
Low demand for agricultural labour	54.0	38.3	6.7	-0.10	0.31	0.42	0.02	0.38	0.29	0.21
Increased prices for seed & fertilizers	79.1	18.7	0.6	0.04	0.27	0.03	0.20	0.02	-0.10	**0.75**
Increase in market price for purchased foodstuffs	90.2	8.0	0.9	0.12	-0.16	0.03	-0.12	0.03	0.11	**0.81**
Destruction/loss of infrastructure	37.1	39.3	22.7	0.02	0.18	0.24	0.15	-0.03	**0.79**	0.02
Reduced access to markets	44.2	32.8	22.1	0.00	0.23	**0.72**	0.24	0.04	0.21	-0.02
Increased post harvest losses	57.4	25.5	16.3	0.13	-0.12	**0.70**	0.23	0.07	0.04	-0.03
Reduction in credit sources	49.1	31.0	19.0	-0.05	0.03	0.26	**0.76**	-0.02	0.19	0.04
Reduction in remittances	35.6	35.6	27.9	-0.13	0.19	**0.57**	0.39	-0.09	0.07	0.09
Unexpected sale of HH durables/assets	55.2	25.2	18.7	0.16	0.14	**0.80**	0.00	-0.03	-0.01	0.04
Death of livestock	78.5	13.2	7.4	**0.84**	0.08	-0.01	0.11	0.10	0.01	-0.01
Unexpected sale of livestock	69.9	20.9	7.1	**0.82**	-0.05	0.19	-0.07	0.04	0.10	0.02
Reduction in production of livestock products (e.g milk)	73.3	20.2	5.5	**0.77**	0.26	-0.04	-0.07	-0.04	-0.11	0.18
Reduction in water availability for irrigation	69.9	25.5	3.4	-0.07	**0.71**	0.14	-0.01	-0.19	-0.22	0.13
Long distance to fetch water for domestic use	62.6	23.0	13.5	0.41	**0.54**	-0.15	0.35	0.07	0.24	-0.03
Infestations of water by pathogens	42.9	39.9	16.3	0.19	**0.70**	0.07	0.18	0.09	0.19	0.01
Increase in human diseases.	64.4	26.4	8.3	0.48	0.47	0.15	0.35	0.01	-0.04	-0.01
Increase in malnutrition cases	63.2	25.8	8.0	0.16	0.40	0.17	0.54	0.07	0.00	-0.02
Long distance to trek with animals in search of water.	61.0	24.8	13.2	0.45	0.47	-0.03	0.38	0.05	0.36	0.01
Reduction in sale of forest products	33.7	38.7	22.7	0.02	**0.63**	0.17	0.01	0.38	0.23	-0.03
Over exploitation of forest resources	46.3	23.0	25.5	-0.05	**0.57**	0.40	-0.11	0.32	0.32	0.02
Eigenvalue				**6.2**	**3.0**	**1.9**	**1.6**	**1.4**	**1.3**	**1.0**
Tracer				**24.9**	**12.1**	**7.4**	**6.4**	**5.5**	**5.5**	**4.0**

It is possible that as one of the ASAL districts mostly associated with drought, flooding in Tharaka District may be overlooked yet floods have been found to be a hazard and damaging even in drought prone areas as was established by Tarhule (2005) in Niger's Sahelian region. This calls for a need to evaluate the frequency and impacts of floods in Tharaka – both on ecosystems and livelihoods.

Practitioners and policy-makers observed that the impact of rainfall variability on livelihoods and natural resources ranged from very severe to moderately severe as shown in Table 5.5. The practitioners view was that crops are hardest hit by rainfall variability than forest products, livestock, business opportunities and water resources among others. This could be observed on fields where maize failed due to lack of adequate rainfall (Plate 5.1). However more drought tolerant crops such as pigeon peas and fruit trees (especially pawpaw and mango) could still be seen standing on fields. Livestock, especially goats are browsers and therefore can withstand rainfall variability. Whereas factor analysis results show that households perceive the impact of rainfall variability to be severest on livestock related variables, practitioners opined it was crops. This may be attributed to many households in semi-arid Tharaka seeing themselves more as pastoralists than agriculturalist. This attitude may by itself be positive given the higher level of adaptability associated with livestock compared to crops. But livestock keeping potentially has its limits. A study by Burke (2004) showed that in Namibia, available grazing rather than access to water appeared to limit stock densities, particularly in the drier areas. With increasing population and land adjudication in Tharaka (Smucker, 2003), keeping of large herds of animal may be a major constraints due to the expected decline in land carrying capacity and limited community land.

Table 5.5: Perceived impact of rainfall variability on livelihoods and natural resources- the practitioners view (N= 24).

	Severity of rainfall variability		
	Very severe	*Moderately Severe*	*Not severe*
Crops	16	8	-
Livestock	12	12	-
Water	13	10	1
Forest products	5	13	6
Non-wood forest products	13	9	2
Business/trade	13	10	1
Employment opportunities	13	10	1

Source: Field data, 2009

Plate 5.1: A field of maize and sorghum that failed due to inadequate rainfall

Source: Field data, April 2011. Chief's Camp Tunyai

The permanent rivers such as Thingithu, Tana and Kathita in the district turn out to be alternative sources of water for domestic use and livestock watering. The setback is when households far off the rivers have to walk long distances to fetch water. In a perception study on risk to livelihoods in semi-arid Tanzania, Quinn et al. (2003) found water availability as the highest ranked risk (threat) to livelihoods, being most prevalent among agro-pastoralist and pastoralist than agricultural respondents. In Tharaka, water related impacts appear to be a lesser problem compared to livestock impacts; perhaps due to the fact that the district has eight permanent rivers with several other seasonal rivers traversing it. However, climate variability affects the quantity and quality of water, making it a significant problem in Tharaka. In the rainy season, water quality is affected following flooding arising from up-stream human activities. According to Kundezewicz et al. (2008), the projected rainfall increase is likely to increase pathogen load and reduce water quality in East Africa. The increase in distance to reach watering point is of concern to people of Tharaka as indicated by their low satisfaction level. Although the impact of rainfall variability on forest products is not severe in Tharaka, prolonged drought can reduce the purchasing power of buyers. Prolonged drought may also result in high food stuff prices. A study by Brown et al. (2006) shows that in some of the Sahel countries (Mali, Burkina Faso and Niger), growing season vegetation productivity was related to prices of millet at annual and seasonal timescale. Thus, if a growing season was characterized by erratic, sparse rainfall, it resulted in higher prices and well-distributed abundant rainfall in lower prices. This fact is corroborated in this study with the high loading on increase in food prices in factor 7. With a significant number of households relying on on-farm employment, variations in rainfall make scarce these opportunities - leaving the concerned households vulnerable.

In summary, most livelihoods and related resources are perceived to be severely affected by climate variability; and livestock and water related impacts are the most felt. This is expected given the community's over-dependency on livestock as a main source of livelihood. The high proportion of respondents stating severe impacts of climate variability is evidence of the high level of awareness of their level of vulnerability and weak adaptive capacity. As Hansen (2002) put it, awareness in itself presents an opportunity (entry point) to reduce vulnerability. This would include promotion and diversification of livelihoods that are adaptive to the climatology of the district, and appropriate use of early warning information. Factor analysis results show that there is discernible pattern on the effect of climate variability on livelihoods natural resources, with livestock, water and forestry resources explaining most of the variance. Results of factor analysis show that impact of rainfall variability accounts for 65.5% (34.5% is unaccounted). It is postulated that 34.5% can be accounted by quantifying the magnitude of rainfall impacts on each of the identified factors. This will provide the magnitude of the impact – other than perception. Nonetheless, these results are significant as they provide direction on the most affected livelihoods and natural resources and the direction adaptation efforts should take.

5.4 The Place of Climate Variability as a Stressor in Tharaka District

This sub-section presents results of focus group discussions with local communities and views of the practitioners on how important climate variability as a stressor was compared to other socio-economic and environmental hazards. The sub-section further evaluates the satisfaction level of social amenities and community understanding of the basic terms in climatology and causes of climate change and variability.

5.4. 1 Socio-economic Stressors and the Place of Climate Variability

Figure 5.3 shows the results of respondents' perspective on individual problems. The most frequently identified stressors by incidence index (I) were lack of money (0.81), drought (0.73), bad health (0.71) and livestock diseases (0.71). Other stressors that had a higher incidence index (I> 0.5) were poor soils, lack of pasture, lack of farm inputs, low quality food, low agricultural productivity, cost of education, irregular rains, lack of employment and water scarcity. In terms of severity, water scarcity and lack of money scored the least (1.2) – thus they were the most severe of the stressor. Problems such as irregular rains, lack of employment, lack of pasture, livestock diseases and bad health presented medium risk. All medium to severe risk stressors also recorded a higher incidence.

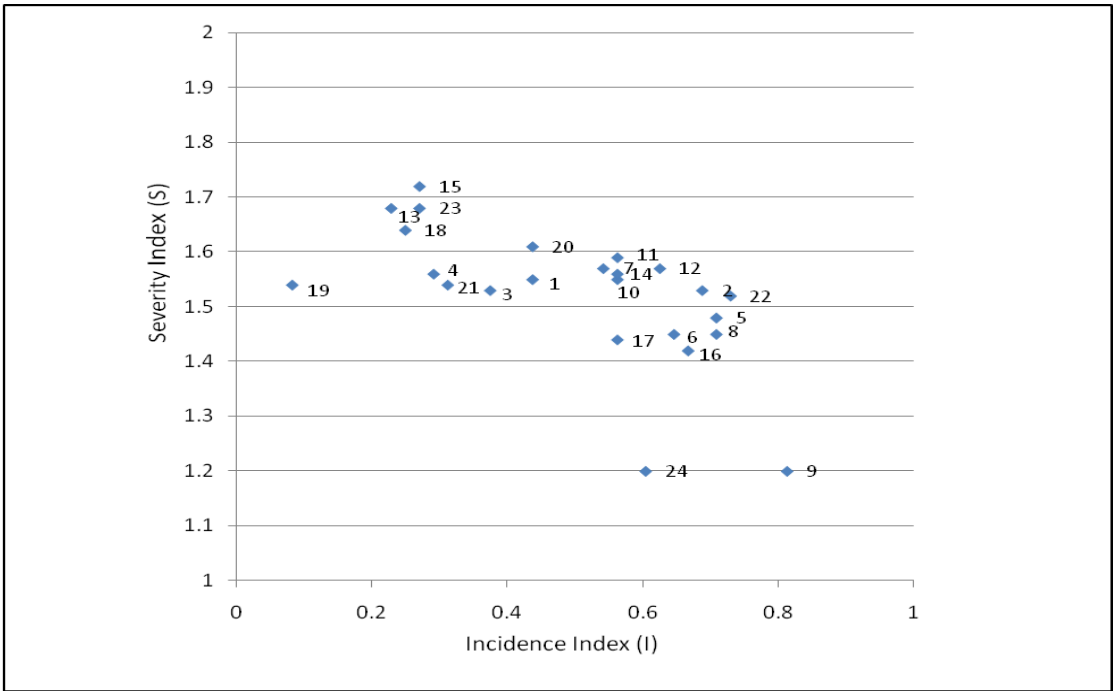


Figure 5.3: Risk Index map overview. The severity index ranges from 1 (most severe) to 2 (least severe) while the incidence index ranges from 0 (not mentioned) to 1 (mentioned by all). Refer to Table 5.6 (column 1 & 2) to infer the codes for each stressor.
Source: Field data, 2009

Scrutiny of the results by study sites (AEZ) show that water scarcity was the most severe stressor at Tunyai – LM4 (1.2), Chiakariga – LM5 (1.3) and Kathangacini – IL6 (1.4), while lack of money was the severest stressor in Marimanti (IL5) (See Appendix 6). Besides Marimanti, Chiakariga also rated lack of money (1.3) as a severe stressor. Results at Tunyai were of interest; besides water scarcity, drought (1.2) and irregular rains (1.3) were ranked severe stressors than at any other site. The high ranking of lack of money at Marimanti can be attributed to its increasing urbanization. Thus as a district headquarter, the expectations of the people in Marimanti were to secure employment in government and the growing employment opportunities in non-governmental organization. Tunyai, a LM4 zone has a majority of the people as agriculturalist. Thus, to them water scarcity, drought and irregular rains are very severe stressors.

When severity results are analyzed by gender, lack of money and bad health ranked highest among women than men. In the other top stressors (water scarcity, lack of employment, lack of pasture and livestock diseases, men gave a higher ranking than women. The severity of irregular rains (1.4) was perceived in the same way by both men and women. It is possible that since women are the fulcrum of household activities, especially in terms of food stuffs, they feel more the burden of lack of money than men. On the other hand, men, regarded as overall providers in the household, who also have the overall responsibility on livestock, are more worried with unemployment (1.4) and lack of pasture (1.4) than women.

When analyzed by age, lack of money and scarcity of water were rated as severe stressors by both the youth and adults. But the youth (age 18-35years) were also worried about lack of employment (1.4) and bad health (1.4). On the other hand, adults (age 36 years and above) were worried about irregular rains (1.4), lack of pasture (1.4) and livestock diseases (1.4). Given, the youth are keener on securing employment while adults are more concerned with irregular rainfall which is key to livestock keeping and crop farming. Generally, one would expect 'adults' to be more concerned with their health than the young. But in this study, the youth are more worried of their health than the 'adults'. The high ranking of bad health among the youth can be attributed to the HIV/AIDs pandemic which currently has no cure. The youth are the more vulnerable given that they are more sexually active than the 'adults'.

Table 5.6 shows the total risk index for all the stressors, and also the risk index by agro-ecological zones, gender and age. Overall, stressors with the most acute risk were lack of income (0.70), need for water storage facility (0.51), bad health (0.51) and livestock diseases (0.50).

Table 5.6: Summary of subjective risk index (R) of the sample population by AEZs, gender and age. The index ranges from 0 (no incidence of risk) to 1 (most severe risk).

No	*Stressor*	*Risk Index (I)*	*Main agro-ecological zone*				*Gender*		Age	
			LM4	*LM5*	*IL6*	*IL5*	*Men*	*Women*	Youth	Adult
1	Deforestation	0.29	0.30	0.33	0.25	0.28	0.29	0.29	0.29	0.29
2	Poor soils	0.47	0.44	0.49	0.44	**0.52**	0.46	0.47	0.49	0.45
3	Conflict	0.26	0.24	0.32	0.28	0.23	0.25	0.28	0.26	0.26
4	Pollution of rivers	0.19	0.22	-	0.18	0.15	0.22	0.17	0.19	0.19
5	Livestock diseases	**0.50**	**0.51**	0.47	**0.52**	0.48	**0.52**	0.49	0.47	0.52
6	Lack of pasture	0.46	0.46	0.47	0.47	0.46	0.48	0.45	0.45	0.47
7	Lack of farm inputs	0.36	0.34	0.40	0.35	0.35	0.37	0.34	0.35	0.36
8	Bad health	**0.51**	**0.52**	0.42	**0.53**	0.49	0.45	**0.55**	**0.52**	**0.50**
9	Lack of money	**0.70**	**0.72**	**0.62**	**0.58**	**0.79**	**0.66**	**0.76**	**0.72**	**0.69**
10	Deficient/low quality food	0.37	0.34	0.37	0.41	0.41	0.34	0.40	0.38	0.36
11	Food insecurity	0.37	0.36	0.41	0.35	0.36	0.37	0.36	0.39	0.35
12	Low agricultural productivity	0.41	0.44	0.44	0.37	0.39	0.43	0.39	0.42	0.41
13	Lack of seeds	0.14	-	0.14	0.14	0.13	0.13	0.14	0.13	0.14
14	Cost of children education	0.37	0.35	0.40	0.37	0.38	0.36	0.38	0.32	0.39
15	Skill acquisition /training	0.16	0.14	0.17	0.17	0.16	0.16	0.16	0.17	0.16
16	Irregular rains	**0.49**	**0.55**	0.47	0.48	0.48	**0.50**	**0.49**	0.46	**0.51**
17	Lack of employment/work	0.41	0.42	0.39	0.41	0.41	0.42	0.40	0.42	0.39
18	Scarce social amenities	0.16	0.13	0.15	0.18	0.15	0.15	0.16	0.16	0.15
19	Poor infrastructure	0.06	0.25	0.30	0.23	0.32	0.04	0.06	0.04	0.06
20	Poor roads	0.28	0.25	0.30	0.23	0.32	0.29	0.28	0.25	0.30
21	Poor housing	0.28	0.18	0.21	0.23	0.21	0.22	0.20	0.19	0.22
22	Drought	0.21	**0.64**	0.40	**0.51**	0.47	**0.53**	**0.50**	**0.53**	0.48
23	Water storage facility	**0.51**	0.14	-	0.16	0.17	0.18	0.16	0.16	0.17
24	Water scarcity	0.16	**0.54**	**0.51**	**0.53**	0.40	**0.51**	**0.50**	**0.52**	**0.49**
	Sample size	**48**	**15**	**10**	**12**	**11**	**21**	**27**	**20**	**28**

Source: Field data, 2009

When the risk index results are analyzed by agro-ecological zones, gender and age, lack of money stood out as a stressor of acute risk. A breakdown of results by agro-ecological zone show that in LM4 (Tunyai), lack of money, drought, irregular rains, livestock diseases and water scarcity are the stressors with the most acute risk. Respondents in LM5 (Chiakariga) perceived lack of money and water scarcity as stressors with the most acute risk. In addition to lack of money, people in IL6 (Kathangacini) were more at risk with livestock diseases and drought. Those in IL5 (Marimanti) were most concerned with lack of money. Although lack of money and scarcity of water are stressors under acute risk in the four main agro-ecological zones, there are differences in perception of the other stressors. The high ranking of drought and irregular rainfall in LM4 is informed by the agricultural tendencies of people who are hardest hit when seasonal rains fail or drought persists. People in (IL6) Kathangacini are more stressed with drought and livestock diseases. In LM4, some households keep dairy animals and rely on animal products such as milk. Thus, drought not only implies lack of pasture but also a decline in milk production. Whereas in IL6 (Kathangacini), drought implies walking for long distances in search of pasture and in some cases, livestock death. Lack of pasture is usually a recipe for conflict especially along the Tharaka-Tigania boundary. The harsh climate of IL5 (Marimanti) makes rain-fed farming difficult. This is complicated further by the growing population which has led to land fragmentation. To the people in Marimanti, access to employment opportunities or other income generating opportunities are of major concern.

There were no major differences in the way men and women perceived lack of money, drought and water scarcity as stressors of acute risk. However, men were more worried with the risk of livestock diseases and irregular rains. These two stressors definitely impact on their ability to provide or sustain livelihoods as heads of family. Analyzed by age, there were no major differences in the rating of lack of money and bad health. There were however differences in the way irregular rains, drought and water scarcity were perceived as stressors of acute risk. Whereas 'adults' perceived irregular rains as a major threat, the 'youth' thought drought and water scarcity were most threatening.

Analysis of individual perception of stressors yield an understanding that lack of money, water storage facility and bad health are the most acute risk stressors. Irregular rains - a climate related stressor is ranked moderately. A breakdown of results however show drought as a major stressor in two AEZs and by gender. The dominance of water scarcity as a stressor may also indirectly infer to the impact of rainfall variability on water availability for livestock and domestic use. The high ranking of lack of money as a stressor is a reflection of the central role money plays in supporting livelihoods. But how does the community perceive and rank stressors and how do they cope with them?

FGD participants, as a group, were asked to list and rank 10 main stressors that concern the community. Results of this ranking are presented in Table 5.7. It is important to note that whereas there were differences in the ranking of stressors at community level, irregular rainfall was the only stressor listed and ranked in the four sites of study. As a stressor, irregular rains received the least ranking in Tunyai (8^{th}) and highest ranking in Marimanti (1^{st}). Drought, another climate variable, was ranked as a stressor in three of the four study sites.

Table 5.7: Ranking of major stressors in the community.

Stressor	***Rank***			
	LM4 (Tunyai)	*LM4-5 (Chiakariga)*	*IL5 (Marimanti)*	*IL6 (Kathangacini)*
Deforestation		8	10	
Poor soils		4		
Conflict				10
Livestock diseases	10		6	4
Lack of pasture	5	5		
Bad health	2			8
Lack of money			2	2
Food insecurity	4	3	8	
Low agricultural productivity	6		7	
Lack of seeds				9
Cost of children education	9		5	6
Skill acquisition/training		6		
Irregular rains	**8**	**2**	**1**	**3**
Lack of employment/work		7	3	7
Poor roads	7	9	4	
Drought	**1**	**10**		**5**
Water storage facility	3			
Water scarcity		**1**		**1**
Lack of banking facility			9	

Source: Field data, 2009

The ranking of irregular rainfall and drought was informed by their impact on crop yields, quality of pasture, livestock, water accessibility and food insecurity. To participants in LM4 (Tunyai), drought, bad health and water storage facility were their main problem. In LM4, livestock related stressors are viewed by the community as a lesser problem. As a remote area, hospitals/dispensaries are far apart and therefore people walk long distances in search of medical attention. The FGD participants in Kathangacini observed that the area has only one health centre which is usually inadequately equipped. The perception of water storage facility as a major problem may be informed by a need for more boreholes to offer an alternative source of water and reduce the distance of walking long distances to streams.

In LM5 (Chiakariga), water scarcity, irregular rains and food insecurity are the lead problems. Although drought is ranked 10, its persistence is a major cause of food insecurity and water scarcity in LM5. In Chiakariga, Kijege forest and the neighbouring hills are being decimated to create room for farmland and charcoal burning. According to residents, deforestation of these hills is a major concern since it has altered climate and reduced grazing area especially during the dry season. Similar concern for deforestation was expressed by participants from IL5 who attributed the wrong practice to the budging population in Marimanti. Deforestation was however a lesser problem in IL5 when compared to irregular rains and lack of money.

FGD participants in IL6 identified water scarcity and irregular rains as major stressors. They however rated conflict, unlike other sites as a challenge. To the inhabitants of Kathangacini, they are regularly faced with cattle rustling and attacks from the neighbouring Isiolo County. These raids rob them their main livelihoods – livestock and leave them more vulnerable. Kok et al. (2009) argued that land conflict is particularly common where alternative livelihoods are absent (cited in Bob & Bronkhorst, 2010). This scenario can be exacerbated by desertification, unsustainable use of resources or drought can bring communities with competing livelihoods into further conflict. Conflict can therefore be seen not only as a cause of human insecurity but also one that enhances vulnerability to climate change.

From a practitioner and policy-maker perspective, limited social amenities and poor roads are the leading constraints to resource exploitation (Fig 5.4). Specific reference was made to the unsatisfactory state of health and educational facilities and the inaccessibility of the district due to poor roads. Other constraints mentioned by a higher number of practitioners were high levels of poverty, erratic rainfall/drought and illiteracy. Cultural practices such as overstocking and the communities' negative attitude towards irrigation were cited as constraints to resource exploitation. The continued prevalence of these practices was attributed to lack of awareness and high illiteracy level within the community.

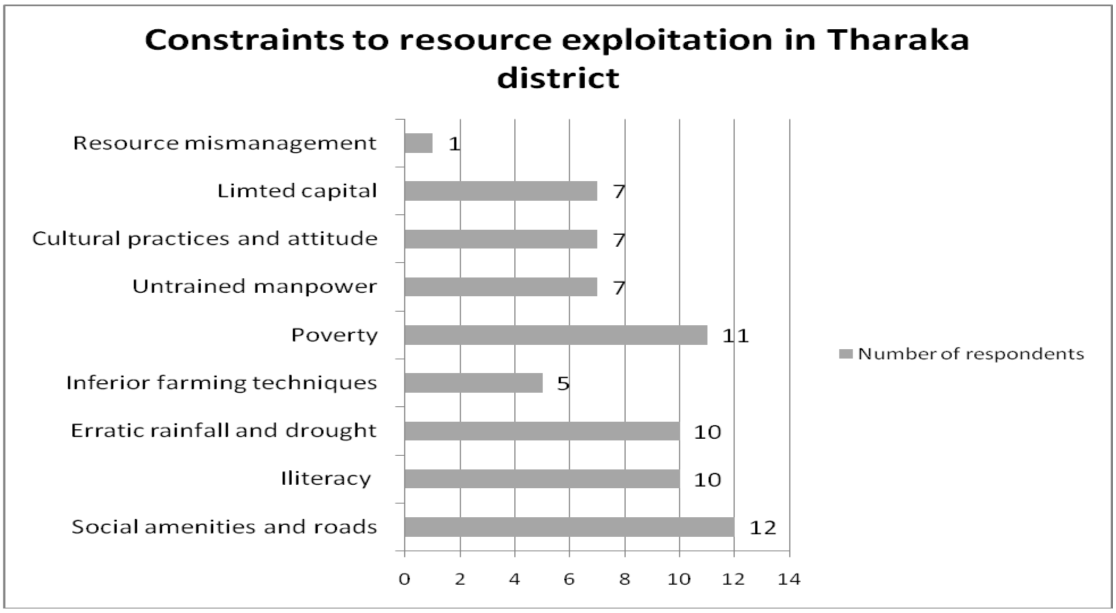


Figure 5.4: Constraints to resource exploitation in Tharaka District - practitioners' perspective.
Source: Field data, 2009

In conclusion, a comparison of individual and community ranking of stressors show that climate related stressors, namely: drought and irregular rainfall are more acknowledged at the community level than at household level. Practitioners and policy-makers regarded the poor state of roads and social amenities and poverty as the lead constraints to resource exploitation. Divergence in perception among groups to climate change and adaptation is also found in Ebi, Paggham, Doumbia, Kergna, Smith, Butt & McCarl (2011) where farmers were more focused on addressing risk associated with climate variability, while agricultural experts and extension agents emphasized management options to reduce current and future vulnerabilities. There is however a convergence of thought between practitioners and individuals as illustrated by the high incidence index for lack of money and poverty as constraints to adaptation. The desire to have money is largely informed by high levels of poverty - a product of the difficult environmental (read climate) and developmental challenges that affect Tharaka. Shiferaw & Bantilan (2004) attributes this state of affair, particularly in less favoured areas of the arid and semi-arid tropics, to unfavourable policies, lack of markets and institutional structures that prevent smallholder farmers from undertaking profitable resource improving investment. Lacking infrastructure and basic social amenities, the people of Tharaka have been left very much on their own – weakening their livelihood support systems.

It is clear from this analysis that whereas rainfall variability is an acknowledged constraint to resource exploitation and a stressor at the community and individual level, it is not the severest. This relate to those of Lorenzoni & Pidgeon (2006) who established that although there is wide spread concern about climate change in Europe and United States of America, it is of secondary importance in comparison to other issues in people's daily lives. To address adaptation to climate variability in Tharaka District, one has to first address the high poverty levels and the wanting state of roads and social amenities. These findings relate to earlier studies of practical adaptation initiatives that have revealed that impacts of climate variability are experienced in the context of other changing conditions (environmental, socio-economic, political) and that vulnerabilities are rarely to climate change stimuli alone.

5.4.2 Satisfaction Level of Social Amenities.

Noting the importance of social-amenities and infrastructure in enhancing community's adaptive capacity, the study sought to examine households' level of satisfaction. Fig 5.5 shows a majority of respondents were not satisfied with accessibility to social amenities. Access to primary level school received approval of about 50% of the respondents. Marimanti and Kathangacini had the highest number of respondents who disapproved accessibility to health centres, small markets and secondary schools. Disapproval of proximity to a large market and district headquarters was highest across the four sites. This included those at Marimanti, the district headquarters. At least 57% of the respondents at Chiakariga and 50% at Tunyai were satisfied with the distance to tertiary level institutions. Nearly 40% of the respondents were satisfied and not satisfied with accessibility to roads in Tharaka. The highest proportion of those satisfied with roads came from Chiakariga while the highest proportion of those not satisfied came from Tunyai.

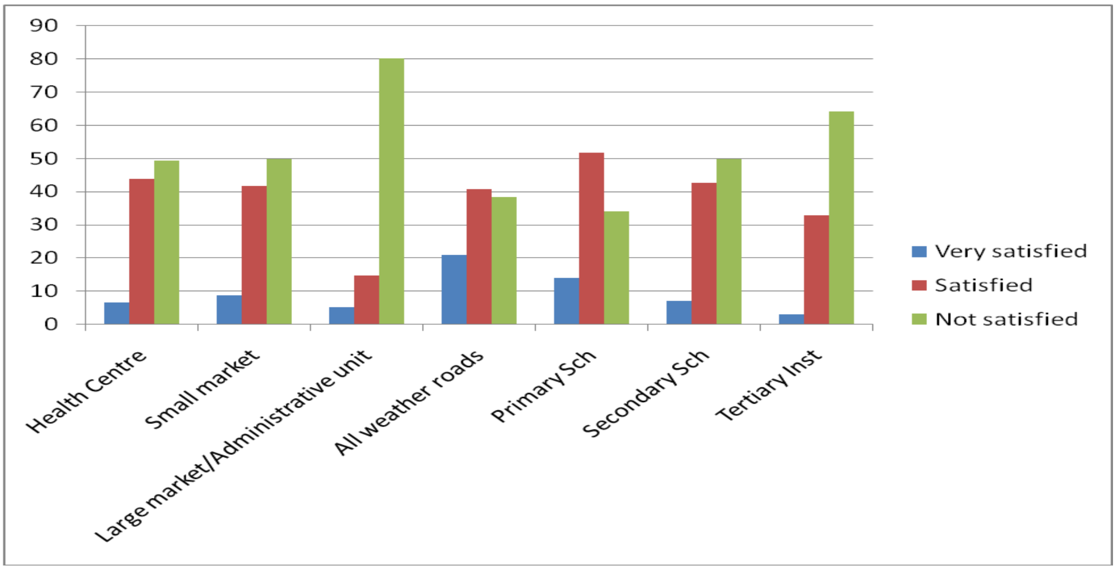


Figure 5.5: Rating of satisfaction level of social amenities in percentage (%)
Source: Field data, 2009

Results of X^2 test ($p<0.05$) found the rating of satisfaction level by study sites significant for all the social amenities (Appendix A3), implying the rating is a vindication of the wanting state of social amenities in Tharaka District. In cases where the social amenities exist, their quality was below par and service delivery poor. For instance, accessibility to hospital alone may not yield satisfaction since services in some are poor and in most cases, charges are beyond the reach of many. The hospitals in Tharaka do not necessarily charge high fees (between Ksh 20-100) since most of them are either mission or government sponsored hospital. Due to high poverty levels, majority of patients cannot afford to secure treatment. The high number of respondents dissatisfied with the distance to hospital in Kathangacini can be attributed to the very remote location of the area. To the people of Kathangacini, they have to travel for over 40km to reach the district hospital located at Marimanti. An inaccessible administrative unit alienates residents from mainstream policy and development programs. In particular, when government or other development agencies launch programs aimed at reducing community vulnerability to impacts of climate change (e.g relief food or work for food programs), this information can potentially fail to reach the most affected. The solution to this would rest in investing in infrastructure (mainly roads and information dissemination channels) to simplify information flow at the village level. Despite the high proportion of respondents not satisfied with tertiary education institutions, at least more than half of them at Chiakariga and Tunyai were satisfied. This is not surprising given that in Chiakariga, there is the Kenya Water Institute – the only government tertiary-level institutions in the district. At Tunyai, satisfaction for access to tertiary institutions can be attributed to the site's proximity to the Meru County which has a number of training institutions. The approval of roads at Chiakariga can be attributed to the tarmac road that connects Kathwana (in Meru South) and Chiakariga. In Tunyai, the roads are usually impassable during the rainy season and very dusty during the dry season.

These findings point to the need to examine socio-economic factors impending adaptation to climate change and variability by households rather than focusing on climate variability in isolation. A study by Shisanya and Khayesi (2007) found that despite residents of Nairobi, Kenya being prone to extreme climate events, they considered corruption, crime, street children and waste management as more critical problems than global warming. In Senegal, Tschakert (2007) found that bad health, lack of money, lack of quality food were the main worries among the people living in the Old Peanut Basin. Climate did not feature in peoples' risk assessment in Senegal. It would therefore be prudent to address issues of roads, literacy, water supply, health, employment as part of the initiative to address the bigger problem of climate variability and adaptation in Tharaka District.

5.4.3 Conceptual Understanding of Climate Change and Variability

In a subsequent step, FGD participants in the four study sites were asked to describe what the terms climate, weather, climate variability and climate change meant to them. They were further asked to describe rainfall regime of their area and outline consequences of climate variability in their communities. None of the four groups described weather. An attempt to get a Kitharaka word for weather and climate proved futile. This was despite having very elderly participants of over 75 years. Climate was invariably described as variations in wind, temperature or rainfall. Climate was further understood as the annual change of weather. According to participants, seasons of high and low rainfall, cold and hot represent climate. Climate variability was seen more as variations of seasons. Participants described *nthano* (March-May season); *muratho* (October- December season); *thano* (dry period of August-October) and *kiathu* (the February-March dry period). Respondents further referred to climate variability as the annual variation of seasonal rainfall.

The term climate change was very familiar with the participants as they had heard it from the radio and agricultural officers. They associated climate change with change in weather elements in a specified period. To illustrate climate change, participants gave an example of how the 1970s were relatively cold compared to the present. Participants associated climate change with charcoal burning and industrial pollution which are 'tearing the sky apart'. There was unanimous agreement that there was climate change in Tharaka and this was attributed to cutting of trees which had a cooling effect on the environment.

According to FGD participants, the most notable element that confirmed climate change and variability was change in rainfall patterns. They opine that rainfall onset & cessation have changed, and within-season rainfall distribution has become irregular today when compared to the past (reference made to the 1970s and early 1980s). For instance, in the past, onset for MAM and OND seasonal rains was in early March and mid October respectively. While cessation for MAM and OND used to occur in the end of May and early January respectively. In fact for MAM, participants opined that the months of June and July were characterized by drizzles in the past. At present, Tharaka people reported to receive late onsets, early cessations and growing seasons have increasingly become unreliable due to uneven distribution of rainfall. MAM rainfall season is characterized by few rain days in April while OND has its onset in November and cessation is mostly in December. The decreased length of growing season is seen to have reduced crop yield. In the drier IL6 (Kathangacini), participants said unlike in the past, the area can no longer support maize farming, suggesting rainfall variability has altered cropping systems. Early onsets in the past were always associated with high crop yields, something that cannot be said of today. The reduced rainfall amount is also seen to have contributed to the reduced water levels in streams, especially in LM4 (Tunyai).

Results of Focus Group Discussion on onset and cessation differed with those of household survey. A majority of household respondents observed that onset of the MAM and OND seasons was mainly in the 2nd week (34% - March; 28% - October) and 3rd week (49% - March; 51% - October) of March and October. A majority of household respondents opined that cessation usually occurred during the 4th week of

May (35%) during MAM and the 2nd week of January (52%) during OND. Results of household survey show near concurrence with rainfall data analysis in which onset is in the 5th pentad (21-25th of March and October) and cessation of MAM and OND occur on May 11-15 and January 6-10 (Fig. 4.5 & Fig. 4.6). In fact although onset dates are characterized by high inter-annual variability, trend-lines (Fig 4.7a&b) show a tendency towards pentads 5-6 (21st – 30th) of March and October. Thus, analysis of rainfall data does not suggest a trend towards late onset and early cessation as implied by FGD participants. Perceptions of a changing climate are also reported in Ebi et al. (2011) where stakeholders were concerned with the changing and a variable climate and its impact on agricultural yields in Sikasso region – Mali. In Tharaka, the concern for rainfall variability and its impacts can be seen to stem from within-season variability that characterize both seasons and the persistently below normal OND rainfall.

Participants closely linked climate change and variability to environmental degradation. Deforestation and destruction of wetlands to create land for human settlement were cited as the major causes of climate change and variability. Others cited as causes of climate change and variability were pollution of major oceans (through ship transportation), use of pesticides and insecticides (as a result of land surface run-off), and God's plan. Table 5.8 present results of the consequences of climate variability. A rainy season was seen as a period for business people to make profit. During the rainy season, demand for farm inputs raises and makes it possible for stockists to sale and replenish at a faster rate. Participants at Chiakariga and Marimanti associated good rains with successful tree planting and reduced distance to water point. It is noteworthy that in Chiakariga, rains were associated with increase in water sources. As discussed elsewhere in this work, people in Chiakariga rely on springs and wells which usually dry up during the dry season. Due to lack of supplementary irrigation to support crop farming and limited livelihood options, the negative effects of climate variability included lack of food and malnutrition, limited water supply, rise in food prices and school dropout.

Table 5.8: Causes and consequences of climate variability in Tharaka District

Causes of climate change and variability	**Consequences of climate variability**	
	Positive	*Negative*
God's plan	Booming business for traders and farm input stockists	Lack of food and increase in malnutrition among children
Pollution of major oceans	Tree planting is successful	Scarce pasture
Deforestation	Increased water sources	Limited water supply
Destruction of wetland (*Kinyaka*)	Increase in pasture availability	Increased human and livestock diseases
Use of pesticides and insecticides to pollute air		High prices of food stuffs
		Rise in school drop out

Source: Field data, 2009

From the FGD, it appeared that the words weather and climate are synonymous in Kitharaka. Lack of differentiation of these terms has the risk of failing to tap climate as a resource. This can be corrected by educating communities on quantitative characteristics of climate and generally providing facts of their locality by agro-ecological zones. The community understanding of climate variability and change mirrors standard definition such as given by van de Steeg et al. (2009). However, there were misconception and gaps in understanding the causes of climate change and variability. The correct identification of deforestation, wetland destruction and industrial pollution as causes of climate change and variability can be seen as a product of the increased awareness and can be used to serve as a basis to encourage collective learning on land degradation as observed by Tscharkert (2007). However, to associate climate change and variability with pollution of the ocean and use of pesticides demonstrates a gap in understanding the role of oceans in climate change and variability. It is important to better local community understanding of role of sea surface temperatures, atmospheric winds in climate variability. In East Africa for example, provision of basic information on the role of the ITCZ, monsoons on East Africa climatology (Odingo et al., 2002; Mutai et al., 1998), especially seasonal rainfall; dry seasons and variations in temperature would erode the current misconception on pollution of oceans. Relating good rain season with successful tree planting among participants demonstrate a level of awareness on the need to conserve the environment and to mitigate climate change. Although respondents in IL6 attributed the decline in maize farming to climate change, this should be seen as a realization by farmers that maize farming is not a tenable venture. The choice of maize farming may have been informed by dietary preferences (Finkel & Darkoh, 1991) but persistent failure of the crop over the years may have gradually informed the decision to increase acreage of more drought tolerant crops such as millet and green grams. To associate rise in food prices with climate variability is a statement of the deplorable state of the road network in the district. Although a rainy season will mostly be welcome in Tharaka, roads usually become impassable; cutting off the district with the neighbouring Nkubu (Meru Central) and Chuka (Meru South) trading centres. Thus transport becomes a big challenge and subsequently traders experience difficulty in securing essential items to Tharaka. This unfortunately leads to high prices of these essential foodstuffs and items. The poor roads thus increase people's vulnerability to impacts of climate variability. By the time of writing this thesis, a tarmac road had been constructed from Kathwana (in Meru South) and linked to Chiakariga. It is hoped that the other major road, Nkubu-Marimanti will receive tarmac to open up the district for more trade. Hopefully, this will exit the notion of seeing a rainy season as a hazard that increases their vulnerability. But instead perceive climate as a resource that will enhance their wellbeing.

5.5 Chapter Summary

This chapter has presented results of livelihood activities, perceived impact of climate variability and the conceptual understanding of climate change and variability in Tharaka.

Sale of livestock and crop yields are the main sources of income. A significant population however depends on forest and non-wood forest product and on-farm wage employment. The total number and type of livelihoods in Tharaka mirror differences in agro-ecological zones. People in LM4 and LM5 had more livelihoods and generate more income than those in IL5 and IL6. Similarly, respondents in LM4 and LM5 rely mostly on agriculture and forest and non-wood forest product. Those in IL5 and IL6 draw most of their income from sale of livestock. Despite the variety in livelihoods, income from these livelihoods is very low, a phenomena that weakens adaptive capacity. Livestock & water related impacts are the most affected livelihoods. It would therefore be prudent to prioritize building livelihoods that enable farmers cope better with current climate variability as a first essential step to adapting to climate change in future.

Water scarcity and lack of money (poverty) are the most severe of the socio-economic problems in Tharaka. Although irregular rainfall and drought are acknowledged as problems at individual, community levels and practitioners, fast tracking development of social amenities (such as schools and health centres), construction of roads and poverty reduction are primary to the enhancement of adaptive capacity in Tharaka. People of Tharaka are aware of climate change and variability and its impact on the environment and their wellbeing as illustrated by the FGD and factor analysis results. Respondents associated climate change and variability with deforestation and industrial pollution, showing awareness on the role of man in altering the climate. This awareness should be harnessed into an opportunity to reduce vulnerability. There are however distortions on the causes of climate change and variability such as pollution of the ocean raising a need for a more coordinated and informed sensitization on determinants of climate variability and the role of atmospheric winds and sea surface temperatures.

The next chapter presents results of the state of adaptive capacity to climate variability in Tharaka District.

CHAPTER SIX

6.0 ATTRIBUTES AND INDICATORS OF ADAPTIVE CAPACITY IN THARAKA DISTRICT

6.1 Introduction

This chapter presents results of an analysis of the current state of adaptive capacity at household and community level as identified by Wehbe et al. (2005). Variables of analysis were resource base, cropping diversity and resource access. Results of resource base (soil quality, land tenure & size, livestock ownership, household characteristics and access to machinery) and cropping diversity shall highlight the extent of flexibility in adapting to climate variability. This will take into account community's flexibility and resource availability on one hand and institutional adaptability (e.g technology, infrastructure) on the other hand.

6.2 Household Characteristics and Resource Base

The subsection presents results of the existing resource base at households. Among the variables (indicators of adaptive capacity) are household characteristics (composition, age, and education), land tenure and size, soil quality and livestock ownership.

6.2.1 Demographic Characteristics

The majority of the residents in Tharaka District are in their most productive age: these are 18-35 and 36-55 years who accounted for 40% each. While those aged 56-70 and 70+ years accounted for 13% and 7% respectively (Table 6.1). Seventy-two percent of the households had both resident mother and father while the rest of the households were headed by either the mother (48%), father (30%) and 22% without any of the parents. Households headed by women are more vulnerable to extreme events of climate, potentially leaving them dependant on relief food. Those without any of the parents were headed by first-borns or a relative. The main reason for lack of either of the parents or both parents was death (89%), with a few cases of divorce or separation and away for rural employment.

Table 6.1: A cross tabulation showing sample population by study sites and sex

Location			Age of respondent (in yrs)				Total
			18-35	36-55	56-70	70+	
Kathangacini	Sex	Male	13	13	4	1	31
		Female	19	8	0	0	27
	Total		***32***	***21***	***4***	***1***	**58**
Marimanti	Sex	Male	23	19	3	1	46
		Female	22	18	6	0	46
	Total		***45***	***37***	***9***	***1***	**92**
Tunyai	Sex	Male	11	24	10	9	54
		Female	9	11	3	1	24
	Total		***20***	***35***	***13***	***10***	**78**
Chiakariga	Sex	Male	20	29	15	10	74
		Female	12	9	1	2	24
	Total		***32***	***38***	***16***	***12***	**98**
	Grant Total		***129***	***131***	*42*	***24***	**326**

Source: Field data, 2009

Across the four study sites, each household had an average of four members but there were households with as many as 8 or 9 members (Table 6.2). This is a high population to sustain in difficult time of famine especially for resource-limited households. Households in Tharaka have an average of three children (less than 14 years of age) with the highest having six children. At least 36 respondents stayed with their relatives, majority of whom were in Marimanti. The relatively high number of respondents at Marimanti can be attributed to some of them joining their relatives who are either employed or running business at Marimanti- the district headquarters. The number of households living on-farm mirrors that of total number of household members. Although this is good when it comes to distribution of labour in the family, it would also imply a strain on limited income. Indeed, there were very few respondents who mentioned cash remittances as a source of income. There were only 5 respondents who had employed labourers, a scenario that can be attributed to low income levels among many households. It is possible that with an average of four members, households had the capacity to do their own work – especially farm labour for subsistence.

Table 6.2: Results of household composition

Location		HH members	No. of children	No. of relatives	No. of HH members staying on-farm	No of HH members staying off-farm	HH members: No. with Pri education	HH members: No. with Sec education	HH members: No. with Tertiary education
Kathangacini	N	58	55	5	55	7	58	16	2
	Mean	4.6	2.8	1.6	4.6	2.6	3.3	1.6	1.0
Marimanti	N	92	85	15	88	10	80	50	19
	Mean	4.5	2.5	1.5	4.4	2.3	2.8	1.7	2.1
Tunyai	N	76	70	6	71	22	60	29	19
	Mean	4.4	3.0	1.3	4.2	2.0	3.1	1.6	1.7
Chiakariga	N	98	87	10	95	32	89	41	11
	Mean	4.1	3.0	1.8	3.6	1.6	2.8	1.6	1.5
Total	**N**	**324**	**297**	**36**	**309**	**71**	**287**	**136**	**51**
	Mean	**4.4**	**2.8**	**1.6**	**4.1**	**1.9**	**2.9**	**1.6**	**1.8**

Source: Field data, 2009

6.2.2 Literacy Level

Literacy levels in Tharaka District are very low. Sixty-four percent of all the respondents have primary level education, 16%-no education, 13%-secondary level and 7%-midlevel training. Eighty-six percent of the respondents were peasant farmers with less than 10% of them saying they had acquired skills that enable them earn income. About 10% of the respondents had not attained any formal education, with Marimanti (19.5%) and Tunyai (17%) having the majority. Tunyai had the highest attendance of secondary education (20.5%). Marimanti and Chiakariga had just over 10% of the respondents with secondary-level education. Attendance of mid-level training was reported at Marimanti (11%), Tunyai (6%) and Chiakariga (5%).

Interview with practitioners and development agencies also confirmed that illiteracy was a major constraint to technology uptake in Tharaka District.

Whereas most members had either attained or were attending primary-level education, very few had attained tertiary level education. Yet it is after tertiary education that one can acquire relevant skills and competence that enable him/her to engage in business or secure employment. In a semi-arid district dependant on rain-fed agro-pastoralism, a household member with skills or qualification to secure employment is an asset. But limited training at tertiary level should be seen in the lens of limited secondary education and poverty. For families struggling to make ends meet, raising cash to take a household member to a tertiary institution would appear a luxury they can afford to ignore. To solve the problem, the government and local community can take a two-prong approach: create opportunities to allow a majority join and complete secondary level education. This has partly been addressed by the Grand National Coalition Government of Kenya (2008-2012) which is supplementing secondary education. But are the parents able to pay the remaining amount for secondary education of their children? The other approach would be the establishment or revitalizing of youth polytechnics which would inculcate skills among unsuccessful primary school leavers and secondary school dropouts. Low levels of education limit a society's ability to use technology. Farmers' personal characteristics, education and outlook influence the way he/she searches for and acts upon information received.

6.2.3 Livestock Ownership

Cattle, sheep, goats and poultry are owned by 55%, 34%, 64% and 72% of the households sampled (Fig 6.1). But a sizeable (27%) of the respondents had no livestock. This left the households vulnerable to climate risk, particularly erratic rains which lower yield and leave households prone to famine. Livestock ownership usually comes in handy to households in such times as they are sold to purchase food stuffs. Livestock is regarded as important in the mixed crop-livestock system of the semi-arid areas, which increases resilience of vulnerable people especially in the light of a projected decline of crop production under climate change (Thornton, Jones, Alagarswamy, Andresen & Herrero, 2010; Thornton, Herrero, Freeman, Mwai, 2007).

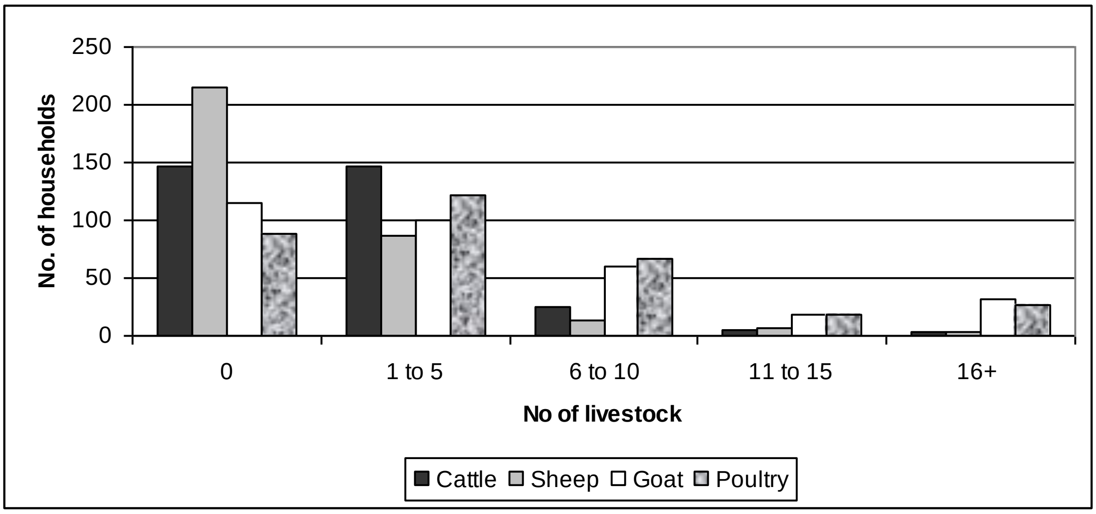


Figure 6.1: Livestock ownership by numbers**.**
Source: Field data, 2009

But livestock keeping in Tharaka is vulnerable to diseases and prolonged drought. Forty-five percent of the respondents said their livestock (excluding poultry) died in the past one year with the highest proportion of them from Kathangacini, Tunyai and Chiakariga. Diseases appear to be the main causes of livestock death; followed by drought and the most affected were cattle and goat. Cases of death arising from diseases were least in Marimanti and this can be attributed to respondents' proximity to veterinary services at Marimanti - the district headquarters. Cases of death arising from drought were prevalent at Chiakariga. This raised suspicion since Marimanti & Kathangacini are drier than Chiakariga. Possibly, the death reported at Chiakariga may be due to access to veterinary service than climate variability related. The results demonstrate that proximity to veterinary service could potentially reduce prevalence of livestock diseases and subsequently reduce household vulnerability. On the other hand, prolonged drought lead to livestock death and can increase household vulnerability. Could these deaths be attributed to reduced carrying capacity of land due to population growth? Thornton et al. (2007) observed that the most evident and important effect of climate change on livestock production is mediated through changes in feed resources. In Tharaka, population growth, land adjudication and a variable climate are expected to put pressure on large scale livestock keeping.

6.2.4 Land Tenure, Size and Soil Quality

The main land tenure systems in Tharaka District are inheritance (54%) and purchase (36%); and to a lesser extent community land (4%) and government (4%). Community land tenure was exclusively reported in Chiakariga and government land in Tunyai. At household level, land is mostly used for purposes of arable farming and pasture, underscoring agro-pastoralism as the main economic activity (Table 6.3). Households at Kathangacini (IL6) and Marimanti (IL5) still have fairly large farms partly because of the sparse population due to their aridity and remoteness.

That majority of household own land through inheritance is an attestation that land ownership has shifted from customary tenure system to individual ownership (Smucker, 2003). The implication is individual ownership can encourage optimization of the land resource than under customary ownership. Unfortunately in Tharaka, land adjudication (to individual ownership) had sparked conflict (Smucker, 2003) especially along the administrative boundaries, north of the district. Indeed interviews with residents of Kathangacini indicated frequent conflict arising from land and cattle rustling. In addition, land adjudication, especially in Marimanti has reduced pasture flexibility that the people of Tharaka enjoyed under localized customary laws. This in every sense lowers the community's adaptive capacity to the prevalent climate shocks.

Table 6.3: Land use allocation (in Acres) in Tharaka District

Study sites	Homestead		Arable land		pasture		Unsuitable land	
	mean	*sum*	*mean*	*sum*	*mean*	*sum*	*mean*	*sum*
Kathangacini	1.02	58.2	5.86	328.5	6.07	297.5	3.1	62
Marimanti	0.98	84.7	4.11	279.5	3.03	230.6	2.29	103.25
Tunyai	0.65	48.65	3.6	281.05	6.36	350.1	2.77	30.5
Chiakariga	0.44	43.14	1.81	177.5	1.51	86.2	1.06	51.16
Tharaka District	**0.74**	**234.69**	**3.55**	**1066.55**	**4.07**	**964.4**	**2**	**246.91**

Source: Field data, 2009

It was also observed that at Marimanti, there was more land (103.25acres) considered unsuitable for farming; although the Kathangacini and Tunyai had the largest size of unsuitable land per household. Forty-six percent and 35% of the respondents opined that soil quality in Tharaka District was good and fair respectively. Despite this endorsement, 35% of the respondents in Chiakariga considered their soils poor. The soils around Chiakariga range from footslope soils which are very low in fertility to hill soils which are stony and shallow (Jaetzoldt et al., 2007).

Observations during the study also revealed that in many parts of Chiakariga (notably along the Chiakariga - Marimanti road) farms were on slopes and had stony soils as shown in plate 6.1. Soils in Tunyai and Marimanti, are well drained, very deep, dusky red to dark red and are low in fertility (Jaetzoldt et al., 2007). This would mean farmers need to apply fertilizers and manure if higher yields are to be achieved.

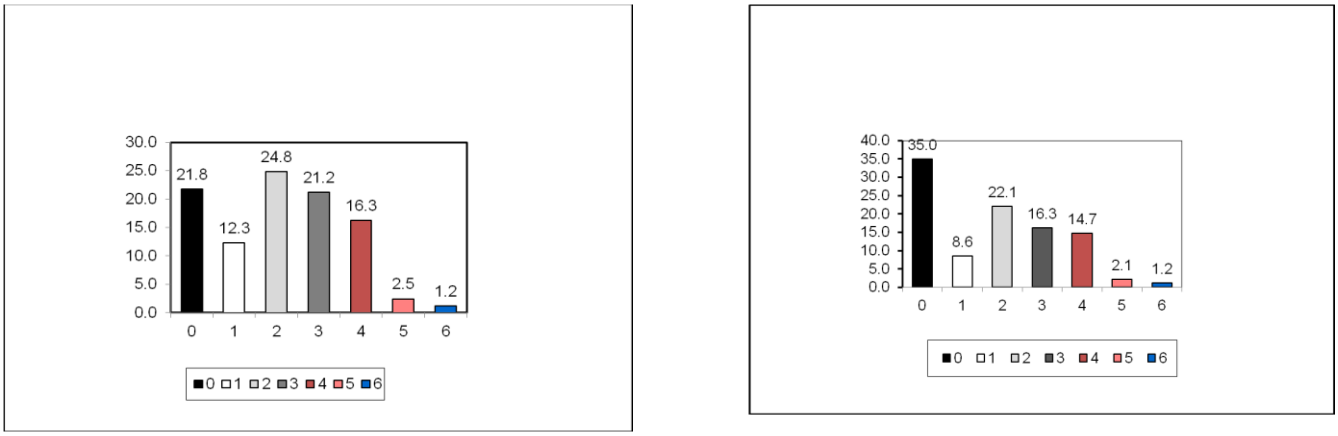
It is therefore safe to conclude that agriculture in Tharaka is least affected by land size. However, the perception by majority of farmers that soil quality is good, combined with a variable rainfall, could be a reason for the low agricultural yield.

This is because soils in Tharaka have generally low fertility ((Jaetzoldt et al., 2007). According to Breman, Groot & Keulen (2001) the main constraints on agriculture in Sub-Saharan Africa are poor soils and unfavourable climates. It makes it therefore urgent to improve soil management through integrated natural resource management and facilitate access to credit for fertilizer – applicable when above normal climate forecast are projected. Land adjudication and change in land tenure to individual ownership would be expected to increase investment. But this has not been the case, suggesting that other social and environmental factors inhibit investment in land. The current conflict along the administrative boundaries is a hindrance to agriculture and pastoralism - both key livelihoods to the local community.

Plate 6.1: A stony farm-land along Marimanti-Chiarakiga road.
Source: Field data, October 2009

6.3 Cropping Diversity

Among sub-Saharan subsistent farmers, households predominantly grow a variety of crop cultivars as a way of diversifying risk. In Tharaka, 66% and 56% of the respondents had more than one crop cultivar for OND and MAM seasons respectively (Fig. 6.2a-b). During the OND season, majority of the farmers at Kathangacini and Marimanti planted three cultivars while their counterparts in Tunyai and Chiakariga had two cultivars. During MAM season, the number of households who cultivated more than one crop reduced compared to OND, with majority (35%) not planting any crop (Fig 6.2b). In rural–based economy where crop farming is a lead livelihood, failure to engage in farming is a statement of other factors (not necessarily rainfall) being a hindrance. With the high cost of farm inputs (especially seeds and fertilizers), resource-limited households find it difficult to engage in crop farming by the time of onset. The high number of households who do not engage in farming during MAM (compared to OND) can be seen as farmers' realization of the unreliability of the MAM season.



(a) OND (b) MAM

Figure 6.2: Percentage of respondents (y-axis) and number of crop cultivars (x-axis) for (a) OND and (b) MAM growing seasons.
Source: Field data, 2009

The specific crops cultivated in Tharaka District are green grams, millet, sorghum, cowpeas, pigeon peas, maize and beans. A comparison of acreage for these crops by seasons shows that there is a marked difference, with MAM recording the least acreage across all crops (Table 6.4 a-b). From the respondents, millet and green grams are the most cultivated crops during both seasons with a total acreage of 315acres and 286acres during OND and 239acres and 228acres during MAM, respectively.

Table 6.4: Cropping diversity and acreage by study sites for (a) OND and (b) MAM.

(a) OND

Site	Crop acreage						
	Maize	Millet	Sorghum	Green grams	Cowpeas	Pigeon peas	Beans
Kathangacini	5	115	41	100	55	8	0
Marimanti	27	78	52	102.5	44	7	1
Tunyai	82.95	56	31	54	65	44	17
Chiakariga	8.2	66	37.5	29.5	25	10	0
Total acreage	**123.15**	**315**	**161.5**	**286**	**189**	**69**	**18**

(b) MAM

Site	Crop acreage						
	Maize	Millet	Sorghum	Green grams	Cowpeas	Pigeon peas	Beans
Kathangacini	3	92	41	89	50	8	0
Marimanti	16	43	37	62	37	2	1
Tunyai	67	48	19	46	54	49	16
Chiakariga	2	56	40.5	31	25	6	0
Total acreage	**88**	**239**	**137.5**	**228**	**166**	**65**	**17**

Source: Field data, 2009

While beans and pigeon peas are the least cultivated; on a total area of less than 20 acres and 70 acres for both seasons respectively. It is also significant to note that maize and beans require more moisture and are mainly grown in Tunyai where annual rainfall is slightly over 1000mm. Although households cultivate more than one crop, yields remain low (Fig 5.1a-b). Taking the example of the lead crop – millet; from acreage of 315 during OND, only 15411Kg were harvested. This translates to 0.5 bags (90Kg) per acre. Analyzed by agro-ecological zones, Tunyai received the highest yield for all crops during OND. During MAM, millet yield is highest at Kathangacini and Tunyai; while Marimanti recorded the highest yield for sorghum and green grams. A comparison of total yield by study sites show OND recorded higher yield than MAM for nearly all the crops. When analyzed by sites, Marimanti recorded the highest yields for millet, sorghum, green grams and cowpeas during MAM than OND. Kathangacini too recorded higher yields for green grams during MAM than OND.

Noting that Kathangacini – IL6 and Marimanti - IL5 are the driest (Jaetzold et al. (2007), the high number of respondents cultivating more than one crop is a demonstration of their in-built coping strategies that help spread the risk of crop failure and buffer them against year-to-year rainfall variability. The cultivation of millet, green grams and sorghum, all drought tolerant crops, demonstrates farmers' awareness of the adaptability of these crops to rainfall variability in the semi-arid Tharaka District. A study by Hornetz et al. (2001) established that green grams have potential for high yield in lowlands that are characterized by high temperatures. Thus, green grams should be promoted in the low lands of Tharaka. Even though pigeon peas is among the least cultivated in Tharaka, there is need for its promotion as it is the only crop that gives grain yield during dry spells when other legumes have wilted (Odeny, 2007). This is in addition to its nutritional value and its ability to nodulate on *Rhizobium* that is naturally present in most soils.

Acreage results suggest that farmers rely on OND season more than MAM for their farming activities. Indeed in Eastern Kenya, OND is the main growing season. This is because of the relatively higher rainfall amount recorded during OND (Amissar-Arthur et al., 2002; Barron et al., 2003) than MAM season. The strong link between OND rainfall and El Niño Southern Oscillation (ENSO) has led to improved skill of prediction (Cooper et al., 2008; Goddard et al., 2001). This should be turned into an opportunity to enable farmers plan for their rain-fed dependent livelihood. But the high crop yield realized at Marimanti (IL5) during MAM when related with the insignificant difference between OND and MAM rainfall amount discussed earlier, are a pointer that MAM is the main season in IL5. To the policy- makers, practitioners and farmers, it calls for a re-evaluation of the current emphasis on OND rainfall season especially in IL5. These results should however be treated with caution given that crop yield were based on one season. But they offer a fertile ground for further investigations on the link between seasonal rainfall and crop yield over time.

Results of cropping diversity suggest that farmers in Tharaka have flexibility at two levels. First, they have two rainfall seasons. Thus, crop failure in one season can be compensated by re-planting in the following season. Secondly, most farmers plant more than one crop and most of these crops are drought tolerant and with good timing of the onset, farmers can be assured of a harvest. A study by Thornton et al. (2010) show that the semi-arid mixed crop-livestock systems of East Africa are projected to see reductions in maize and bean production due to climate change by 2050. This therefore makes cultivation of drought tolerant crops such as green grams, cowpeas, millet and sorghum welcome in Tharaka. These attributes – bimodal rainfall and cultivation of drought tolerant crops, when harnessed, can reduce household's vulnerability to climate variability. With emphasis of and preference for OND rainfall season, it is possible that farmers in AEZ IL5 are missing out on an opportunity to fully optimize MAM rainfall which records higher yield and nearly equal rainfall amount as OND yet cultivated land for MAM is less than OND's. Despite these merits, erratic rainfall, low yields, and unstable income from yield may serve to discourage farming. Wehbe et al. (2005) found that part of the reason why peanut farmers in Argentina are vulnerable is due to unstable prices, preventing them from overcoming climatic and market impacts.

6.4 Access to Credit, Technology and Institutional Adaptation

This sub-section presents results of households' access to financial resources and participation in support programs. This will entail a discussion of indicators of adaptive capacity such as access to formal and informal credit, technology transfer (e.g access to climate forecasts) and technical assistance to households. The study also examined the extent to which institutions enhance adaptation to climate variability.

6.4.1 Access to Formal and Informal Credit

Access to credit, especially from banks and co-operative movements is almost non-existent in Tharaka District. The most common source of credit was where members make monthly contribution to one another on rotational basis – locally referred to as *Merry-go-round*. In some cases, a part of the contribution is saved to enable members to borrow when in need. Limited access to credit can be explained by three factors. To smallholder farmers of semi-arid Tharaka, borrowing money for farming does not make economic sense as chances of crop failure are much higher than success. Secondly the majority of them are poor and therefore lack collateral, including land title deeds. Thirdly, the district has no operational bank. For residents who have bank account, they have to travel long distances on all weather roads to Meru or Chuka towns in neighbouring districts. It is hoped that the establishment of the district headquarters at Marimanti will spur the establishment of essential services.

6.4.2 Access to Climate Forecast Information

Access to climate forecast information has potential to reduce impacts of climate variability and enhance households' adaptive capacity. When asked the specific forecasts they receive, 41% received daily forecasts, weekly- 10%, seasonal-13% and monthly - 3%. Access to seasonal forecast was most common in Chiakariga and Tunyai. The limited number of respondents accessing seasonal forecast is evidence that farmers do not get the most useful forecast to aid them in agricultural and livelihood decision-making, effectively constraining adaptive capacity. Out of the respondents who accessed forecast, 31% of them said they receive meteorological advice from the Kenya Meteorological Department. Radio was the single most source of forecast information among respondents (62%). It was surprising that none of the respondents mentioned extension officers as sources of forecast information despite the current structure of forecast dissemination through the Ministry of Agriculture and Ministry of State for Special Programs (ASAL Department) (Odingo et al., 2002). Extension officers offer a better opportunity to accurately interpret forecasts to farmers during field visits. Their absence in the climate forecast dissemination pathway can be attributed to its none-prioritization. It is possible that the extension officers are engaged in other development programs such as *Njaa Mrufuku Kenya* and water harvesting for crop production, (http://www.kilimo.go.ke/index.php?option=com_content&view=section&layout=blog&id=40&Itemid=133). The limited role of extension agents in the dissemination of forecast information is a critical concern. KMD needs to train extension agents in the use, interpretation, strength and weaknesses of forecast information. In the opinion of practitioners, dissemination of seasonal climate forecast at the district and divisional levels would ensure forecasts reach users on time.

Majority of the respondents who accessed meteorological forecast considered the information somewhat accurate (Fig 6.3). Chi-square (X^2) test show that the difference in perception of forecast accuracy cannot be attributed to non-random factors ($p = 0.05$, X^2 *calc*. 152.7) (Appendix A3-10). This perception would perhaps underscore an evolution towards understanding the nature of climate forecast by farmers. It is possible that after several years of receiving forecasts and with some being accurate, farmers' confidence is improving. Case in point is the accuracy of the 1997 and 2009[1] El Niño rains which may have influenced farmers to attach 'some truth' to the forecasts from KMD. It further explains cautiousness among farmers in applying forecast information in decision-making.

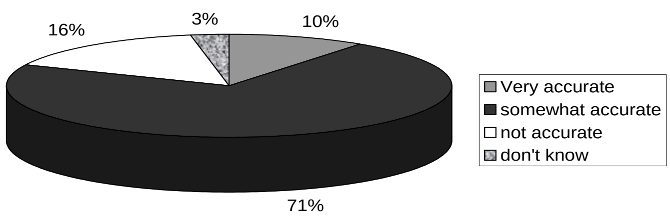


Figure 6.3: Rating of accuracy of seasonal climate forecast information.
Source: Field data, 2009

Despite the improved rating, only 17% use the forecasts in agricultural decision-making. Farmers tend to apply forecasts in decision-making only when it is above-normal. Application of forecast during below-normal seasons would help farmers reduce risk and losses, and enable them plan for alternative livelihoods.

For respondents who did not access forecasts, decisions on farming and water conservation was invariably based on traditional schemes of prediction (53%), own knowledge/experience (28%) and 'follow usual season'(19%). Respondents admitted

[1] The survey was conducted just after the onset of OND rainfall of 2009. KMD had accurately forecast moderate El Niño rains which had started in mid October and continued to pound in the better part of the season.

that there are traditional forecasting techniques which they use in making decisions. When asked if they use indigenous knowledge in combination with meteorological forecast, 68% preferred using indigenous knowledge separately compared to 32% who would combine both. The findings imply that traditional schemes of forecasting are common among farmers than meteorological forecasts.

Besides the approval of seasonal climate forecast at a household level, practitioners observed that there was potential in seasonal climate forecast. Twenty of the twenty-four practitioners found seasonal climate forecasts to be useful in resource management. The positive attitude towards forecasts does not however translate into application since only 17% of the farmers use the forecasts in agricultural decision-making. According to Lemos et al. (2002), farmers' inability to respond to climate forecasts (irrespective of quality and precision) leaves them vulnerable to climate variability. Vasquez-Leon et al. (2003) consider literacy as a possible obstacle to coping with, and recovering from climate events. This view may apply to Tharaka District where 64% and 16% of the respondents have primary level education and no formal education at all. There is also need to develop capacity of local institutions to factor climate forecasts in their policies and programs at a local level. Indeed a section of the practitioners opined that the regional level dissemination of seasonal climate forecast was not target specific. The following observation captured the view:

> "The Kenya Meteorological Department should disseminate forecasts at a district level and not at a regional level. Tharaka District cannot be classified together with Meru South and Imenti districts"
>
> (District Officer, Tunyai Division – per. Comm.)

Rainfall reliability (47%), date of onset (32%) and alternative decisions (21%) are the most needed forecast information by respondents. These results were found to be significant (p= 0.05, X^2 *calc*. = 31.34). Dates of onsets and alternative strategies are usually a part of the advisory issued by KMD while disseminating seasonal forecasts (Recha, Shisanya, Makokha & Kinuthia, 2008). Rainfall reliability, which entails information on within-season variability, remains elusive in climate science. Partitioning of rainfall in terms of onset, cessation and distribution within the season would complement seasonal forecasts and enable farmers to select appropriate cultivar and management techniques that will reduce their vulnerability to impacts of climate variability. Indeed Hansen (2002) observed that crop production and appropriate crop management are likely to depend as much on the distribution of precipitation within a season as on the seasonal total.

Although practitioners observed that there is potential in seasonal climate forecast, none considered application of climate forecast as a potential tool of reducing vulnerability, an indication that its application may not be a priority to them. Perhaps this can be attributed to the inaccuracy arising from large scale of prediction. According to Coelho & Costa (2010), most of the physical based and empirical based climate models generally produce forecast information at coarse spatial resolution of the order of 100-200km. Climate forecast application models require climate forecast information at a much refined spatial and time resolution, and therefore need for downscaling forecasts produced by climate models to the desirable level of details (Coelho & Costa, 2010). In addition, practitioners may not know how best to utilize forecast information in decision-making. Hansen (2002) noted that decision-makers will realize the potential benefits of climate prediction only if climate scientists go beyond providing climate information alone. Thus, forecast information should be supplemented with interpretation of impacts and management implication.

Application of forecasts in the drought prone Tharaka District would help farmers reduce risk and losses, and enable them plan for alternative livelihoods. As Patt & Gwata (2002) stated, applying forecasts at the level of individual farmers offers both the greatest challenge and rewards in developing countries. Whereas there are efforts by KMD, IGAD Climate Prediction and Application Centre (ICPAC) and partners to generate and disseminate forecasts on regular basis (Recha et al. 2008, Odingo et al., 2002) through Climate Outlook Forums, their contribution is largely at the national level and regional scale. This has tended to reduce forecast accuracy and subsequently watered down confidence in forecast.

To improve application, practitioners suggested a district-level brain storming of the expected season and coping mechanisms. This should be an improvement from the current approach where KMD issues advisories to different sectors alongside seasonal forecasts. Being the officers on the ground, deliberations among practitioners would lead to informed decision-making at community and household-level. However, such a meeting would need meteorological experts to give proper interpretation of forecasts to avoid distortions. Thus, appropriate use of climate forecast requires effective communication and sustained use require institutional commitment and favourable policies (Hansen, 2002).

6.4.3 Institutional-level Support Programs:

There are several social programs that are on-going in Tharaka District. The programs are mainly meant to cushion people against vulnerability arising from erratic rainfall and persistent drought in the district. Households in Tharaka District are dependent on relief food (52%) and seed distribution (28.2%). Other support programs visible in the district were water supply and installation of irrigation equipment. When these welfare and support programs were compared by study sites, relief food was most mentioned in Chiakariga (70.4%), Kathangacini (64%) and Marimanti (54%). Only 19% of the respondents in Tunyai had benefited from relief. The same pattern applied to seed distribution where 41%, 42%, 34% and 6% of the respondents at Kathangacini, Marimanti, Chiakariga and Tunyai respectively had benefited. Water supply, installation of irrigation equipment, participation in training and technology transfer were mainly mentioned in Tunyai with a few cases reported in Marimanti. The focus of these development programs in Tunyai can be attributed to the AEZ's potential in agriculture. The residents of Marimanti may be benefiting from water supply/irrigation and training programs due to their proximity to the district headquarters from where policy matters in the district are directed.

Ninety percent and 70% of the respondents who received relief food and seeds respectively attributed it to prolonged drought. Orindi & Ochieng (2005) discussed seed fair (assistance to the poor households in form of seeds) as a drought recovery strategy in semi arid South-East Kenya. Seed fairs are a better coping strategy to impacts of drought than food relief. Majority of the respondents considered water supply and irrigation equipment, training in natural resource management, technology transfer, and extension service as development programs that are not necessarily triggered by drought. Irrigation has been found to be highly beneficial in reducing poverty among the poor and in providing employment opportunities which diversify income base (Eshetu, Belete, Goshu, Kassa, Tarimu, Worku, Lema, Delelegn, Tucker, Abebe, 2010; Panahi, Malekmohammadim, Chizari, Samani, 2009). In Tharaka, promotion of irrigation can reduce vulnerability caused by erratic rainfall. However, promotion of irrigation activities in Tharaka needs to take into consideration upstream uses if conflict arising from water use is to be prevented. The Kenyan government – mostly through the then Provincial Administration, is acknowledged by respondents for playing a role in food relief and seed distribution. The problem with support initiatives from government is that they become political: their launch is sometimes guided more by political interests than the need to cushion households against drought as reported in Vasquez-Leon et al. (2003) and Lemos et al. (2002).

To mitigate the impact of climate variability, religious organizations, government and NGOs are involved in supporting various programs. For instance, food relief and seed distribution among the main support programs in Tharaka, are mainly spearhead by the Ministry of State for Special Programs and the Catholic Diocese of Meru. Given its coverage and established network in supporting vulnerable people in Tharaka, the Catholic Diocese of Meru usually receives support (financial and material) from other agencies such as UNDP and WFP in the distribution of food relief, farm inputs and education programs. Distribution of seeds is mainly intended to enable poor households that cannot afford to purchase seeds especially in the drought prone Tharaka District. Non-governmental institutions and research institutions were the least involved in seed distribution. The Kenya Agricultural Research Institute (KARI) has a sub-station in Marimanti. In KARI's attempt to involve local community, some trials on crop cultivars are conducted on farmers' plots and this is achieved by distributing seeds to the farmers. Farmers are usually involved in the management of the cultivars on trial and upon harvest; most of the yield is left to them.

More than 80% of the respondents who benefited from water supply and irrigation equipment cited support from the NGOs. The Plan International, an international NGO spread in Eastern, Southern and West Africa (http://plan-international.org), has focus on poverty reduction, support for orphans and vulnerable families and children. In Tharaka, the Plan International was widely quoted as helping in the installation of water storage facilities in addition to supporting the education of vulnerable children. Installation of water storage facilities is expected to enable schools harvest rain water for use during the dry season. This would ensure children are kept in school and not walk long distances to fetch water for use at school. With many schools in Kenya having lunch programs for pupils, water harvesting is further expected to limit occurrence of outbreak of such diseases as cholera and dysentery. There are also water conservation initiatives in Tharaka that are spearheaded by Community Based Organizations such as Ngiuru Gakirwe Water Project in Tunyai and Kijege Spring Water Project in Chiakariga. Extension services (mainly in agriculture and natural resource management), training and technology transfer programs are provided by the government and NGOs.

It is however not clear whether researchers (or research institutions) are involved in some of the support programs, notably technology transfer and training in natural resources programs. Either, there is little going on in research in supporting communities in Tharaka District to adapt, or researchers are embedded in NGO and government as channels of dialogue and engagement.

Multiple interviews with practitioners/policy-makers and observations further revealed that institutions are supporting rainwater harvesting and livelihood diversification among Common Interest Groups (CIGs) in Tharaka. Water harvesting, particularly small dams (pans) have been constructed and water tanks erected in schools and at strategic locations within the community. An interview with the District Agricultural Officer revealed that the government is investing KSH

900,000 (Approx. US$ 12,000) in each of the ASAL districts to construct water pans. A number of pans have been constructed in Tharaka District (Plate 6.2a). Water from these pans is used for domestic purposes and irrigation of fruit trees which are planted nearby.

In addition to water pans, the Catholic Diocese of Meru (in Chuka) with financial support from the World Food Program (WFP) partnered with the Ministry of Agriculture to encourage rainwater harvesting techniques in Tharaka District. Among the sites where these techniques were being promoted were Marimanti and Gituma (Marimati Division), Chiakariga and Nkarini (Chiakariga Division) and Gatunga and Gatue Divisions. The techniques being promoted are *zaipits*, *negarims* and semi-circular bands. Crops cultivated under rain water harvesting are green grams, bulrush millet, sorghum, maize and cowpeas as shown in Plate 6.2b-d.

Adoption of rainwater harvesting techniques for farming is still at the preliminary stage in Tharaka. By the time of study, the Diocese of Meru had identified the most vulnerable households who were being trained in the use of these techniques. Through the *Food for Asset Project*, poor households prepare rain water harvesting techniques on selected farms (of schools, churches or volunteer farmers). Work on these trial plots was paid in form of food. Important though was the acquisition of skills and the eventual adoption of these techniques on individual farms. As noted in Hatibu & Mahoo (1999), rainwater harvesting is a low-cost alternative of making water available for marginal area farming when compared to irrigation. These efforts therefore need to be scaled up to ensure maximum water harvesting.

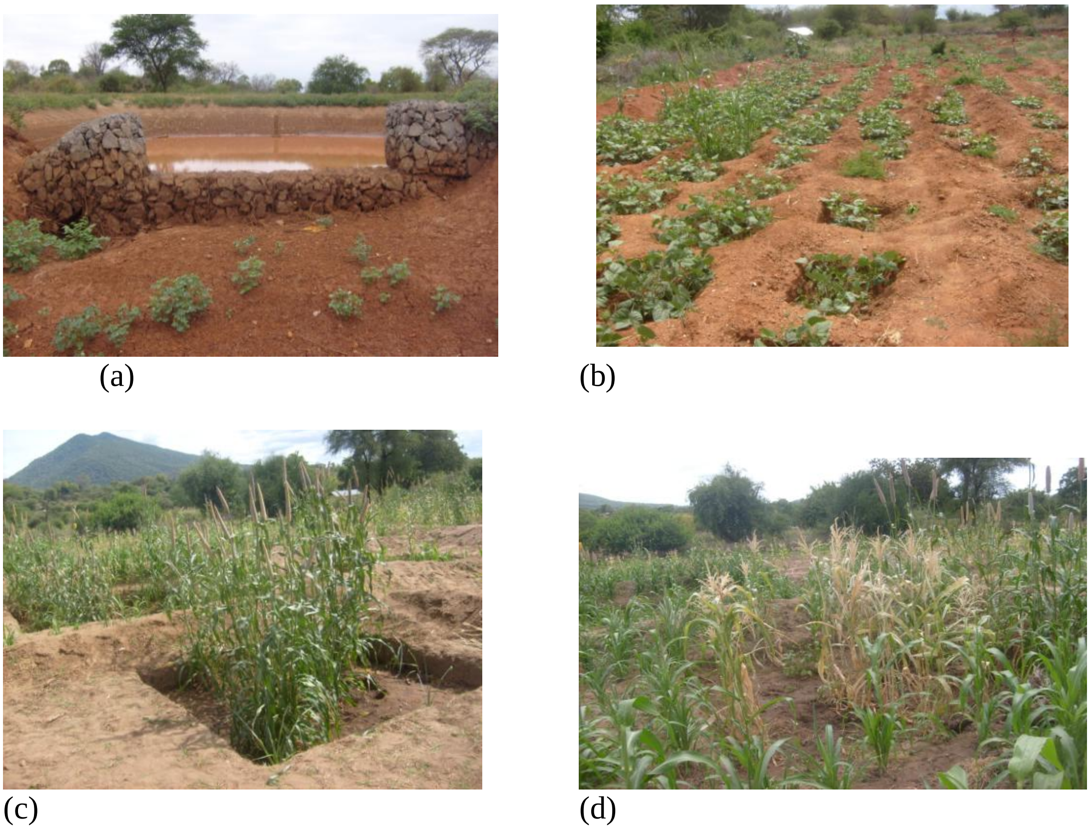


Plate 6.2: Rainwater harvesting in Tharaka District: (a) small dam along Chiakariga – Marimanti Road; green grams in *zaipits* in Gatunga (b); bulrush millet (c) and wilting maize (d) in *Negarims* at Gituma)
Source: Field data, June 2011.

Preference for rainwater harvesting as an adaptation strategy to the changing climate is also reported in Ebi et al. (2011) where farmers in Southern Mali (Sikasso) prioritized a water gate that would flood adjacent fields and allow for furrow irrigation of the potato crop during the dry season. In a comparative study between irrigation agriculture and rainwater harvesting, the former is characterized by reductions in annual flows at the basin level, varying from 8-15%; unlike rainwater harvesting which was characterized by annual variations of 2-5% (Masih, Maskey, Uhlenbrook & Smakhtin, 2011). Similarly, Wang Wei, Wang, Ma & Ma, (2011) established that furrow planting with straw-covered ridges improved maize yield in

China than conventional flat planting. It is clear from these findings that rainwater harvesting is an adaptation to climate variability that has potential to improve yields and reduce vulnerability. Nonetheless promotion of these techniques needs to take into consideration the hydrological balance of the crops and the general ecosystem of the area (Hatibu & Mahoo, 1999). Thus promotion of rainwater harvesting need to be accompanied by synchronization of seasonal soil water supply and crop needs. It was good to note that the promoters of rainwater harvesting techniques are encouraging cultivation of drought tolerant crops and not high water demand crops such as maize and beans. Observations from the field showed that crops with high water demand such as maize, even with rainwater harvesting, can wilt when the distribution of rainfall within the season is erratic (Plate 6.2d)

Rainwater harvesting was supplemented by such other activities as promotion of non-rain-fed farming (irrigation) by programs such as Mount Kenya East Pilot Project (MKEPP) that are visible in Tharaka District. MKEPP aims at reducing rural poverty by promoting more effective use of natural resources and improved agricultural practices (Mwanundu, 2010). Interview with practitioners further revealed that MKEPP was encouraging farmers to cultivate drought tolerant crops, seek off farm employment and relief food, practice agro-forestry and provides alternative water sources as mitigation towards rainfall variability. The Ministries of Livestock and Special Programs encourage households to sell-off their livestock before drought to avoid losses. Agencies such as the Ministry of Agriculture and MKEPP were engaged in the training of communities in environmental conservation and promotion of agro-forestry. While the Provincial Administration was involved in the awareness on the need to ensure food security through appropriate farming practices and food preservation techniques. Vogel et al. (2007) raised the need to find out what a practitioner does and what decisions are pending (rather than asking what kind of information he/she needs). This is seen as the best strategy to match scientific information with practitioners' actual information needs. Results of current adaptation practices and rainfall variability are vital to scientists in guiding decisions by practitioners.

Vogel et al. (2007) emphasized the importance of science-policy-practice communication in the quest for enhancing adaptation to climate variability. In Tharaka District, there is a limited interaction between scientist and practitioners and this increases community vulnerability to climate variability impacts. Opinion was divided on the importance of science – practitioner interaction: with 15 and 9 practitioners approving and disapproving respectively. Practitioners approving indicated that interaction with scientists would provide solution to rising environmental challenges and offer a dissemination platform for research findings. Limited climate research in Tharaka District limits policy-makers from making informed decisions in the planning and management of resources. This causes a disconnect between policy and practitioners who are asked to implement policies that are not necessarily in tandem with the needs and priorities of the local community, particularly in designing adaptation strategies to climate variability.

The importance of institutions in enhancing adaptive capacity to climate change and variability has been underscored by Vogel et al. (2007), Crabbe & Robin (2006) and Vasquez-Leon et al. (2003). The current institution-led support programs are both short term (relief food and seed distribution) and medium term (installation of irrigation equipment and water storage facility). It is however the introduction of rainwater harvesting techniques that has potential to help communities to better adapt to climate variability. Use of rainwater harvesting techniques when adopted, can improve food security in semi-arid Tharaka District. Institutions will also need to walk the talk in supporting use of climate forecast in agricultural planning and resource management in Tharaka. Putting seasonal climate forecast at the centre of decision-making at an institutional level is an adaptation strategy practitioners and policy-makers cannot afford to ignore. This is only possible if institutions access credible climate information about the district and factor the information in their programmes. Intensified climate research in Tharaka District such as this is likely to spur community-led adaptation to climate variability.

Design and implementation of adaptation to climate variability should be informed by within-season characteristics of seasonal rainfall for both policy-makers/practitioners and communities. Knowledgeable in rainfall characteristics, stakeholders will make informed decisions and discard assumptions. Farmers in particular will make informed cropping choices that will minimize losses. Practitioners will also seek to implement programs that are informed by the climatology of the area. Such an approach will not only give local-level stakeholders to take a lead in intervention plans, but also be linked upward to national and international policy structures in enhancing adaptation to climate change and variability.

6.5 Chapter Summary

The chapter has presented results of the state of adaptive capacity in Tharaka District. Diversity of livelihoods, land availability and the two growing season (MAM and OND), cultivation of drought tolerant crops (millet, green grams, sorghum and cowpeas) are indicators of adaptive capacity, a demonstration of the communities' in-built adaptation to climate variability. In Tharaka, there was a mismatch between land allocation and crop yields for the two growing seasons - MAM and OND. Given farmers preference for OND rainfall season, more land is allocated for farming during OND than MAM. Analysis of crop yield shows that there is an untapped opportunity in the MAM rainfall season. Farmers in IL5 (Marimanti) and IL6 (Kathangacini) can benefit more from MAM rainfall season by allocating more farmland to cowpeas, green grams and millet. In addition, households' adaptive capacity was constraint by low literacy levels, limited access to credit and use of climate forecasts. Use of meteorological forecasts remains scant despite the positive rating of the degree of accuracy.

To support adaptation, institutions are engaged in support programs that are both short and medium term. Acknowledging the vital role seed distribution and food relief are playing in reducing vulnerability to impact of extreme climatic events – at least in short term, it is the promotion of rainwater harvesting techniques and use of climate forecast in agricultural planning and resource management that are key to risk reduction.

CHAPTER SEVEN

7.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

The purpose of this study was to quantify climate variability; establish its effects on water resources and livelihoods; assess the conceptual understanding of the problem of climate variability and assess on-going adaptation initiatives in semi-arid Tharaka District. To achieve the objectives, the study utilized three data sets, namely: daily rainfall data, household survey, focus group discussions (FGD), and interview schedule with practitioners and policy-makers.

Rainfall data was analyzed to yield results of inter-annual seasonal rainfall variability, number of rain days, onset & cessations and dry spells using *INSTAT* software version 3.36 and presented using *Ms Excel 2007*. Rainfall anomaly index and cumulative departure index were used to analyze inter-annual rainfall variability while t-test was used to determine the difference between the two mean rainfall amount of MAM and OND. Percentage cumulative mean was used to determine mean onset and cessation dates in the three sites. Factor analysis was used to detect any underlying structure in the identified rainfall variability impacts on livelihoods and water. A participatory risk ranking and scoring method was used to evaluate community perception of climate change and variability as a problem in relation to other socio-economic problems. Chi-square was used to test satisfaction levels to access to water, seasonal climate forecast and social amenities. Finally, the study utilized a combination of household survey, interviews and field observations to evaluate attributes and indicators of adaptive capacity. This chapter summarizes the findings of the study, draws conclusions and makes recommendations necessary for policy formulation and the way forward for future research.

7.2 Summary of Findings

7.2.1 Rainfall Variability

The study found that inter-annual rainfall variability is persistent in Tharaka District since the 1970s. Results of cumulative departure index show that MAM rainfall season has varied less from the mean across the three stations. While OND and annual rainfall were persistently below normal, an indication that OND rainfall is a major determinant of annual rainfall. With the exception of LM4 (Tunyai), AEZ LM5 and IL5 receive less than 1000mm annual rainfall. A comparison of rainfall amount and rain days shows that OND is a longer season than MAM at Tunyai and Chiakariga. But at Marimanti rainfall amount for MAM (408mm) is nearly the same as OND (386mm). The difference between OND and MAM rainfall at Chiakariga and Tunyai is significant (two sample t-test), suggesting the two seasons merit different cropping systems. MAM rainfall is characterized by within-season variability than OND rainfall. Results of cumulative percentage mean show that 21-25th of March and October are the mean onset dates for MAM and OND respectively. While May 16-20th and January 1-5th are the mean cessation dates for MAM and ONDJ respectively. Despite these mean dates, onset dates are highly variable than cessation dates. Estimation of dry spells after onset show that there can be as high as 15days of dry spell after onset in AEZs LM5 and IL5 although there is a trend showing reduced number of dry spells.

7.2.2 Effect of Climate Variability to Water Availability

People of Tharaka are dependent on climate sensitive water sources, namely: rivers, wells and springs. To a majority of respondents (81%), water points were within a distance of 1 kilometre during the wet season. But this reduced to 58%

during the dry season. Respondents at Chiakariga and Kathangacini perceived the impact of rainfall variability to be more severe. To improve water availability and reduce household vulnerability, science-policy interface need to be recognized as an essential of Integrated Watershed Resource Management (IWRM) where development of water saving technologies and institutional capacity are at the centre.

7.2.3 Perceived Impacts of Rainfall Variability on Livelihoods

Households in Tharaka engage in more than two livelihoods. Livestock (and livestock products) and crop yield are the main sources of income although a significant number rely on forests and non-wood forest products. Although livestock keeping and the current cropping system (of millet, green grams and cowpeas) have a higher resilience in semi-arid environment, the low income generated from them demonstrates that households can be vulnerable to extreme events. The main reasons for engaging in these livelihoods were lack of food, prolonged drought and need to raise school fees. The future of sustainable development in drylands such as Tharaka lies in the rational use of dryland resources and development of markets that can encourage efficient adaptation to climate change; particularly in sectors whose goods are traded such as agriculture, forest and non-wood forest products, and livestock. It is concluded that design of an adaptation policy needs to focus on developing tools and policy instruments to facilitate livelihood diversification into higher value activities.

The high proportion of respondents stating severe impacts of climate variability on livelihoods and water is evidence of the high level of awareness of their level of vulnerability and weak adaptive capacity. Factor analysis results show that there is a discernible pattern on the effect of climate variability on livelihoods, with livestock, water and forestry resources explaining most of the variance. Factor analysis only explained 65.5%, leaving 34.5% unaccounted. It is postulated that 34.5% can be accounted by quantifying the magnitude of rainfall impacts on each of the identified factors. This will provide the magnitude of the impact – other than perception. Nonetheless, these results are significant as they provide direction on the most affected livelihoods and natural resources and the direction adaptation efforts should take.

7.2.4 The Place of Climate Variability as a Stressor

Analysis of individual perception of stressors yield an understanding that lack of money, water storage facility and bad health are the most acute stressors. The high ranking of lack of money as a stressor is a reflection of the central role money plays in supporting livelihoods and the high level of poverty that characterize Tharaka District. Irregular rains- a climate related stressor is ranked moderately. A breakdown of results however shows drought as a major stressor in AEZs LM4 and IL6. The dominance of water scarcity as a stressor may also indirectly infer to the impact of rainfall variability on water availability for livestock and domestic use. A comparison of individual and community ranking of stressors shows that climate related stressors; drought and irregular rainfall, are more acknowledged at a community level than are at an individual level. But practitioners and policy-makers regarded the poor state of roads, social amenities and poverty as the lead constraints to resource exploitation in Tharaka. Thus individual households, community and practitioners & policy makers have different perspectives on stressors in Tharaka. It is clear from this analysis that whereas rainfall variability is an acknowledged constraint to resource exploitation and a stressor at the individual, community and practitioner/policy levels, it is not the severest. Thus, to address adaptation to climate variability, one has to first address the high poverty levels and the wanting state of roads and social amenities

During focus group discussions, respondents were able to associate climate change and variability with deforestation and industrial pollution, showing awareness on the role of man in altering climate. This awareness should be harnessed into an opportunity to reduce vulnerability. There were however distortions on the causes of climate change and variability such as pollution of the ocean raising a need for a more coordinated and informed sensitization on determinants of climate variability and the role of atmospheric winds and sea surface temperatures.

7.2.5 State of Adaptive Capacity

A mixed crop-livestock system, land availability, two growing season (MAM and OND), cultivation of drought tolerant crops (millet, green grams, sorghum and cowpeas) are indicators of adaptive capacity - a demonstration of the communities' in-built adaptation to climate variability. Farmers in Tharaka have preference for OND rainfall season as demonstrated by land allocation for farming and cropping diversity when compared to MAM. But there is an untapped farming potential during MAM rainfall season where farmers can benefit more from higher yields from cowpeas, green grams and millet in IL5 (Marimanti) and IL6 (Kathangacini). Apart from this untapped opportunity, Tharaka peoples' adaptive capacity is constraint by low literacy levels, low fertility of soils, limited access to credit and use of climate forecasts. Use of meteorological forecasts remains scant despite the positive rating of the degree of accuracy.

To support adaptation, institutions were engaged in supporting programs that are both short and medium term. Acknowledging the vital role seed distribution and food relief are playing in reducing vulnerability to impact of extreme climatic events – at least in short term, it is the promotion of rainwater harvesting techniques and use of climate forecast in agricultural planning and resource management that are key to risk reduction.

7.3 Conclusion

Results presented in this study have established that seasonal rainfall – both MAM and OND are highly variable as demonstrated by onset dates, inter-annual variability and within season-characteristics. The two seasons are markedly different in LM5 (Chiakariga) and (LM4) Tunyai implying a difference in cropping system. In IL5, the two seasons are not significantly different when rainfall amount and rain days were compared. A comparison of crop yields (sorghum, millet and green grams) show that farmers in IL5 and IL6 can benefit as much from MAM rainfall as is from OND. Thus farmers need to increase acreage of farm land during MAM if they have to optimize output from the season.

It was also established that livestock and access to water are the most constraint by rainfall variability. Constraints to water availability are reflected in the increase in distance covered during the dry spell and the high and significant level of dissatisfaction; while livestock impacts are reflected in the high percentage of variance (of factor analysis) and the reported livestock death associated with drought and diseases. Although there are attempts to sink boreholes and support rainwater harvesting for domestic use, stakeholders in the water sector need to double efforts to ensure water availability to a majority of people in Tharaka and subsequently reduce distance covered in search of water during the dry season. Through the WRMA, springs – mostly found in Chiakariga, need to be mapped and conserved as critical water resources.

Most of the households in Tharaka engage in more than two livelihoods. Livelihood options in Tharaka include livestock, agriculture and forest & non-wood forest products. Although these are well selected to cope with ASAL environment, extreme events, infertile soils, an underdeveloped market for agro-based and forest based products continue to account for low income. Construction of roads will open up the district and significantly provide market for some of the lead farm produce such as green grams, millet and sorghum. Harnessing of forest and non-wood forest products such as honey, gum Arabica & resin, and handicrafts would contribute to livelihood diversification in Tharaka and subsequently increase resilience to impacts of climate variability.

In Tharaka, adaptive capacity is reflected in two growing seasons, cropping diversity (of drought tolerant crops), provision of relief food, distribution of seeds, small scale irrigation programmes and promotion of rainwater harvesting techniques. There are institutions - government, NGOs and Community-based, all working towards enhancing adaptive capacity in Tharaka District. Much more success can be realized if the existing communication gap between climate science, practitioners and community can be addressed. This should include communicating best adaptation practices, including application of climate forecasts in decision-making and research in evaluating the effectiveness of rainwater harvesting that are currently being promoted in Tharaka.

7.4 Recommendations

The findings of this study identified implication on climate variability and adaptation in semi-arid Tharaka. First, the study characterized rainfall variability in semi-arid Tharaka District; providing trends since the 1970s, mean rainfall amount, rain days, dates of cessation and within-season characteristics - information useful for on-farm management. It has been established that MAM and OND rainfall seasons are significantly different at Chiakariga (LM5) and to some extent, at Tunyai (LM4); but not at Marimanti (IL5). Thus, there is untapped potential of MAM rainfall season at Marimanti (IL5). Farmers in IL5 should consider treating the two seasons in the same way (e.g in terms farmland acreage and number of cultivars) since the difference in rainfall amount for the two seasons is not significant. To optimize both rainfall seasons and be able to deal with within-season variability (of onset, cessation and rainfall amount), livelihood planning (e.g crop farming) decisions should be guided by the seasonal climate forecast.

A time series show that OND rainfall – the main growing season has been below normal since the 1970s. These are sign of climate change. Steeg et al. (2009) and Kundezewicz et al. (2008) are among studies showing projected climate change scenarios in East Africa Studies. Projected climate change is likely to place a strain on programmes that aim to increase adaptive capacity. In Tharaka, the current changes (seen in the results of cumulative departure index) of rainfall variability - of a trend towards normal rainfall should lead to a re-evaluation of the current cropping and livelihood support systems, especially for OND season.

The study has further established that households engage in more than one livelihood strategy but the main ones are livestock and agriculture related; and both are sensitive to climate variability. It is clear that both are key sectors in supporting livelihoods especially in the food insecure Tharaka District. The impact of climate variability on these key livelihoods has necessitated food relief, seed distribution programmes among others in the district. FAO (2010) has observed that although agriculture is a key livelihood sector, it is not properly reflected in aid flow, accounting for only 4% of the humanitarian Overseas Development Aid in countries of protracted food crisis such as Kenya. There is need for livelihood enhancement initiatives that not only reflect people's preference, but also take cognizance of the irregular rainfall and its impact across the four AEZs in Tharaka. Although food relief assists to save lives, development of agricultural adaptation such as rainwater harvesting needs to be scaled up. Determination of the drylands resource base and subsequent exploitation for the benefit of local communities should be given priority by Kenya Forest Research Institute (KEFRI). This study shares the position taken by Mendelsohn (2006) that development of markets can encourage efficient adaptation to climate change. Thus, livelihood enhancement in Tharaka needs to go hand-in-hand with development of market for agricultural, livestock, forest & non-wood forest products.

There are institutions, both government and NGOs that are working to better the adaptive capacity of households and community in general. Among such efforts include promotion of irrigation, distribution of food relief, improvement of crop cultivars, soil and water conservation measures. These institutions are necessary in containing and recovering from climate change & variability impacts. Local (than national) institutions have the potential to play a key role in adaptation to climate change and variability. Substantial investment in local institutions (at district and locational levels) in Tharaka can enhance adaptive capacity. These can be government agencies such as Department of Arid Lands, Ministry of Agriculture, Ministry of Water and Irrigation or funding of Community Based Organizations and Development agencies with operations in Tharaka.

The people of Tharaka show adaptation to climate change and variability as demonstrated in their cropping diversity and the extent to which they are embracing new technologies such as irrigation, soil and water conservation with the support of existing local institutions. But these adaptation options are constraint by an unclear communication pathway of science – practitioners – end users and a nearly non-existent use of meteorological forecast. To scale-up adaptation to climate variability in Tharaka, it is recommended that:

i. Design of a more efficient interaction among climate scientists and decision makers with the end users driving the assessment of the entire end-to-end innovation in what Johnson, Lilja & Ashby (2003) refer to as the collaborative approach of research. This includes collaborations in all innovations supporting adaptation namely: seasonal climate forecasts, soil and water conservation and improvement in cropping diversity.

ii. Investment should be channeled to knowledge intensive, low input systems that are consistent with the resilience picture drawn from farmers. Among the low input technologies that need to be promoted in the semi-arid Tharaka is the evergreen agriculture that is proposed by the World Agro-forestry Centre (http://www.worldagroforestry.org/downloads/publications/PDFS/B09008). Evergreen agriculture is a form of more intensive semi-arid farming that integrates appropriate fertilizer trees with annual crops, maintaining a green cover on the land. Evergreen agriculture bolsters nutrient supply through nitrogen fixation and nutrient cycling, increases direct production of food, fodder, fuel and income from products produced by the trees. Evergreen agriculture has been found to yield results in Malawi, Zambia and Niger. Indeed promotion of evergreen agriculture can be part of what is today referred to as 'triple win' which can increase food production, reduce green house gas emissions and enhance resilience.

This study established that although climate variability is a limitation to resource exploitation, it is not the main factor that exacerbates vulnerability to climate variability. It is crucial for private and public actors to address the underlying causes of vulnerability in Tharaka such as accessibility into Tharaka, literacy level, rural unemployment, bad health and under-utilized water resources. Tschakert (2007) considers these as generic adaptive capacity which are particularly the responsibility of governments (through line ministries) to fund, help implement, and mainstream climate change adaptation measures into national development priorities.

In conclusion, the findings need to be incorporated in implications of climate variability and vulnerability assessment (Fussel & Klein, 2006). This would particularly be critical to the existing national coordination structures of disaster risk management in Tharaka District.

7.5 Suggestions for Future Research

Following the findings of this study, the following are possible research areas that need to be undertaken to better understand the impact of rainfall variability and state of adaptive capacity in semi-arid Tharaka:

i. This study characterized rainfall variability, particularly rain days, rainfall amount, dates of onset and cessation, dry spells after onset and within season variability for the two seasons. There is need to quantify drought according to severity, frequency, magnitude and spatial distribution across the main agro-ecological zones. Such a study can benefit from previous studies such as Al-Qinna et al. (2011) and Potop, Turkott, Koznarova & Mozny (2010). Relating drought episodes to impacts on agriculture and livestock in Tharaka will significantly shape the direction of adaptation. But the effectiveness of this will require an updated meteorological data of all the stations in Tharaka and its environs.

ii. For on-farm management, rainfall partitioning alone has limited value. Crop growth is also dependant on agro- ecological conditions (e.g. water holding capacity of the soil) and growth stages. Consideration of these variables in future studies would complement the present findings and provide farmers with the needed information on the occurrence of crop water stress for specific crops within the season.

iii. Although this study peered into examining yields of different crops for different seasons through household surveys, a quantitative analysis of the impact of rainfall variability on yields of major crops grown in Tharaka will provide a much more informed stand point on a viable cropping system. This is particularly important in view of the fact that:

    a. MAM and OND rainfall seasons have been found to be significantly different in LM5 (and to some extent LM4)
    b. OND is perceived to be more reliable (as demonstrated by the high number of crop cultivars and acreage) than MAM yet the later appear to be less variable from mean (cumulative departure index results) and show potential to yield more in IL5 and IL6 for green grams, millet and sorghum.

iv. There are attempts to promote irrigation and rainwater and soil conservation techniques in Tharaka as some of the medium to long term strategies to enhance adaptation. These approaches will be more meaningful when:

   a. Given that rivers traversing Tharaka - generally a lowland, are originating from highlands areas of Mt. Kenya and Nyambene hills where water uses are high, it would be helpful that design of irrigation infrastructure take cognizance of upstream activities and availability of water downstream (in Tharaka). This can be followed by a WRMA (and other stakeholders) initiative that will sensitize both upstream and downstream communities on the need for sustainable water use practices. Related to this can be a pricing of water as suggested by Shisanya (2005).

   b. Promotion of rainwater and soil conservation initiatives is pegged on soil and hydrological characteristics of each agro-ecological zone. Thus, knowledge of rainfall amount and distribution within the season need to be supplemented by information on soil evaporation rates and crops' evapo-transpiration rates. The relevance of supplementary irrigation can be evaluated in this context. Studies by Masih et al (2011), Wang et al (2011), Hortnetz (2001) and Shisanya (1998) can richly inform a study on viability of rainwater and soil conservation techniques and the relevance of supplementary irrigation in Tharaka.

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APPENDICES

A1: QUESTIONNAIRE INTERVIEW SCHEDULE AND FGD TOOL

A1-1 QUESTIONNAIRE:

ASSESSMENT OF EFFECTS OF CLIMATE VARIABILITY ON LIVELIHOODS AND WATER

I am Wambongo Recha – a graduate student at Kenyatta University, Department of Geography. The objective of this survey is to assess the effect of climate variability on water and livelihood, and evaluate the state of adaptive capacity in Tharaka District, Kenya. The research is meant for academic purpose only. Kindly provide answers to these questions as honestly and precisely as possible. Responses to these questions will be treated as confidential. Thank you.

(i) Interview information

Name of Interviewer: ________________________________ Date of Interview: ____________________

Starting Time: _________________Time Ended: __________________________

Status of Questionnaire: (a) Complete______________ (b) Not complete___________________

Checked By Supervisor: ______________________________________ Date: _____________

Division: ______________________________ Location: __________________________________

Sub-location: _________________________Town/village: ______________ AEZ________________

SECTION A: DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS.

Respondent

Name: ___________________________ Age: ____ Sex: _________ Marital status: _______________

Occupation: ________________________ Highest level of schooling, completed: ____________________________

Level of agricultural training: __________________

Community participation (through membership): Church__________________ CBO _______________

Projects (specify) _________________________

Permanent residence: (on this farm or another farm) ____

Household Composition

Table A1. Type of household depending on gender and where the of household(hh) head resides

Does this household has <u>both resident father and mother?</u> YES NO.

If NO

it has Resident Mother only Resident father only no resident father or mother

because mother, father both

away looking for employment away on urban employment

away on rural employment never married

divorced separated

 deceased both are deceased

If HH is deceased the HH is headed by Son/Daughter/Grand parent/ Uncle/ Aunt from mother/father side of family ……………………….. aged

Table A2: Household size and composition (gender, age, and activity of the people who lived in the household in last 12 months). Household refer to 'members that the household normally cooks for'

Age	Sex	Marital status	Relationship To head Head---1 Wife/husband—2 Child---3 Relative—4 Labourer---5	Primary Residence (on/off farm)	Occupation	Educational Level (highest level reached)

NB: Occupation: Below school age = 1; fulltime pupil or student = 2; Farming HH farm = 3; Casual farm wage/employment = 4; Government/private sector employee = 5; Running own business: Shop/kiosk keeping = 6; skilled labourer (specify) = 7

SECTION B: HOUSEHOLD ASSETS, INCOME AND NATURAL RESOURCES

1.0 Land tenure and use:

Table B1: Land tenure and use: For how long have you been living/farming on this area? (in years)_____________.

What is the total area of your land…………………….acres

Area and type of tenure	*Homestead is on (tick one)*	*Arable land*	*Grazing livestock*	*Not suitable for grazing/farming*	**Rate soil fertility*
Own purchased					
Inherited					
Hired land					
Communal land					
Government land					
TOTAL					

**1- Very good; 2-good; 3-fair; 4-poor*

2.0 Livestock

2.1 Number of livestock.

Table B2: Livestock

Type of livestock	*Local breed*	*Cross*	*Exotic*	*Total*
Cattle				
Sheep				
Goat				
Poultry				
Donkey				

2.2 Has any of your livestock died in the past 1 year? Yes☐ No☐

2.3. If yes, what was the main reason? Disease☐ Drought☐ Conflict☐ Predation☐ Slaughter☐

3.0 Characteristics of the dwelling, possession of durables and access to general infrastructure and social amenities

3.1 The main dwelling house is made of the materials:

a. Roof: Grass thatched☐ Corrugated☐ Tiles☐
b. Wall**:** Mud ☐ Semi-permanent☐ Bricks (red)☐
c: Floor: Earth☐ Cement☐ Tiles☐

3.2 Which of these does the household have**?**

Radio☐ TV☐ Wheel barrow/cart☐ Bicycle☐ Car☐ Plough☐

3.3 Distance and level of satisfaction to basic social amenities

Table B3

Social Amenity	Sub-categories	Distance	Level of satisfaction for service provided (1- Very satisfied; 2-satisfied; 3-not satisfied
Distance to the nearest water point	Wet season		
	Dry season		
Health service			
Small market			
Large market/ administrative HQ			
All weather road (motorable)			
School:	Primary		
	Secondary		
	Tertiary		

4.0 Sources of income:

NB: [1]1 = for most important (1, 2, 3…)

[2] Main uses→ Food =1; Sch fees & expenses = 2; Health expenses = 3; Seed or fertilizer= 4; Buying livestock = 5; Other farm investment = 5; Constructing house = 6; Buying land = 7; Cash savings = 9; Others (specify) = 1

Table B4: Source of income in the past 12 months

	Name	Rank in stability of income over the last 5 years[1]	Normal year income	Above normal year income	Drought year income	[2] Main use(s)
			Amount in KESH	Amount in KESH	Amount in KESH	
Crops sales (specify)						
Livestock products sales (specify)	Hides/skins					
	Milk					
Livestock sales (specify)	Cattle					
	Goat					
	Sheep					
	Poultry					
	Others (specify)					
Forest products	Charcoal					
	Timber					
	Basketry/handicraft					
	Furniture manufacture					
Non-wood forest products	Bee keeping/ sale of honey					
	Gum Arabica					
	Fruits (specify)					
Business/trade (Specify)						
Salary/employed						
Waged farm work						
Waged non-farm work.						
Remittances						
Financial institutions (including Saccos)						
Sale of land						
Lease of land						
TOTAL INCOME						

5.0 Access to credit.

Table B5: Please indicate in the table below access to credit; formal or informal.

Did you borrow credit in the last 12 months? If YES NO? If NO why not ………………………………………. If Yes In the table below, indicate your sources of credit and what is used for					
Source	Main condition to qualify for credit	Amount	Repayment period (in months)	Interest rate (in %)	Purpose

6.0: Information on natural resource base.

6.1 Which of these resources are available for your exploitation? State the status and reliability of each one of them.

Table B6a:

Resource	**Availability (Yes/No)**	**Status of its quality/reliability** (1-Very good, 2-good, 3-fair, 4-poor
Land/soil		
Water		
Forest /shrubs		
Rainfall		

6.2 Information on rainfall patterns

6.2.1 Are you of the opinion that rainfall patterns have changed in this locality over the last 20 years?

Yes☐ No☐

If yes, give reason… *(To the Field Assistant: Do not read the option below to the respondent)*

☐Change in dates of onset
☐Change in rainfall amount
☐Prolonged drought
☐ Increased frequency of extreme events.
☐ Decline in growing season period

6.2.2 When do you usually expect your rains – ONSET (Tick as appropriate) (specify range of dates)

Table B6b:

	March- May season						**October- November season**					
	MARCH				APRIL		OCTOBER				NOV	
	1st week	2nd week	3rd week	4th week	1st week	2nd week	1st week	2nd week	3rd week	4th wk	1st week	2nd week

6.2.3 When do you expect end of rain season rains- CESSATION (Tick as appropriate) (specify range of dates)

Table B6c:

	March- May season						**October- November season**					
	APRIL		MAY				DEC				NOV	
	3^{rd} week	4^{th} week	1^{st} week	2^{nd} week	3^{rd} wee k	4^{th} week	1^{st} week	2^{nd} week	3^{rd} week	4^{th} wee k	1^{st} week	2^{nd} week

6.3. Water resources and sources

6.3.1 What was the **main source** of water for this household? River/stream ☐ Wells ☐ Pans and dams ☐ Boreholes ☐ Springs ☐ Rock catchment ☐

6.3.2 Is this main source of water the normal source for the whole year? Yes ☐ No ☐

If NOT, what was the alternative? River/stream ☐ Wells ☐ Pans and dams ☐ Boreholes ☐ Springs ☐ Rock catchment ☐

6.3.3 What was the return distance to the main source of water from the grazing area? ....KM

6.3.4 What was the return distance to the main source of water for the household? …… KM

6.3.5 What was the return time to the main source of water for the household? ….. MINUTES

SECTION D: IMPACT OF CLIMATE VARIABILITY ON LIVELIHOOD & WATER, AND COPING STRATEGIES

1.0 Ranking of negative impacts of climate variability and coping strategies.

Table D1 *: Negative effects of climatic variability on hh resource base & ranking in severity*

In which ways did **climatic variability in the last 5 years affect negatively** livelihood-related activities of your HH and their ranking in severity 1= Most severe; 2= moderately severe; 3= not severe

NEGATIVE EFFECT	Rank
Crop reduced yield/failure	
Crop destruction	
Low pasture production	
Pest & disease infestation	
Loss of soil fertility/land degradation	
Low demand for agricultural labour	
Increased prices for seed & fertilizers	
Increase in market price for purchased foodstuffs	
Destruction/loss of infrastructure	
Reduced access to markets	
Increased post harvest losses	
Reduction in credit sources	
Reduction in remittances	
Unexpected sale of HH durables/assets	
Death of livestock	
Unexpected sale of livestock	
Reduction in production of livestock products (e.g milk)	
Reduction in water availability for irrigation	
Long distance to fetch water for domestic use	
Infestations of water by pathogens	
Increase in diseases.	
Increase in malnutrition cases	
Long distance to trek with animals in search of water.	
Reduction in sale of forest products (specify)	
Over exploitation of forest resources	
Others (specify)	

Table D2: *Factors which limit your hh from coping with negative effects caused by climatic variability and their rank in order of importance (1= most important; 2= important; Least important)*

Factor	Rank
Lack of information (specify)	
Culture	
Lack of diversified enterprises	
Lack of diversified sources of income	
Lack of awareness/ illiteracy	
Low incomes	
Persistence of the negative condition	
Unavailability of credit	
Soil type	
Topography	
Unavailability of irrigation	
Limited/no water-efficient irrigation technologies	
Lack of water storage facility	
Remoteness of location	
Lack of access to inputs	
Lack of access to agric. technology (e.g quality seeds)	
Health (specify)	
Age (specify)	
Gender related disadvantages (specify)	
Access to relief/ rescue (does it decrease tendency to be self reliant)	
Ethnic animosity/conflict	
Others (specify)	

2.0 In the last 12 months, did you engage in any of these livelihoods–support strategies?

Table D3:

a)Sale of Assets		Quantity (Specify Unit)	Total amount Ksh	Month (s)	**Main reason:** 1= lack of food; 2= prolonged drought; disease outbreak; 3= conflict; 4= school fees; 5= medical bill; 6= farm inputs
Land (sale or rental, specify)					
Livestock:	Cattle				
	Sheep/goat				
	Draught animal				
	Poultry				
Sale of crop harvest(specify crop)					
Sale of forest (wood & non-wood) products (Specify)					
HH goods (e.g TV, radio, bicycle)					
Sale of farm implements					
Harvest in advance					
Mortgaging/pledging an asset (specify)					
Consume stored seed					
Human capital related					
Seek off-farm employment					
Distress migration					
Withdraw children from school to seek employment					
Send children to live with relatives					
Food security measure					
Reduce No. of meals/day					
Consume wild food					
Swapped consumption to less preferred/cheaper					
Join social programs (e.g work for food)					

3.0 List all the crops you planted in the last 12 month (by season); indicating the acreage, approximate yield harvested and seed availability for each.

To the Field Assistant: The crops envisaged are maize (specify variety), finger millet, sorghum, beans, green grams, cowpeas, pigeon peas, others (specify).

Table D4:

Crop	Short rains (Oct-Jan)			Long rains (Mar-May			Dry spell		
	Acreage (acre)	Yield (Kg)	Seed availability[1]	Acreage (acre)	Yield (Kg)	Seed availability[1]	Acreage (acre)	Yield (Kg)	Seed availability[1]

[1]Access to seeds: 1-Use own; 2-Easy; 3-difficult;

b. Based on your experience what has been the main determinant of crop yield?

Irrigation water☐ farm inputs☐ Health☐ Soil quality☐ labour☐ Rainfall☐

4.0 **Vulnerability concerns and perceptions of the impact of climate variability on livelihoods and water**

Table D5: (tick as appropriate).

Vulnerability factor				
Water availability	Scarce	Moderately available	Abundant	
Climate impact	Low	Medium	high	Extremely high
Risks related to drought	Low	Medium	high	Extremely high

4.2. What is your major vulnerability concern?

Policy☐ Access to diversified system☐ Market prices☐ Drying up of rivers☐ Depletion of forest resources☐

SECTION E: ACCESS TO TECHNOLOGY AND SUPPORT FOR ADAPTATION:

I) Metrological Information as an adaptive capacity to climate variability

1. Do you receive any climate forecast information? ? YES (go to Question 2) NO? If no, go to **question 8**
2. Which type of forecast do you receive? Daily Weekly Monthly Seasonal
3. Do you receive the seasonal forecasts regularly issued by the Kenya Meteorological Department? YES NO
4. Do you receive the general advisories that usually accompany these forecasts? YES NO
5. How would you rate the accuracy of forecasts? Very Accurate Somewhat accurate Not accurate Don't know
6. What is your main source(s) of meteorological forecast information Radio TV Newspaper Private climate service agent Meteorological/extension officer Personal contact
7. Do you use forecast information in making livelihood and water management decisions?

   YES NO?

   a. If yes, what decision did you make in case of

      i. Livestock………………………………………………………

      ii. Crop management……………………………………………

      iii. Water…………………………………………………………

iv. Trade/business ……………………………………………….

b. If no Why? Inaccurate Lack of understanding/interpretation inaccessible on time Not useful

8. If you don't receive climate forecast, what informs your decision on farming and water conservation? Follow usual season Use own knowledge/experience Use traditional schemes of prediction
9. What is the most useful forecast information you need? Onset of the season Reliability of rainfall Alternative decisions
10. Do you make effort to receive forecast information? YES NO

II) Traditional climate information

Table E1:

TRADITIONAL CLIMATE INFORMATION				
1. Are there traditional/customary methods of predicting climate in your area? YES NO If No, go to Question				
2. If YES, give the DETAILS indicate in the spaces below				
Traditional indicator used	Characteristic/ parameter of indicator used	Climate aspect predicted	How long in advance the climate can be predicted	Reliability**
a.				
b.				
**Reliability ranking: 1 = very reliable; 2 = sometimes reliable; 3= not reliable; 4 = used to be reliable but no longer is				
3. Do you use traditional schemes of climate forecast in making farm and water management decisions YES NO If No, go to Question 7				
4. If YES, do you use it in combination with meteorological information or separately? ……………………				
5. Given a choice, which information would you use first? Traditional Meteorological ? (Tick one)				
6. If NO to Question 3, how would you use this information? ………………………………				
7. Do you have any comments on any aspect of the traditional climate information system that you would like to make?				

III) Participation in support and social program

1) Have you received any of the listed support in the last 5 years?

Table E2:

	1= Yes , 2= NO	**Source (1=** Church, 2= NGO, 3= Government, 4= local authority, 5= Research Institution others)	**The main cause**: 1= prolonged drought; 2= development program;
Emergence welfare program	Relief food?		
	Seed distribution?		
	Water supply?		
	Livestock re-stocking?		
	Others		
Support programs	Extension services		
	Training in natural resource management/conservation		
	Technology transfer (e.g participation in Project), specify.		

2.0 Are you a member of any agricultural/ ranching/trade association? YES☐ NO☐
(Specify)

4.0 If yes, has your membership to the above been a source of credit? YES☐ NO☐

5.0 Have you received government subsidies to support your livelihood enterprise(s)? YES☐ NO☐

A1 -2: INTERVIEW SCHEDULE:
INSTITUTIONAL SUPPORT TO ADAPTATION TO CLIMATIE VARIABILITY

The objective of this interview is to assess and document water resource and livelihood vulnerability, and adaptive capacity to climatic variability amongst households in Tharaka District, Kenya. The survey will elicit households' livelihood strategies and their adaptive capacity to climate variability. The target populations are policy-makers at the district and the respective lower levels. The target

TARGET POPULATION

1. Provincial administration
    a. Local D.O /chiefs/Assistant Chiefs (Tunyai, Chiakariga, Marimanti, Kathangacini) (7)
2. Ministry of Special Programs
    a. Dept of ASAL/ drought relief (1)
3. Ministry of local government
    a. Councilors (one from each of the AEZ: Total 4)
4. Ministry of Water and Irrigation (District Water Officer) (1)
5. WRMA (sub-catchment water managers): Mutonga-Kazita (1)
6. Min of Agriculture (Extension
    a. DAO (1)
    b. Extension officers (4)
7. Ministry of livestock
    a. DLO (1)
8. NGOs
    a. Dioceses of Meru, Chuka (1)
    b. Plan International (1)
    c. Christian Children Fund (1)
    d. Ngiuru Gakirwe Water Project (1)

(i) Interview information

Name of Interviewer: ______________________________ Date of Interview: ___________________

Starting Time: ________________Time Ended: ________________________

Status of Questionnaire: (a) Complete_____________ (b) Not complete__________________

Name of institution: _____________________________ Area of operation: ______________________

Respondent

Name: _________________________ Age: ____ Sex: _________ Occupation: ___________

highest level of schooling, completed: _____________

1) What is the broad area of your interest in the district a) Environmental conservation b) Food security; c) Agriculture; d) Livestock; e) Agro-forestry; f) trade; g) Water Resource Management i)Supporting the Vulnerable (children, poor, women, disabled) j)Others (specify)
2) For how long has the organization been in existence ? ____
3) How long has the organization been in Tharaka district______________________
4) Kindly describe the nature of your activities in Tharaka district. …………………………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………Do you have a policy that guides your activities? YES NO
5) List at least five major constraints (in order of importance) in resource exploitation in Tharaka
   i. …………………………………………………..
   ii. …………………………………………………..
   iii. ……………………………………………………
   iv. ……………………………………………………
   v. …………………………………………………..
6) How best can these problems be solved? …………………………………………………………………………………………… …………………………………………………………………………………………
7) Based on your activities/experience in Tharaka district, is climate variability a constraint in resource exploitation? YES NO If yes please explain how. …………………………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………If climate variability is a problem, how do you cope as an organization/institute? …………………………………………………………………………………………… ………………………………..………………………………………………………… ……………………………………………………………………………………
8) What specific livelihoods/ natural resources are affected by climate variability (Tick as appropriate)? Provide a scale of severity (1- Very severe; 2- Moderately Severe 3) Not severe
   a. Crops (specify)…………………………………………………
   b. Livestock (specify)…………………………………………………………
   c. Water……………………………………………………………………………
   d. Forest products (e.g basketry, timber, charcoal)………………………………….
   e. Non-forest products (honey, resin) ………………………………………………
   f. Business/Trade……………………………………………………
   g. Employment opportunities…………………………………………………….
   h. Others (Specify)…………………………………………………………

9) Are there specific measures taken by your organization/institution or any other agency known to you that assist households reclaim the above-mentioned livelihoods? YES NO
If yes,
   a. Which institution? ……………………………………………….
   b. Specify the type of support: Subsidy on farm inputs Relief Education Provision of pasture Market for products Re-stocking of livestock Free distribution of farm inputs (specify) Provision of credit Water storage facility Create employment

10) As a policy maker/manager, what is your major vulnerability concern in this district? Depletion of forest resources☐ Policy☐ Access to diversified system☐ Market prices☐ reduced river volume☐ Persistent drought☐
11) How often do you interact with scientists in addressing vulnerability issues in Tharaka? Regularly☐ Annually☐ Semi-annually☐ Rarely☐
12) Do you find your engagement with scientists in away relevant to your activities? YES☐ NO☐
If yes, please explain…………………………………………………………………………….. ………………………………………………………………………………………………… ………………………………………………………………………………………………… ………………

13) KMD regularly issues seasonal climate forecasts at the beginning of every onset in Kenya. Are you aware of this? YES NO
14) If YES, do you factor climate information in the planning and implementation of your activities in Tharaka district? YES NO
   a. If YES,
      i. What is the source (s) of your information? (Radio, Newspaper, KMD, Provincial Administration, MOA/L)
      ii. Describe the type of forecast information you receive (seasonal, monthly weekly, daily).
      iii. In practical terms, do you find the information useful for your activities in the district? YES NO
   b. If NO, why? inaccessible Inaccurate Not useful to our activities Untimely dissemination
   c. What are the main limitations in using climate information in the planning and management of natural resources in Tharaka?
   ………………………………………………………………………………………… ………………………………………………………………………………………… ………
15) Do you see potential in the improvement and application of climate forecast? YES NO
   a. What specific areas would you recommend for improvement in the generation and dissemination of climate forecast products?
   ………………………………………………………………………………………… ………………………………………………………………………………………… ……………………………………………………………………………

A1 -3: FOCUS GROUP DISCUSSION (FGD): RESEARCH TOOL.

The objective of this focus group discussion is to determine livelihood risk and assess the conceptual understanding of climate change & variability among the inhabitants and policy-makers in Tharaka District, Kenya. The underlying rationale of the FGD is to highlight problems relevant in enhancing the adaptive capacity and underscore the importance of climate variability/stressors in relation to other socio-economic factors.

TARGET POPULATION

1. Extension/policy-makers (20)
2. Local community: farmers/households sampled from previous Field Survey (30): To be sampled across the 4 selected areas: Marimanti, Chiakariga, Tunyai, Tharaka North.

SECTION A: DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS.

Respondent
Name: ___________________________ Age: ____ Sex: _________ Marital status: _______________

Division:_________________Location______________Sub-location_____________
Village_________

Occupation: Policy maker☐ (specify sector: health, agriculture, etc) ___________________ (☐
Local residents (specify livelihood: trader, agro-pastoralist, farmer) ___________________

Highest level of schooling, completed: ______________________

SECTION B: Perception of climate in relation to other socio-economic factors

1. Use the table 1 below, list down and rank your worries/stressors as a resident/professional in Tharaka district. I suggest you do the following:
   - (i) List all your worries in *column B*
   - (ii) Rank each one of them in *Column C*. That is, assign rank 1 to the most stressing and … 10 to the less stressing. You are NOT limited to 10 stressors.
   - (iii) Indicate the most severe of the worries/stressors in *column D.* For each worry/stressor, assign 10 to the life threatening and 1 to a barely noticeable stressor. It does not necessarily follow that a highly ranked stressor is the most severe.

A. No	**B**. *Worry/stressor*	**C:** *Rank* (from the most worrisome to the least)	**D:** *Severity*
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

2.0 For each of the stressors/worries identified in table 1, give reason for each ranking and strategies undertaken to reduce the problem.

A. No	**B**. *Worry/stressor*	*Reason for the rank*	*Strategies undertaken to solve the problem*	*Rate of success (1-Very good; 2- good, 3- Satisfactory, 4- Poor)*
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

C: Assessment of the conceptual understanding of climate change and variability and related terms (Group Discussions: Residents and Professionals)

1. What is your understanding of the following term:
    a. Weather………………………………………………………………………………
    ………………………………………………………………………………………
    b. Climate………………………………………………………………………………
    ………………………………………………………………………………………
    c. Climate variability
    ……………………………………………………………………………………..
    ………………………………………………………………………………………
    d. Climate change
    ……………………………………………………………………………………
    ………………………………………………………………………………………

2. Has climate in Tharaka (your locality) changed? .... Give reason(s) for your answer.
…………………......……………………………………………………………………………
………………………………………………………………………………………………………
3. What are the causes of climate change/variability
    a. ………………………………………………………………………………………
    b. ………………………………………………………………………………………
    c. ……………………………………………………………………………………..
    d. ………………………………………………………………………………………
    e. ………………………………………………………………………………………
4. What are the consequences of climate change and variability?
    a. Positive consequences
        i. ………………………………………………………………………………
        ii. ……………………………………………………………………………
        iii. ………………………………………………………………………………
        iv. ………………………………………………………………………………
        v. ………………………………………………………………………………
    b. Negative consequences
        i. ………………………………………………………………………………
        ii. ………………………………………………………………………………
        iii. ………………………………………………………………………………
        iv. ………………………………………………………………………………
        v. ………………………………………………………………………………
    c. What are the coping strategies to climate change and variability?
    ………….……………..……………………………………………………………………
    ………………………………………………………………………………………
5. Comment on Policy/manager- user interaction in addressing vulnerability in Tharaka.
………………………………………………………………………………………………………
………………………………………………………………………………………………………
6. Comment on technology transfer for climate adaptation in Tharaka and semi-arid environment. (Role of scientists in working with policy makers and users in communicating science)
………………………………………………………………………………………………………
………………………………………………………………………………………………………

APPENDIX 2: t-TEST, STDDEV AND CV CALCULATION OF MARCH-MAY AND OCTOBER-DECEMBER RAINFALL

	Chiakariga		Marimanti		Tunyai	
	MAM	**OND**	**MAM**	**OND**	**MAM**	**OND**
Mean	408.6	527.0	407.8	386.4	502.80	605.59
StdDev	138.1	218.0	134.6	165.5	168.67	260.53
CV	0.3	0.4	0.3	0.4	0.34	0.43
Difference in mean	-118.4		21.4		-102.78	
Variance σd^2	19062.1	47578.7	18125.0	27397.5	28447.98	69996.17
$\sigma d^2/n$	733.2	1830.0	625.0	944.7	862.06	2121.10
$\Sigma\sigma d^2$	2563.1		1569.7		2983.16	
Standard error σd	50.6		39.6		54.62	
T-test (cal)	-2.3		0.5		-1.88	
n	26.0		29.0		33.00	
df (n-2)	24.0		27.0		31.00	
T-test (table)	2.1	p= 0.05	2.1	p= 0.05	1.96	p= 0.05

A3: CHISQUARE TESTS

A3-1: Satisfaction level: distance to water point during the wet season

	Satisfaction level			X^2		
	Very satisfied	Satisfied	Not satisfied	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$
Kathangacini	16	25	17	0.8	0.0	2.0
Marimanti	24	30	38	2.0	2.9	18.4
Tunyai	39	32	7	5.3	0.2	5.3
Chiakariga	34	58	6	0.0	4.8	10.2
Total	113	145	68	**8.1**	**7.9**	**35.9**
Calculated X^2				**51.9**		
Table X^2(at 4df)				9.49		

DF = (3-1)(3-1) - 4

A3-2: Satisfaction level: distance to water point during the dry season

	Satisfaction level			X^2		
	Very satisfied	Satisfied	Not satisfied	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$
Kathangacini	9	17	32	0.1	0.5	0.5
Marimanti	21	29	42	1.9	0.3	0.2
Tunyai	19	38	21	2.6	4.4	7.5
Chiakariga	6	29	63	6.7	0.7	5.1
Total	55	113	158	**11.3**	**5.9**	**13.2**
Calculated X^2				**30.4**		
Table X^2(at 4df)				9.49		

DF = (3-1)(3-1) = 4

A3-3: Number of livelihoods

	Study site					X^2		
No. of livelihoods	IL6	IL5	LM4	LM4-5	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$
None	8	31	14	5	0.6	12.4	0.0	9.1
1-2	11	28	16	23	0.7	1.5	0.4	0.0
3-4	16	22	25	34	0.1	1.1	0.1	0.8
5-6	14	6	16	30	0.3	9.1	0.0	4.5
7-8	9	5	7	6	7.4	0.1	0.8	0.0
Total	58	92	78	98	**9.1**	**24.1**	**1.4**	**14.5**
Calculated X^2						49.0		
Table X^2(at 12df)						21.0		

DF = (5-1) (4-1) =12

A3-4: Satisfaction level of social amenities: health facility

	Satisfaction level			X^2		
	Very satisfied	Satisfied	Not satisfied	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$
Kathangacini	10	12	36	2.9	5.6	1.9
Marimanti	7	28	57	0.6	2.3	2.9
Tunyai	10	35	33	0.6	0.4	0.8
Chiakariga	6	57	35	1.5	7.6	3.7
Total	33	132	161	**5.6**	**15.8**	**9.3**
Calculated X^2					**30.8**	
Table X^2(at 4df)					12.6	

DF = (4-1)(3-1) = 6

A3-5: Satisfaction level of social amenities: proximity to small market

	Satisfaction level			X^2		
	Very satisfied	Satisfied	Not satisfied	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$
Kathangacini	9	15	34	1.7	3.1	1.0
Marimanti	8	25	59	0.2	4.0	4.0
Tunyai	6	39	33	0.5	1.7	0.8
Chiakariga	10	53	35	0.0	4.5	3.7
Total	33	132	161	**2.3**	**13.3**	**9.6**
Calculated X^2					**25.2**	
Table X^2(at 4df)					12.6	

DF = (4-1)(3-1) =6

A3-6: Satisfaction level of social amenities: Proximity to large market/administrative centre

	Satisfaction level			X^2		
	Very satisfied	Satisfied	Not satisfied	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$
Kathangacini	8	6	44	1.3	0.8	0.0
Marimanti	6	25	61	0.7	9.7	1.2
Tunyai	7	8	63	0.0	1.1	0.2
Chiakariga	9	9	80	0.0	2.0	0.4
Total	30	48	248	**2.1**	**13.5**	**1.8**
Calculated X^2				**17.4**		
Table X^2(at 4df)				12.6		

DF = (4-1)(3-1) = 6

A3-7: Satisfaction level of social amenities: Roads

	Satisfaction level			X^2		
	Very satisfied	Satisfied	Not satisfied	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$
Kathangacini	13	21	24	0.1	0.3	0.1
Marimanti	23	35	34	0.8	0.2	0.0
Tunyai	5	26	47	7.8	1.1	9.8
Chiakariga	27	51	20	2.1	3.0	8.2
Total	68	133	125	**10.7**	**4.6**	**18.2**
Calculated X^2				**33.5**		
Table X^2(at 4df)				12.6		

DF = (4-1)(3-1) = 4

A3-8: Satisfaction level of social amenities: Primary level education

	Satisfaction level			X^2		
	Very satisfied	Satisfied	Not satisfied	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$
Kathangacini	13	18	27	2.8	4.8	2.7
Marimanti	16	35	41	0.7	3.4	3.0
Tunyai	7	51	20	1.5	2.8	1.6
Chiakariga	10	65	23	1.1	4.0	3.2
Total	46	169	111	**6.1**	**14.9**	**10.5**
Calculated X^2				**31.5**		
Table X^2(at 4df)				12.6		

DF = (4-1) (3-1) = 6

A3-9: Satisfaction level of social amenities: Secondary level education

	Satisfaction level			X^2		
	Very satisfied	Satisfied	Not satisfied	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$	$\frac{\sum[(O-E)]^2}{E}$
Kathangacini	12	12	34	9.9	6.3	1.0
Marimanti	6	23	63	0.5	6.3	6.8
Tunyai	5	43	30	0.4	3.2	1.9
Chiakariga	5	59	34	1.4	7.7	4.3
Total	28	137	161	**12.2**	**23.5**	**14.0**
Calculated X^2				**49.6**		
Table X^2(at 4df)				12.6		

DF = (4-1)(3-1) = 6

A3-10: *Seasonal climate forecast accuracy rating*

Accuracy rating	**Observed O**	**Expected E**	**O-E**	$\frac{\sum[(O-E)]^2}{E}$
Very accurate	21	68.7	-47.7	33.1
Somewhat accurate	152	68.7	83.3	101.0
Not accurate	33	68.7	-35.7	18.6
Total	**206**	**206**		
Calculated X^2				**152.7**
Table X^2(at 1df)				**3.84**

A4: CORRELATION RESULTS: WATER RELATED VARIABLES

		Location	Classification by income	Main source of water	Is this the only source for the whole year?	If not, what is the alternative?	Return distance: main source of water, grazing area	Return distance: main source of water, household	Return time: main source of water, household
Location	Pearson Correlation	1	.136(*)	.445(**)	-.205(**)	.141(*)	.056	.138(*)	-.010
	N	326	247	326	326	326	326	326	326
Classification by income	Pearson Correlation	.136(*)	1	.084	-.060	.004	-.061	-.079	-.131(*)
	N	247	247	247	247	247	247	247	247
Main source of water	Pearson Correlation	.445(**)	.084	1	-.152(**)	.067	.062	.062	.092
	N	326	247	326	326	326	326	326	326
Is this the only source for the whole year?	Pearson Correlation	-.205(**)	-.060	-.152(**)	1	-.850(**)	-.131(*)	-.096	-.002
	N	326	247	326	326	326	326	326	326
If not, what is the alternative?	Pearson Correlation	.141(*)	.004	.067	-.850(**)	1	-.038	-.038	-.132(*)
	N	326	247	326	326	326	326	326	326
Return distance: main source of water, grazing area	Pearson Correlation	.056	-.061	.062	-.131(*)	-.038	1	.747(**)	.593(**)
	N	326	247	326	326	326	326	326	326
Return distance: main source of water, household	Pearson Correlation	.138(*)	-.079	.062	-.096	-.038	.747(**)	1	.741(**)
	N	326	247	326	326	326	326	326	326
Return time: main source of water, household	Pearson Correlation	-.010	-.131(*)	.092	-.002	-.132(*)	.593(**)	.741(**)	1
	N	326	247	326	326	326	326	326	326

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

A5: TOTAL AND AVERAGE INCOME BY STUDY SITES AND LIVELIHOODS

Study site		Crop sale (total)	Livestock products total	Livestock sale (total)	Forest products (total)	Non-wood forest products (total)	Business/trade	salary	Waged farm labour	Waged non-farm labour	Remittances	Financial institutions	Lease/sale of land	Total income
Kathangacini	Mean	7700.00	2087.00	19994.88	925.00	1350.00	35250.00	10000.00	605.00	20000.00		20000.00	56000.00	25578.49
	Sum	53900	33392	819790	5550	2700	141000	10000	2420	20000		20000	56000	1151032
	% of Total N	9.0%	25.0%	22.5%	11.3%	6.7%	28.6%	6.7%	13.8%	25.0%		12.5%	7.1%	18.2%
Marimanti	Mean	8879.17	910.00	7802.37	1762.00	2714.29	18000.00	22500.00	1825.00				29000.00	14190.63
	Sum	106550	10010	296490	17620	19000	36000	135000	7300				87000	681150
	% of Total N	15.4%	17.2%	20.9%	18.9%	23.3%	14.3%	40.0%	13.8%				21.4%	19.4%
Tunyai	Mean	26320.81	2679.55	11924.95	3066.43	4076.47	65500.00	26363.20	3342.86	400.00	51360.00	136666.67	46888.89	47854.57
	Sum	973870	58950	441223	42930	69300	393000	131816	70200	800	256800	410000	422000	3349820
	% of Total N	47.4%	34.4%	20.3%	26.4%	56.7%	42.9%	33.3%	72.4%	50.0%	55.6%	37.5%	64.3%	28.3%
Chiakariga	Mean	6032.95	6298.73	16942.50	4230.00	7650.00	99000.00	52000.00		1000.00	5000.00	47500.00	2000.00	24402.83
	Sum	132725	94481	1118205	97290	30600	198000	156000		1000	20000	190000	2000	2049838
	% of Total N	28.2%	23.4%	36.3%	43.4%	13.3%	14.3%	20.0%		25.0%	44.4%	50.0%	7.1%	34.0%
Total	Mean	16244.17	3075.52	14701.69	3082.83	4053.33	54857.14	28854.40	2755.86	5450.00	30755.56	77500.00	40500.00	29278.70
	Sum	1267045	196833	2675708	163390	121600	768000	432816	79920	21800	276800	620000	567000	7231840
	% of Total N	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

A6: **SEVERITY INDEX**

Results of subjective severity index (S) of the whole sample by agro-ecological zones, gender and age. The index ranges from 1 (most severe) to 2 (least severe) **(Results in sub-section 5.4.1)**

No	*Stressor*	*Severity Index*	*Main agro-ecological zone*				*Gender*		Age	
			IL5	*IL6*	*LM4-5*	*LM4*	*Men*	*Women*	Youth	Adult
1	Deforestation	1.55	1.57	1.79	1.39	1.54	1.56	1.54	1.57	1.54
2	Poor soils	1.53	1.34	1.60	1.52	1.62	1.56	1.50	1.43	1.58
3	Conflict	1.52	1.64	1.42	1.18	1.64	1.61	1.44	1.50	1.56
4	Pollution of rivers	1.56	2.0	1.62	-	1.40	1.38	1.75	1.51	1.60
5	Livestock diseases	1.47	1.51	1.45	1.56	1.44	1.42	1.51	1.55	1.41
6	Lack of pasture	1.44	1.45	1.43	1.44	1.45	1.41	1.47	1.47	1.42
7	Lack of farm inputs	1.57	1.61	1.59	1.39	1.67	1.50	1.62	1.62	1.53
8	Bad health	1.45	1.57	1.40	1.69	1.38	1.63	1.32	1.44	1.45
9	Lack of money	1.20	1.02	1.50	1.35	1.16	1.31	1.09	1.16	1.22
10	Deficient/low quality food	1.55	1.39	1.42	1.57	1.69	1.67	1.44	1.50	1.61
11	Food insecurity	1.59	1.65	1.65	1.44	1.60	1.55	1.64	1.47	1.68
12	Low agricultural productivity	1.57	1.66	1.70	1.49	1.48	1.51	1.64	1.55	1.58
13	Lack of seeds	1.68	1.79	1.64	1.64	-	1.76	1.65	1.77	1.62
14	Cost of children education	1.56	1.52	1.58	1.48	1.62	1.60	1.53	1.78	1.46
15	Skill acquisition/training	1.72	1.76	1.54	1.62	1.94	1.74	1.70	1.64	1.76
16	Irregular rains	1.42	1.46	1.44	1.48	1.26	1.41	1.42	1.49	1.38
17	Lack of employment/work	1.44	1.41	1.47	1.51	1.35	1.39	1.46	1.39	1.47
18	Scarce social amenities	1.64	1.70	1.42	1.63	1.86	1.70	1.63	1.56	1.73
19	Poor infrastructure	1.55	1.27	1.09	2.0	1.82	1.82	1.45	2.0	1.39
20	Poor roads	1.61	1.42	1.91	1.52	1.77	1.54	1.65	1.75	1.54
21	Poor housing	1.54	1.53	1.39	1.54	1.76	1.42	1.60	1.71	1.42
22	Drought	1.52	1.60	1.50	1.83	1.18	1.48	1.55	1.45	1.59
23	Water storage facility	1.68	1.59	1.68	-	1.91	1.54	1.73	1.74	1.64
24	Water scarcity	1.24	1.54	1.16	1.26	1.12	1.23	1.26	1.19	1.30
	Sample size	**48**	**15**	**10**	**12**	**11**	**21**	**27**	**20**	**28**

A7: ANALYSIS OF CROP YIELD BY STUDY SITES FOR (A) OND AND (B) MAM GROWING SEASON

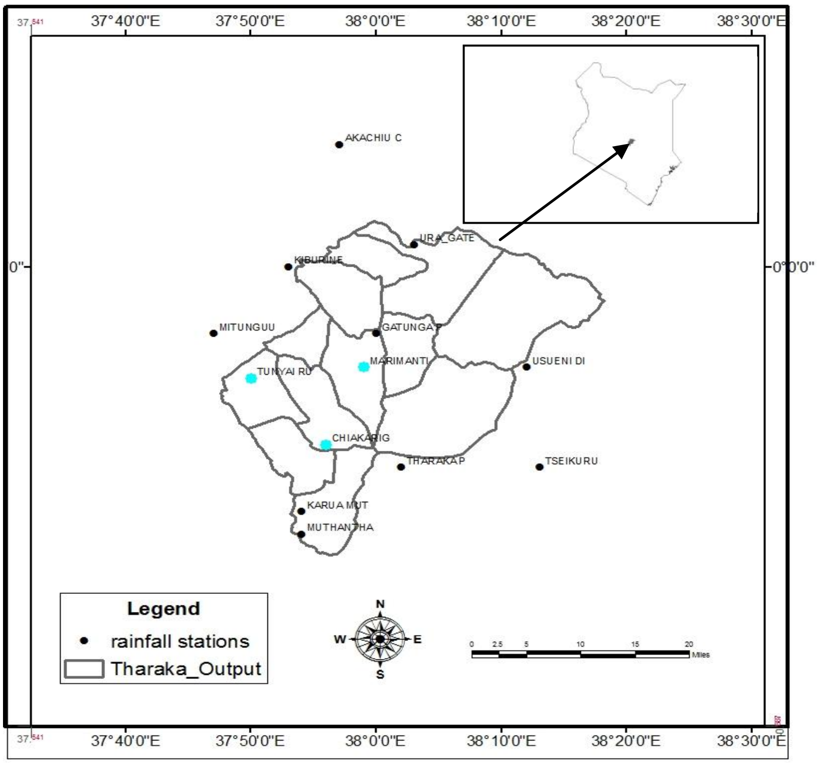
(a) OND

Location		OND: maize	OND: millet	OND: sorghum	OND: green grams	OND: cowpeas	OND: pigeon peas	OND: beans
kathangacini	Mean		197.42	101.00	57.88	42.50	10.00	
	Sum		2369	505	926	340	10	
	% of Total N		9.8%	7.8%	14.2%	10.4%	3.2%	
Marimanti	Mean	75.00	103.88	59.46	68.20	47.93	14.00	
	Sum	675	3532	1427	3137	1438	56	
	% of Total N	15.0%	27.6%	37.5%	40.7%	39.0%	12.9%	
Tunyai	Mean	218.38	227.57	345.36	294.30	140.12	156.24	45.83
	Sum	9827	6372	4835	8829	3643	3281	550
	% of Total N	75.0%	22.8%	21.9%	26.5%	33.8%	67.7%	100.0%
Chiakariga	Mean	60.83	64.04	24.05	28.00	52.23	89.00	
	Sum	365	3138	505	588	679	445	
	% of Total N	10.0%	39.8%	32.8%	18.6%	16.9%	16.1%	
Total	Mean	181.12	125.29	113.63	119.29	79.22	122.32	45.83
	Sum	10867	15411	7272	13480	6100	3792	550
	% of Total N	100.0%	100%	100.0%	100.0%	100.0%	100.0%	100.0%

(b) **MAM Report**

Location		MAM: maize	MAM millet	MAM sorghum	MAM green grams	MAM: cowpeas	MAM: pigeon peas	MAM: beans
kathangacini	Mean	50.00	243.71	93.64	100.05	49.40	101.00	
	N	1	21	11	19	10	3	
	Sum	50	5118	1030	1901	494	303	
	% of Total N	2.1%	23.3%	20.0%	22.6%	15.9%	9.7%	
Marimanti	Mean	36.22	203.89	165.00	145.20	125.85	30.00	15.00
	N	9	18	18	30	20	1	1
	Sum	326	3670	2970	4356	2517	30	15
	% of Total N	19.1%	20.0%	32.7%	35.7%	31.7%	3.2%	7.7%
Tunyai	Mean	209.78	189.62	189.69	82.96	106.69	118.32	55.08
	N	36	26	8	25	26	22	12
	Sum	7552	4930	1518	2074	2774	2603	661
	% of Total N	76.6%	28.9%	14.5%	29.8%	41.3%	71.0%	92.3%
Chiakariga	Mean	50.00	45.04	40.50	40.60	23.00	37.60	
	N	1	25	18	10	7	5	
	Sum	50	1126	729	406	161	188	
	% of Total N	2.1%	27.8%	32.7%	11.9%	11.1%	16.1%	
Total	Mean	169.74	164.93	113.57	104.01	94.38	100.77	52.00
	N	47	90	55	84	63	31	13
	Sum	7978	14844	6247	8737	5946	3124	676
	% of Total N	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

A8: RAINFALL STATIONS IN AND AROUND THARAKA



A9: STATUS OF RAINFALL DATA IN AND AROUND THARAKA.

No.	Station ID	Rainfall station	Data availability (period)	Altitude	Agro-ecological zone	Status of data after observation
1	9037184	Tunyai	1973-2007	884	LM4	9.2% missing. Used in analysis
2	9037187	Chiakariga	1974-1999	823	LM5	8.6% missing. Used in analysis
3	9037160	Marimanti	1969-1997	587	IL5	9.5% missing. Used in analysis
4	9037232	Karua-Mutonga	1981-1993	701	IL5	Missed full data for the period 1981- 1982, 1986-1994
5	9037170	Muthantha	1972-1997	686	IL5	Missed data for the period 1975-1977, 1984-1986.
6	9038010	Gatunga	1965-1987	610	IL5	Missed full data for the period 1972-1976
7	8938007	Ura Gate	1981-1997	671	IL5	Short period for a climatological analysis
8	9038020	Usueni	1974-1988	411	IL6	24% missing
9	9038006	Tharaka	1959-2004	914	IL5	Missed full data for the period 1988-2001.