IMPACT OF CLIMATE VARIABILITY AND CHANGE ON RAIN-FED FARMING SYSTEM IN SELECTED SEMI-ARID AREAS OF TANZANIA

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EXTENDED ABSTRACT

Climate variability and change pose serious challenges to smallholder farmers and agro-pastoralists. Nonetheless, their trends and impacts on rain-fed farming system (RFFS) in semi-arid areas of Tanzania have not sufficiently been explored. This study was conducted in Iramba and Meatu districts to contribute to this knowledge gap. The study specifically (i) assessed meteorological data trends of rainfall and temperature between 1994 and 2011; (ii) determined farmers' perception of climate variability and change in relation to meteorological data trends; (iii) determined changes in RFFS in response to climate variability and change; and (iv) examined changes in gender relations in response to climate variability and change. Although available meteorological data were less than 30 years suggesting climate variability, farmers' perceptions covered up to 30 years and so addressed the question of climate change. A qualitative phase informed a household survey that covered a random sample of 388 households' respondents (39% women). Qualitative data were transcribed into text and analyzed based on content and meaning of the text. Statistical Package for Social Sciences (SPSS) was used to analyze quantitative data. The results showed that there was no significant increase ($P > 0.05$) in inter-annual rainfall variability. However, seasonal rainfall variability showed a clear decreasing trend in April and December, in Iramba; and in January and April, in Meatu. Decreasing rainfall trend in April occurred simultaneously with increasing temperature trend. In addition, farmers' perception and meteorological data trends compared well on change and on increased rainfall unpredictability as well as on increased warming and dry years. Nonetheless, due to missing data in some periods, meteorological data trends did not show increased frequency of drought since the 2000s as opposed to farmers' perception. As hypothesized ($P > 0.05$), men and women's perceptions were almost the same. Similarly, perceptions of the poor, not so poor and the rich were almost the same ($P > 0.05$). Unlike the hypothesis, the binary logistic regression model showed that climate variability and change had significant impact on changing crop varieties and livestock grazing places relative to non-climatic factors. Warming (ß = -10.61, Wald = 36.26, $P \leq 0.001$) showed the highest impact on changing crop varieties. In addition, drought (ß = 2.16, Wald = 6.82, $P \leq 0.009$) showed the highest impact on changing livestock grazing places. Based on division of labour, control over resources and biased norms, climate variability and change increased and perpetuated existing asymmetrical gender relations. The study concludes that although inter-annual rainfall had not changed significantly, temperature, drought and seasonal rainfall variability had intensified relative to the situation in the 1970s. This had substantial impacts on cropping and livestock systems and on gender relations. Therefore, strategies used by the farmers and interventions promoted by the government and Non-governmental Organizations (NGOs) to address the impacts should comprehensively consider seasonal variability with gender perspectives.

DECLARATION

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

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DEDICATION

This work is dedicated to my father Clement Kabote and my mother Bankolwa Nyanda for laying the foundation of my education.

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LIST OF ABBREVIATIONS AND ACRONYMS

DAAD	Deutscher Akademischer Austausch Dienst
DAS	District Administrative Secretary
DFID	Department for International Development
EPINAV	Enhancing Pro-Poor Innovations in Natural Resources and Agricultural Value Chains
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
FHHs	Female Headed Households
HEI-ICI	Higher Education Institutions Institutional Cooperation Instrument
HIV	Human Immunodeficiency Virus
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-tropical Convergent Zone
IWMI	International Water Management Institute
LVEMP	Lake Victoria Environmental Management Programme
MHHs	Male Headed Households
NAPA	National Adaptation Programme of Action
n.d	Not dated
NGOs	Non-governmental Organizations
PRA	Participatory Rural Appraisal
RFFS	Rain-fed Farming System
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
SUA	Sokoine University of Agriculture
TARO	Tanzania Agricultural Research Organization

TMA	Tanzania Meteorological Agency
UDSM	University of Dar es Salaam
URT	United Republic of Tanzania
VEO	Village Executive Officer

CHAPTER ONE

1.0 INTRODUCTION

1.1 Global and Regional Trends in Climate Variability and Change

Climate variability and change are global phenomena posing environmental and developmental challenges in the 21st Century. They encompass short-term and long-term changes in statistics of rainfall, temperature, relative humidity, winds and extreme weather events (IPCC, 2007). Climate variability differs from climate change in that it is a short-term change that includes temporal and spatial variations of the mean state of the climate beyond individual weather events (IPCC, 2007).

Studies that focus on the climate system have a long history. However, the debate whether climate has changed or not changed over time emerged later in the 1990s. This debate was inspired by, among others, Mann *et al.* (1998; 1999). These pieces of work examined trends in surface temperature over the previous 1000 years. The results demonstrated that the northern hemisphere was warming. The same studies showed that the 1990s was the warmest decade and 1998 was the warmest year. Literature considers this to be climate change or global warming.

An increase in temperature reported by Mann *et al*. (1998; 1999) coincided with an increase in concentration of greenhouse gases in the atmosphere particularly carbon dioxide from natural and human activities. In other words, it is this increasing amount of greenhouse gases that causes warming. Some scholars including Mclntyre and Mckitrick (2003) were sceptical about this observation. They argued that the earth could be warming, yet human activities were not among the causes; or, the earth could be warming and human activities could be responsible, but cautioned that the world needed not to act to stop the phenomenon (Carr, 2010). Others, including Wegman *et al.* (2006), supported the results while recommending further studies to establish mechanisms for dealing with the phenomenon.

Since 2001, evidence has increasingly been showing that climate variability and change have happened (IPCC, 2014). It is reported that the mean global surface temperature has increased by 0.6^0C in the past 100 years (Lambrou and Piana, 2005). Temperature is showing an increasing trend in Africa, Asia (e.g. India and Pakistan) and Latin America (Sivakumar *et al*., 2005). The trend in Africa is increasing from South to North. The Southern parts became increasingly warmer at a rate of 0.05^0C per decade during the 20^{th} Century (Blench and Marriage, 1999). Simulation models show that global temperature will increase between 1.4 and 5.8^0C by the 2100s (IPCC, 2001; 2007).

Precipitation, on the other hand, generally shows a decreasing trend from Southern towards Northern Africa particularly in semi-arid areas of Southern and Western Africa (Nicholson, 2000; 2001; Kotir, 2010). However, some areas in East Africa have seen an increasing trend while others have experienced a decreasing trend (Downing *et al.,* 1997; Olesen and Bindi, 2002; Reidsman *et al.,* 2009; Sivakumar *et al.,* 2005). Interestingly, rainfall does not show any clear trend in Latin America. These differences in trends of climate change imply that the phenomenon is geographically specific and generalization can be difficult. Short-term changes that include increasing frequency of floods, droughts, cyclones and decreasing number of rainy days have also been reported, but more work is required to examine trends of climate variability over time in semi-arid areas where variability may not necessarily be something new. Therefore, studies at the local level are too critical to be able to advise smallholder farmers to minimize risks associated with the phenomena.

1.1.1 Trends in climate variability and change in Tanzania

Tanzania is located in East Africa and is situated between latitudes 1ºS and 12ºS and longitudes 29ºE and 41ºE. Thus, the country's climate is mainly influenced, in addition to variations in topography and presence of great lakes, by an inter-tropical convergence zone (ITCZ). This is a lower pressure belt where large air masses converge near the Equator. The belt moves either northwards or southwards, making the northern and eastern parts of the country to have bimodal rainfall (Mtongori and Innes, 2010). Bimodal rainfall is characterized by short rains that occur during October, November and December and by long rains that occur during March, April and May. Nonetheless, rainfall regime in semi-arid areas of central Tanzania including Meatu and Iramba districts, where this study was conducted, is unimodal (Rubanza *et al.,* 2005; URT, 2007). The rains may start in November and cease in April (Mtongori and Innes, 2010).

Climate variability and change have also been reported in Tanzania. For instance, mean surface temperature has increased between 1 and 2^0C (Lema and Majule, 2009; Mongi *et al.,* 2010), whereas, rainfall has decreased between 5 and 15 millimetres in some parts of the country since 1974 (Mongi *et al.,* 2010). Rising sea level and melting of the ice cap of the Mount Kilimanjaro are also signs of climate variability and change in Tanzania (Agrawala *et al*., 2003). It appears that change in average annual rainfall since the 1960s is not that much substantial except that patterns are no longer predictable and frequencies of floods and droughts have definitely increased in some parts of the country (Mtongori and Innes, 2010).

In order to understand the phenomena sufficiently in the country, it is important to include perception of the local people in addition to meteorological data trends. The perception of climate variability and change is about views of the people with regard to the phenomena

(Grothmann and Patt, 2003; Maddison, 2007; Thomas *et al.,* 2007; Kemausuor *et al.,* 2011). Yet, in some countries in Sub-Saharan Africa (SSA), such perception and meteorological data trend do not coincide (Meze-Hausken, 2004).

1.1.2 Physical and social-economic impacts of climate variability and change

The Intergovernmental Panel on Climate Change (IPCC) has affirmed that climate variability and change at global and regional levels have occurred and that, though empirical evidence is still needed at local level, the phenomena pose wide spread physical and social-economic impacts (IPCC, 2007; 2013; 2014). While physical impacts include environmental and dwindling agricultural production, social-economic impacts are qualitative changes including impacts on gender relations, economy, livelihoods and poverty (Nelson *et al.,* 2002; Kabubo-Mariara and Karanja, 2007; Kabubo-Mariara, 2009; Apata *et al.,* 2011; Roudier *et al.,* 2011; IPCC, 2014).

The National Adaptation Programme of Action (NAPA) for Tanzania identifies climate variability and change as environmental and developmental challenges. The most vulnerable sectors in the country include agriculture, water, energy, health, transport and forestry (URT, 2007). The impacts are likely to be severe in arid and semi-arid areas (IPCC, 2007) due to the fact that such areas receive less rainfall and also experience higher temperature relative to other ecological zones (Crimp *et al.,* 2008).

Literature defines the term semi-arid in different ways based on the climate[1], particularly on mean annual rainfall (Quinn and Ockwell, 2010). Nonetheless, existing definitions lack uniformity and in most cases fail to distinguish semi-arid areas from arid areas, which are drier relative to semi-arid areas. For instance, some scholars put a range of mean annual

[1] Average weather conditions including temperature, rainfall and day length (Quinn and Ockwell, 2010).

rainfall in semi-arid areas between 200 and 600 mm (Huang *et al.,* 2012; Sarr, 2012); 500 and 800 mm (URT, 2007; Mongi *et al*., 2010) and between 600 and 800 mm (UDSM, 1999).

Others give relatively higher range of mean annual rainfall between 400 and 1200 mm with a mean monthly temperature that exceeds 18^0C, for example results of a study by Quinn and Ockwell (2010). The same study posits that evapo-transpiration exceeds precipitation in one or more seasons in semi-arid areas. Arguably, an annual rainfall below 400 mm is too low and can define an arid agro-ecological zone than a semi-arid area. In addition, an annual rainfall of 1200 mm is too much for a semi-arid area. Because of these inconsistencies, this study takes the term semi-arid as an agro-ecological area which receives a mean annual rainfall between 400 and 900 mm with a mean monthly temperature that exceeds 18^0C (Quinn and Ockwell, 2010).

Climate variability and change are also likely to affect men, women, aged and children differently. Women are likely to be more affected than men counterparts (Skutsch, 2002; Brody *et al.,* 2008). This is because, traditionally, women in addition to domestic chores play substantial roles in procuring food for the family. They do so by depending on the natural environment which is sensitive to climate variability and change. Therefore, any change in the climate system that has impact on the environment will definitely pose gendered impacts (Amsalu and Wana, 2013). The poor are also more at risk than the rich due to little adaptive capacity (IPCC, 2007).

People living in semi-arid areas depend on crop cultivation, livestock rearing and agro-pastoralism (Blench and Marriage, 1999). These sub-systems depend mainly on rainfall and so constitute a rain-fed farming system (RFFS). For instance, globally, agriculture depends on rainfall by 80%; while Sub-Saharan Africa's (SSA) dependence on rainfall is about 95% (IWMI, 2010). In addition, more than 95% (NBS, 2009; Afifi *et al.,* 2014) and in some places about all smallholder farmers and agro-pastoralists in semi-arid areas of Tanzania depend on rainfall (Mongi *et al*., 2010). This implies that changes in rainfall patterns will have impact on RFFS and on people's livelihoods as well.

Farming system has generally been defined as a set of inter-related, interacting and interdependent sub-systems acting together to support livelihoods and is capable of reacting as a whole to climatic and non-climatic factors (Behera and Sharma, 2007; FAO, 2008). Non-climatic factors include economic, political, social and cultural, household priorities, biological and resource factors (Behera and Sharma, 2007). Some scholars have defined the concept somewhat differently (Rugumamu, 1997; Dixon *et al.,* 2001). Yet, the converge is that it is a complex relationship of farm enterprises composed of sub-systems that encompass crops, livestock, soils, labour, capital, land, power and technologies used in production.

One of the central arguments in this study is that climate variability and change can either be opportunities when they cause positive impact in the rain-fed farming system (RFFS) or threats when they cause negative impact on the same. Positive impact can improve crop production and livestock keeping as opposed to negative impact, which can cause crop failure, and water and pasture shortage.

Many studies have examined vulnerability, impact, adaptation and mitigations in response to climate variability and change in Sub-Saharan Africa (SSA) and more specifically in Tanzania (Galvin *et al.,* 2001; Paavola, 2008; Lema and Majule, 2009; Mongi *et al.,* 2010; Swai *et al.,* 2012; Juana *et al.,* 2013; Legesse *et al.,* 2013). However, these studies divide the RFFS into single components with an idea that results from the components can be added to one another (Darnhofer *et al.,* 2008; 2010).

Studies which divide the RFFS into different components acknowledge that climate variability and change have impacts on crop and livestock (Smit *et al.,* 1996; Salinger *et al.,* 2000; Smit and Skinner, 2002; Morton, 2007; URT, 2011). Such impacts undeniably represent changes in RFFS (Jones and Thornton, 2003; Altieri and Koohafkan, 2008). As mentioned in this introduction, the phenomena are likely to also cause social impacts particularly on gender relations (Dankelman, 2002; Glazebrook, 2011; Mandleni and Anim, 2011). In addition, social impacts include poverty and threatened livelihoods (IPCC, 2014).

Gender relations relate to specific forms of social, cultural (ideas, beliefs and norms) and power relations between men and women that tend to disadvantage women (Reeves and Baden, 2000; Shayo, 2004). These forms of relations are socially constructed and can change over time depending on circumstances. Yet, change in gender relations in response to climate variability and change is not explored sufficiently in the RFFS. In other words, empirical evidence to support the contention that climate variability and change impacts are gendered is still inadequate.

1.2 Problem Statement

Iramba and Meatu districts lie entirely in a semi-arid agro-ecological zone. The districts are dominated by smallholder farmers and agro-pastoralists. Meatu gets a mean annual rainfall between 400 and 900 mm (Meatu District Council, 2009); while Iramba receives a mean annual rainfall between 500 and 850 mm, with day time temperatures ranging from 15^0C to 30^0C in July and October, respectively (Iramba District Council, 2009). Knowing these meteorological data is important to understand climatic conditions crucial for smallholder farmers and agro-pastoralists. Yet, their trends over time are not clearly understood. In addition, farmers' perception of climate variability and change, which when combined with meteorological data improve understanding of the phenomena, is not well known in the study districts.

Climate variability and change interact with non-climatic factors like economic, political, biological, socio-cultural, household priorities and resource factors in affecting RFFS (Behera and Sharma, 2007). Some studies have assessed impacts of climate variability and change in crop production, but their analyses do not empirically take on board the non-climatic factors mentioned above (Agrawala *et al.,* 2003; Jones and Thornton, 2003; Mongi *et al.,* 2010). As such, these studies have vaguely concluded that crop production is negatively affected by climate variability and change.

Other studies, for example Morton (2007) and Paavola (2008) have reported adaptation strategies such as diversifying to non-farm activities. Nonetheless, the linkage between climate variability and change and agro-pastoralism, which is one of important livelihood strategies in semi-arid areas of Tanzania (Lema and Majule, 2009) is less understood. Similarly, the linkages between climate variability and change and gender relations have not been explored sufficiently. This study examined trends in climate variability and change taking on board meteorological data trends and farmers' perceptions, and their impact in RFFS and smallholder farmers' adaptation strategies. The study also examined changes in gender relations responding to climate variability and change in RFFS.

1.3 Justification for the Study

Tanzania, including semi–arid areas, is dominated by smallholder farmers and agro-pastoralists (Birch-Thomsen *et al.,* 2001; Lema and Majule, 2009). For instance, about 75% out of 44.9 million people depend on agriculture for livelihoods in the country (Shayo, 2006; URT, 2010; URT, 2013). Interestingly, dependence on agriculture and livestock in Meatu and Iramba ranges from 80% to 90% (PMO-RALG, 2007; Iramba District Council, 2009; Meatu District Council, 2009). This dependence is higher relative to that at the national level. Nonetheless, smallholder farmers and agro-pastoralists depend on rainfall by 95% in Tanzania including Meatu and Iramba (NBS, 2009). Therefore, any change in the climate will affect more than three-quarters of the population in the study area. Arguably, the segment of the population whose livelihoods do not depend directly on agriculture and livestock will also be affected by the phenomena through scarcity of drinking water and increasing food prices (Vermeulen *et al.,* 2012; Afifi *et al.,* 2014). While existing studies have concentrated on impacts of climate variability and change in crop production, there is paucity of information on how the entire rain-fed farming system (RFFS) responds to climate variability and change in Meatu and Iramba.

The study took a broader dimension of climate variability and change by capturing different manifestations, so as to understand better, and be able to deal with the phenomena. Therefore, the results from this study contribute to new knowledge on trends in climate variability and change and their impact in RFFS and farmers' adaptation strategies. This information is critical in influencing political, economic and social actions at local and national levels to manage vulnerability and risks associated with climate variability and change. The results can also be used by policy makers to formulate interventions that support smallholder farmers and agro-pastoralists to adapt sufficiently in a sustainable way thereby increasing their adaptive capacity. The results also contribute to the overall goal of a climate change and gender project that is implemented by Sokoine University of Agriculture (SUA) from 2011 to 2015 through its programme named, Enhancing Pro-Poor Innovations in Natural Resources and Agricultural Value Chains (EPINAV). The project aimed at evaluating gendered impacts and adaptation of climate change and other stresses on rural livelihoods in Semi arid areas of Tanzania. The objective of the project that this study addressed was assessing perceptions of climate change with gender perspectives. The results of this thesis also assessed impact of climate variability and change in gender relations, which was the main theme of the project.

1.4 Objectives

1.4.1 Overall objective

The general objective of this study was to examine physical and gendered impact of climate variability and change on RFFS in Iramba and Meatu districts, some semi-arid areas in Tanzania.

1.4.2 Specific objectives

The specific objectives were as follows:

(i) To assess trends of climate variability and change based on meteorological data of temperature and rainfall;

(ii) To determine perception of climate variability and change in relation to meteorological data trends;

(iii) To determine changes in rain-fed farming system and smallholders' adaptation strategies as a consequence of climate variability and change; and

(iv) To examine changes in gender relations in response to climate variability and change.

1.5 Research Questions and Hypotheses

This study was guided by research questions and hypotheses because it adopted qualitative approach to collect and analyse qualitative data, and quantitative approach to collect and analyse quantitative data (Creswell, 2003). To that effect, research questions were unavoidable in guiding the qualitative approach, while hypotheses were unavoidable in applying inferential analysis for quantitative data.

1.5.1 Research questions

The study was guided by the following research questions:

(i) What trends do actual temperature and rainfall data reveal in the study area?

(ii) What is the relationship between farmers' perception of climate variability and change and meteorological data trends?

(iii) How do different socio-economic groups including men and women perceive climate variability and change?

(iv) How does the rain-fed farming system respond to climate variability and change?

(v) How are men and women smallholder farmers affected differently by climate change, and how do they adapt?

(vi) In what ways do climate variability and change transform gender relations?

1.5.2 Research hypotheses

(i) Meatu and Iramba districts, some semi-arid areas of Tanzania, did not experience increasing trends in inter-annual rainfall variability for the period between 1994 and 2011;

(ii) Men and women's perceptions of climate variability and change are the same;

(iii) Perceptions of climate variability and change are the same for the poor, not so poor and the rich;

(iv) Climate and non-climatic factors have the same impact on the chances of smallholder farmers adopting improved crop varieties; and

(v) Climate and non-climatic factors have the same impact on the chances of agro-pastoralists changing grazing patterns.

1.6 Theoretical Framework

1.6.1 Farming system thinking

Farming system researchers established farming system thinking since the 1970s due to limitations of reductionist ‘command and control’ approach that divides the system into ever smaller elements, with the idea that results from small elements can be added to one another (Darnhofer *et al.,* 2008). Farming system thinking considers complexity of the system, contrary to the reductionist approach which ignores complexity.

In addition, farming system thinking views different components and/or sub-systems of the farm as one system. These components include crops, animals, soils, labour, capital, land, power and technologies used. Based on the farming system thinking, change in one component of the system often affects other elements of the system organization (Darnhofer *et al.,* 2010). Emphasis is also put on the interactions of components in the system.

Proponents of the farming system thinking, including Darnhofer *et al*. (2010), posit that there is a need to take on board farmers’ perceptions in order to understand sufficiently the farming system. Perceptions include how farmers see, understand and interpret issues of concern. Positive change in response to stimuli – change that adds value to the farming system in supporting livelihoods − is viewed as an important element for a sustainable system. This study took climate variability and change as one of the stimuli that can trigger positive or negative changes in the rain-fed farming system (RFFS). Based on the farming system thinking, the RFFS can also be affected by non-climatic factors like economic (market, input, and credit), political (institutions), social and cultural (tenure, taboos, local beliefs, marital institutions, religion and food preference), household priorities (food and income), biological (pests and diseases) and resource factors (land, knowledge and labour) (Behera and Sharma, 2007).

In applying the farming system thinking, this study examined the impact of climate variability and change on the RFFS. Measured meteorological data trends were combined with farmers' perception of climate variability and change to broaden an understanding of the phenomena. The underlying logic was that the knowledge on impact on RFFS is complete if climate variability and change and non-climate related factors are both taken on board.

1.6.2 Feminist theories

In examining gender relations, it is logical to situate the study in a theoretical framework. Clearly, feminist theories dominate in the literature of gender. These theories suitably uncover gender inequality at societal and institutional levels. Institutions in this case include household, school, work place, family, relationships, religious institutions, medical system and the media (Wingood and DiClemente, 2000). On the other hand, society can be constituted by an ethnic group like the Sukuma, and/or the Nyiramba societies in Meatu and Iramba districts in Tanzania.

The central goal of feminist theories' is to transform gender inequality. These theories emphasise on women's social, economic and political rights, definitely due to women's subordinate position in society (Lorber, 2010). Gender inequality, according to these theories, is rooted in gender differences and patriarchy ideology (Thompson, 2003; Brody *et al.,* 2008; Lorber, 2010). Feminist theories, though offer an insight regarding inequality in society, do not clearly provide a systematic framework to analyze gender relations.

1.6.3 Social theory of gender and power

The social theory of gender and power was coined by Robert Connell in 1987. This theory illuminates three social structures which are critical for systematic analysis of gender relations. It is important to analyze gender relations in the rain-fed farming system (RFFS) in order to uncover asymmetrical gender relations that can surface as the system changes in response to climate variability and change. This in turn helps to formulate transformative gender sensitive policy interventions (Maharaj, 1995).

According to the Connell's theory (Connell, 1987), the first social structure is division of labour. This is about allocating different occupations to men and women. The second one is division of power, which is about power relations between men and women. The third social structure is structure of cathexis, which encompasses biased social norms. Changes in these social structures constitute changes in gender relations. Connell's theory argues that gender relations at societal level remain intact over a long period of time as society slowly changes. It also posits that changes at the institutional level occur rapidly, but changes in gender relations occur gradually (Maharaj, 1995).

Connell's theory has been applied by Wingood and DiClemente (2000) to examine gender relations in reproductive health for effective interventions. However, they did not use the theory to analyze change in gender relations possibly because it was not within the scope of their study. A study by Mwaipopo (2004) analyzed gender relations in Tanzania's agricultural sector using three social structures including gender division of labour, gender division of power and norms that reinforce these divisions. Nonetheless, the study by Mwaipopo (2004) did not clearly mention use of the Connell's theory of gender and power. This study was inspired by Connell's theory in order to systematically examine changes in gender relations in RFFS. This study took intensification of climate variability and change, as one of the stimuli that can exert changes on social structures and eventually pose positive and/or beneficial, or negative and/or detrimental changes on gender relations.

1.7 Conceptual Framework

The conceptual framework of this thesis is presented in Fig. 1.1. This is informed by theoretical and empirical literature (Smit *et al.,* 1996; Grothmann and Patt, 2003; Darnhofer *et al.,* 2010). This framework establishes linkages between climate variability and change, non-climatic factors (independent variables) and rain-fed farming system (RFFS), which is the dependent variable. According to the farming system thinking, climate variability and change interact with non-climatic factors (Darnhofer *et al.,* 2010) as shown in Fig. 1.1, in driving changes in RFFS and smallholder farmers' livelihoods. A change in RFFS in response to climate variability and change is taken in this thesis to mean any long-term, planned or unplanned adjustment or modification in the system. Therefore, any adjustment in any part of the system, modification, adoption or emerging of new crops, crop varieties, cropping and grazing arrangements and their interactions there in, is considered to be a change in the system. In short, this can be taken as a "farming system adaptation", but this concept is not used in this thesis.

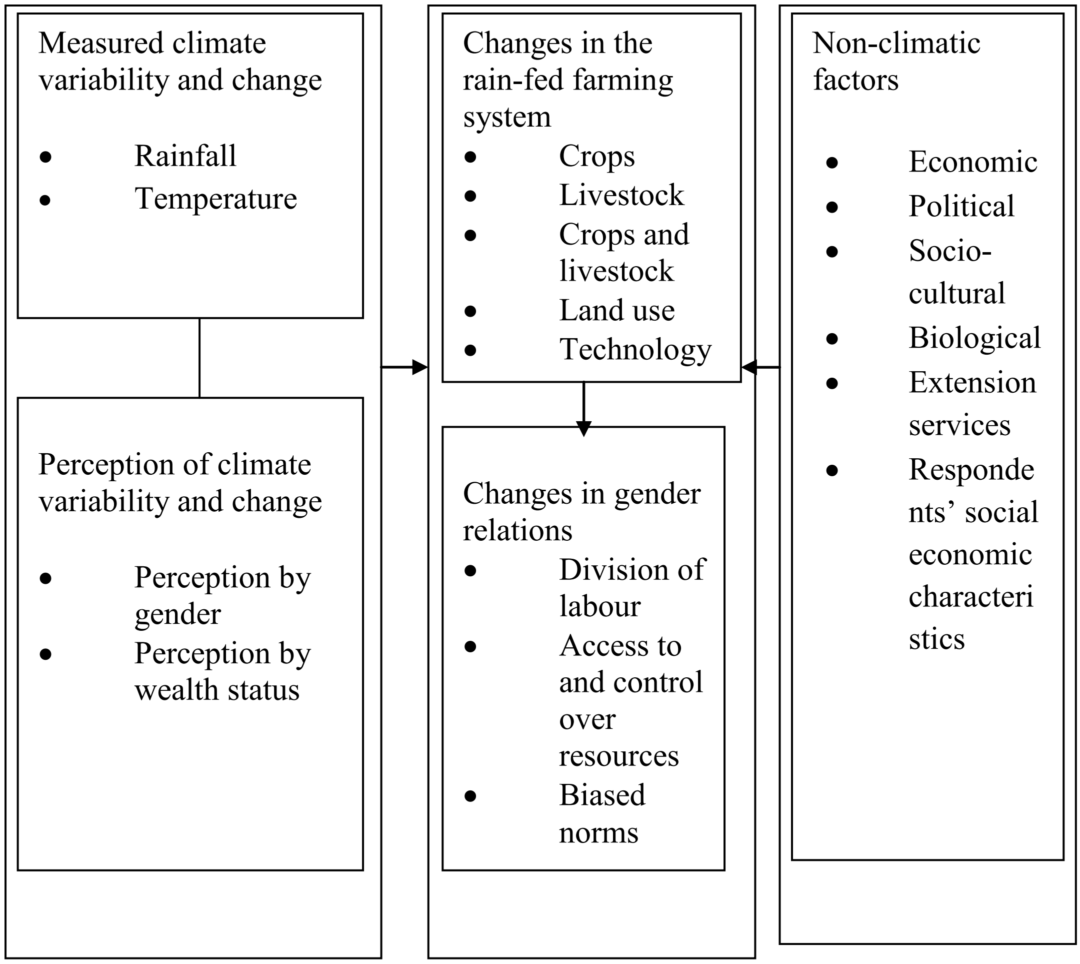

Figure 1.1: Relationships between climate variability and change, non-climatic factors and rain-fed farming system.

Source: Formulated from theoretical literature (Smit *et al.,* 1996; Grothmann and Patt, 2003; Darnhofer *et al.,* 2010).

The study hypothesized that climate variability and change and non-climatic factors have impact on RFFS as changes in the system occur. The impact can be positive when they enhance system's ability to support people's living, or can be negative when they put the system at risk of failure in supporting the living. Another key argument in this thesis is that smallholder farmers who perceive that climate variability and change have happened, adjust RFFS to minimize the impact and or tap the opportunities of temperature and rainfall variability, if any (Grothmann and Patt, 2003). The study also argues that changes in RFFS occur following changes in measured climate variability and change from meteorological data trends and also due to farmers' perceptions of the phenomena. In other words, farmers' perceptions of climate variability and change were validated by meteorological data. According to the framework presented in Fig. 1.1, changes and/or impact on RFFS can trigger changes in gender relations. The changes can be either advantageous or disadvantageous to men or women.

One of the central ideas put forth in Fig. 1.1 is that increased warming, while rainfall is on the decrease, reduces soil moisture, which negatively affects crop and livestock production. As such, smallholder farmers will need to adopt new crop varieties or adopt different livestock keeping systems to address the situation. Those changes will definitely portray changes in RFFS. In the same line of thinking, some smallholder farmers can diversify to irrigated farming system and improve land use management.

The aspect of perception of climate variability and change dealt with in this thesis refers to perception of occurrence of the phenomena. The hypothesis put forth in Fig. 1.1 is that men and women's perceptions of occurrence of climate variability and change were the same. The thesis did not concentrate on perceived risks because it is already known that women perceive more risks relative to men because of gender inequalities that subordinate them (women) (Gustafson, 1998). It was also hypothesized in Fig. 1.1 that the poor, not so poor and the rich had the same perceptions of climate variability and change, because semi-arid areas are dominated by crop producers and agro-pastoralists that depend on rainfall for their survival. Wealth categorization criteria are presented in Appendices 16 to 18.

Another idea in Fig. 1.1 is that smallholder farmers with better access to extension services were more likely to adopt improved technologies like new crop varieties or pasture management. Similarly, they were expected to have better land use plans to overcome the impact of climate variability and change (Hassan and Nhemachena, 2008). Also, an economic factor considered in Fig. 1.1 is input and output market access. Input market access is an ability to purchase improved crop varieties while output market access is an ability to engage in marketing processes to sell the crop produce (Maddison, 2006). The ability of smallholder farmers to purchase input market was expected to enhance adoption of new crop varieties. On the other hand, political factors in Fig. 1.1 refer to a government policy requiring farmers to produce a certain crop or a crop variety. This was expected to restrict smallholder farmers to grow a specific crop and/or crop varieties. Socio-cultural factors are limited, in this thesis, to food preference, which was also expected to affect decision of a farmer to grow certain crops or crop varieties. In addition, biological factors encompass crop and livestock pests and diseases, which can also cause change in RFFS. Respondents' social economic characteristics involved in Fig. 1.1 are defined in Appendix 12.

According to Maddison (2006), social economic characteristics likely to cause changes in RFFS include household size, respondents' age, respondents' sex, respondents' occupation (crop growers or agro-pastoralists) and years of schooling. Larger households were likely to use part of their labour force in non-farm activities to minimize the impact of climate variability and change. They were also expected to take up labour intensive measures in responding to the phenomena. On the other hand, perception of climate variability and change increases with age such that old people were expected to have more experience of dealing with the changes. Similarly, educated respondents have more knowledge and information that can help them to deal with the phenomena. Another argument is that women respondents were likely to have different views because of their high perceived risks of the phenomena relative to men (Gustafson, 1998). In addition, respondents' occupation can influence changes in RFFS in that agro-pastoralists were expected to have more knowledge on dealing with climate variability and change with regard to livestock keeping and crop production. In addition, those who grew crops only were likely to have more experience on crop production and how to deal with climate variability and change.

1.8 Organization of the Thesis

This thesis presents four publishable manuscripts organized into chapters. The whole thesis is organized into six chapters and opens up by presenting an introduction in Chapter One. This sets up background information of the thesis. Chapter Two presents manuscript number one that focuses on inter-annual anomaly and seasonal variability. This is followed by Chapter Three, which presents manuscript two, dealing with people's perceptions and meteorological data trends. Chapter Four presents manuscript number three, which concentrates on changes in rain-fed farming system (RFFS) as a consequence of climate variability and change. Chapter Five, on the other hand, presents the fourth manuscript that deals with impacts of climate variability and change in gender relations. In Chapter Six, the thesis presents a summary of the results and discussion from all manuscripts, and finally draws out conclusions and recommendations.

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CHAPTER TWO

2.0 Inter-annual Anomaly and Seasonal Variability of Rainfall and Temperature in Selected Semi-arid Areas of Tanzania

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2.1 Abstract

Although climate variability and change are not new phenomena, their trends over time are not well understood at the local level in semi-arid areas. Using data from Tanzania Meteorological Agency during the 1994-2011 period, this chapter examined inter-annual anomaly that is defined as deviation from a long term mean; and seasonal variability of rainfall and temperature in Iramba and Meatu districts. As hypothesized, results showed no significant increase of inter-annual rainfall variability (R^2 = 0.17, P > 0.05) in Iramba and in Meatu (R^2 = 0.007, P > 0.05). Nonetheless, a considerable shift of heavy rains was evident in Iramba District. In both districts there was a shift of months with the most rains. In addition, considerable rainfall and temperature variability were depicted by the trends in the number of hot and cold years, and the number of dry and wet years as well as by trends in the number of rainy days in both districts. While temperature showed an increasing trend throughout April in both districts, rainfall showed a decreasing trend. Higher temperature can increase evapo-transpiration that in turn reduces moisture for the crops, exacerbates poor pasture productivity for livestock, and leads to water scarcity for both crops and animals. Hence, adjustments in cropping and livestock production systems are critical to buffer the impact of climate variability in semi-arid areas.

Keywords: Rainfall, temperature, semi-arid, climate change, climate variability, Tanzania

2.2 Introduction

One of the contemporary and serious global problems for sustainable development which is threatening rain-fed farming system (RFFS) is climate variability and change. While climate change occurs over a long-term period, usually a minimum of 30 years, climate variability is a short-term change encompassing temporal and/or spatial variations of the mean state and other weather statistics of the climate beyond individual weather events (IPCC, 2007). In this study, variability is considered between years and between and within growing seasons. In the drought stricken, semi-arid regions of Sub-Saharan Africa (SSA) including Tanzania where poverty is common, livelihoods are largely anchored on crop production and agro-pastoralism.

Dependence on rain-fed agriculture is 80% at the global level, but it is 95% in SSA (IWMI, 2010); while more than 95% and in some places all smallholder farmers and agro-pastoralists in semi-arid rural Tanzania depend on rainfall (NBS, 2009; Mongi *et al.*, 2010; Afifi *et al.,* 2014). Climate variability presents serious risks on rain-fed dependent livelihoods especially in semi-arid agro-ecological zones relative to other regions because rainfall in these zones is uncertain (Blench and Marriage, 1999; IPCC, 2007; Burke *et al.,* 2009; IPCC, 2014). Notwithstanding, crop yields can be more affected compared to livestock production system when climate variability occurs at a critical stage of growth (Midgley *et al.,* 2012).

Defining semi-arid areas has largely been based on the climate. Yet, it is problematic to define semi-arid regions based on their climate[2] (Quinn and Ockwell, 2010). Some scholars have defined these areas as ones having mean annual rainfall as low as 200 and not above 600 mm (Huang *et al.,* 2012; Sarr, 2012). Others give a range between 500 and 800 mm of rainfall per year (URT, 2007; Mongi *et al*., 2010); while some report mean annual rainfall, which ranges between 600 and 800 mm (UDSM, 1999). According to Quinn and Ockwell (2010), the mean annual rainfall in semi-arid regions is between 400 and 1 200 mm with mean monthly temperature exceeding 18^0C, with evapo-transpiration exceeding precipitation in one or more seasons. Unquestionably, an annual rainfall below 400 mm is too low and can define an arid agro-ecological zone, which is drier relative to a semi-arid zone. In addition, an annual rainfall of 1 200 mm is too much for a semi-arid zone. This chapter therefore defines the term semi-arid as an agro-ecological zone which receives mean annual rainfall between 400 and 900 mm with a mean monthly temperature exceeding 18^0C (Quinn and Ockwell, 2010).

Based on less sufficient rainfall and temperature, semi-arid regions form nearly 30% of the total global land surface area (Lambers *et al.,* 2001; Tietjen and Jeltsch, 2007). They form 18% of the total land surface area in SSA, and cover a huge land surface area in Tanzania between 45 and 75% (UDSM, 1999) and/or up to 80% (Quinn and Ockwell, 2010). Regions which lie in semi-arid areas among other places in Tanzania include Singida, Shinyanga, Dodoma, Tabora and some parts of Arusha and Iringa (UDSM, 1999).

[2] Average weather conditions including temperature, rainfall and day length (Quinn and Ockwell, 2010).

Literature reveals a high degree of agreement that climate variability and change have already happened, and that they are global phenomena (Agrawala *et al.,* 2003; IPCC, 2007; Morton, 2007; Paavola, 2008; Kotir, 2010; Roudier *et al.,* 2011). The fifth report of the IPCC provides more evidence on the occurrence of the phenomenon than previous reports (IPCC, 2014). Proponents of the phenomenon like Exenberger and Pondorfer (2011) are of the view that rainfall is decreasing, while temperature is increasing over time. Yet, they fail to explain seasonal variability particularly within crop growing seasons over time. Some scholars are of the view that climate variability is not new in semi-arid regions and that has been affecting smallholder farmers and pastoralists for many decades (UDSM*,* 1999; Tietjen and Jeltsch, 2007; URT, 2007; Vetter, 2009; Midgley *et al.,* 2012).

Tanzania is not exceptional regarding climate variability. Rowhani *et al.* (2011) for example reported inter-annual variability of rainfall and temperature in Tanzania. Frequent drought has also resulted into reduced yields and increased food shortages leading to food insecurity (Lema and Majule, 2009). Generally, annual rainfall reveals a decreasing trend at the rate of 3.3% per decade more so in southern Tanzania, while the mean annual temperature has increased by 0.23^{0}C per decade during the period between 1960 and 2003 (McSweeney, 2011). Both day time and night time temperatures show an increasing trend particularly during January and February, but night time temperatures reveal an increasing trend at 19.8% per year relative to day time temperature, which increased at 13.6% per year between 1960 and 2003 (McSweeney, 2011).

Furthermore, Sarr (2012) predicts more decrease in rainfall in semi-arid regions of Africa including Tanzania and adds that if this trend continues, the growing season in semi-arid regions of Africa will be reduced by 20% in 2050. While climate variability is differentiated by geographical locations (Challinor *et al.,* 2007; Moyo *et al.,* 2012), there is paucity of information regarding trends of climate variability in semi-arid ecological zones. It is clear that climate variability will considerably affect rain-fed farming system (RFFS) and natural resources management in semi-arid areas, and therefore, a clear understanding of the phenomenon is critically important in order to inform decision making process to address the phenomenon.

This chapter examined climate variability with the view of contributing knowledge on rainfall and temperature trends over time in Iramba and Meatu districts, some of the semi-arid areas located in central parts of Tanzania. Specifically, the chapter: (i) analyzed inter-annual variability and (ii) analyzed seasonal variability during crop growing period starting from November to April for a period between 1994 and 2011. It used monthly rainfall and temperature data to analyze inter-annual and seasonal anomaly, which can reveal whether a particular year or season was dry (negative anomaly) or wet (positive anomaly). An anomaly is defined as a deviation of a mean annual or seasonal rainfall and temperature from a long-term mean. The anomaly can also demonstrate whether a certain season was hot or cold and whether the number of dry years increased or decreased over a specific period of time. The trend on the number of rainy days was also analyzed. The thinking in this chapter is that rainfall and temperature are among the most important climatic variables for a rain-fed farming system (RFFS) in semi-arid areas. Rainfall for instance, controls moisture for plant growth, whereas temperature controls physiological processes in crops, evaporation and evapotranspiration. The following sections are devoted to explaining the study area, source of data and presenting results and discussion. Finally, the chapter charts out conclusions and recommendations.

2.3 The Study Districts

2.4 Meatu District

Meatu District is located in Simiyu Region while Iramba District is in Singida Region. The two districts are contiguous. This provided a base for selection of the districts to assess variations of rainfall and temperature between adjacent districts lying in semi-arid areas. Secondly, while located entirely in semi-arid areas, livelihoods in both districts depend on agriculture and livestock keeping by 80% to 90% (PMO-RALG, 2007; Iramba District Council, 2009), and dependence on rainfall is more than 95% (NBS, 2009). Meatu District lies between latitudes 3^{o} and 4^{o} South and longitudes 34^{o} and 35^{o} East. Its altitude ranges between 1 000 and 1 500 m.a.s.l. The district receives a mean annual rainfall between 400 and 900 mm in the southern and northern parts, respectively and the rainfall regime is unimodal (González-Brenes, 2003; Rubanza *et al.,* 2005; Meatu District Council, 2009). The southern zone of the district is drier relative to the northern zone. Food insecurity is also common in the southern zone compared to the northern zone (Meatu District Council, 2009). Vegetation is mostly shrubs and thorny trees scattered or clustered in some areas revealing a characteristic of a semi-arid zone. Most parts in the southern zone of the district have bare soils especially during dry seasons compared to the northern zone. There are a number of seasonal rivers in the district. River Simiyu, is the biggest river that used to flow throughout the year, but is now drying up.

Demographically, women comprise 52.1% out of 299, 619 people, and the average household size was 7.4 in 2012 (URT, 2013). Food crops grown include maize, sorghum, paddy, sweet potatoes, cassava, pulses and groundnuts. About three-fifth of the district's population grew cotton, which was the main cash crop. The livestock that were raised by farmers include cattle, goats, local chicken, donkeys and sheep. It was difficult to separate crop production and livestock keeping in Meatu District because majority of livestock keepers also grew crops and vice versa. Agro-pastoralism was most common in the southern parts of the district which receives relatively less rainfall.

2.5 Iramba District

Iramba District lies between 4^0 to $4^0.3^{'}$ latitudes South and 34^0 to 35^0 longitudes East. The district is divided into three major agro-ecological zones; the western Great East African Rift Valley zone, central highland zone, and the eastern zone. The Great East African Rift Valley zone is drier relative to other zones (Iramba District Council, 2009). Generally, the district receives a mean annual rainfall between 500 and 850 mm. The onset of rainfall occurs during mid-November and cessation is normally during mid-May. Surface temperature ranges between 15^0C in July and 30^0C in October (Iramba District Council, 2009). Vegetation is mainly natural including Miombo woodlands, acacia woodlands and grasslands. More trees are found on hills compared to flat terrains in the low lands. Demographically, women constitute 50.5% out of 236, 282 people and the average household size is 5.3 (URT, 2013).

The profile of Iramba District (2009) shows that the district covers a land surface area of 790 000 hectares of which 44.3% is arable land. However, only 19% to 25% of the arable land is under utilization. The grazing area covers 42.7%, while forest covers 9.3%. The rest of the land surface area is covered by rocks and water bodies mainly Lake Kitangiri. Agriculture, which includes crop and livestock production, is the main occupation; about 85.2% of the population is engaged in agriculture and so are at risk of being affected by climate variability. The major food crops grown were sweet potatoes, white sorghum, bulrush millet, maize and beans. Cash crops comprised of; sunflower, groundnuts, sesame, cotton, onions, pigeon peas, cowpeas, lentils and green gram. Livestock included cattle, sheep, pigs, goats and donkeys. Other economic activities are mining and sunflower oil processing.

2.6 Source of Data and Analysis

Data used in this study were collected from Tanzania Meteorological Agency (TMA) recorded on a monthly basis. The TMA is a government agency responsible for meteorology issues in the country. Due to lack of TMA meteorological station in Meatu District, the study used the mean of data obtained from two different meteorological stations managed by the District Agricultural and Livestock Department. One of the meteorological stations is located at Mwanhuzi (central part of the district) and another one located at Mwandoya in the northern part. Initially, the study intended to analyze rainfall and temperature data for a 30-year period[3] up to 2011. Nonetheless, due to inconsistence in data availability caused by either failure to record readings for a certain day or period of time, or due to failure to submit the readings from meteorological stations to TMA, the time frame with continuous data was reduced to 18 years, covering a period between 1994 and 2011.

Tanzania Meteorological Agency (TMA) does not record temperature at the district level. Data on temperature were therefore obtained from Shinyanga and Singida region meteorological stations situated at the regional headquarters (Table 2.1) to represent Meatu and Iramba districts respectively. Therefore, when interpreting temperature data, caution has been taken because temperature variability can exist from one district to another in one region.

[3] This is the classical period of time defined by the World Meteorological Organization (WMO) in which change in the climate system can be observed (IPCC, 2007).

Importantly, the study analyzed maximum temperature because it is recorded during the day time and thus, it is critical in controlling evapo-transpiration and drying up of water bodies. For rainfall variability, the analysis focused on annual and seasonal anomaly trends because anomaly can reveal dry and wet periods over time. During data analysis, both anomaly and monthly means were computed. The anomaly was computed as a deviation from a long-term (annual) mean. The rainfall and temperature annual anomalies are presented in Appendix 7. The hypothesis that the study districts did not experience significant increasing trends in inter-annual rainfall variability for a period between 1994 and 2011 was tested using a p-value at 5% level of significance.

Table 2.1: Location of meteorological stations involved: 1994-2011

District	Station	Latitude (degrees)	Longitude (degrees)	Elevation (meters)
Iramba	Kiomboi administrative centre – rainfall	$04^0$17'S	$34^0$24'E	1585
	Singida regional HQ - temperature	$04^0$48'S	$34^0$43'E	1307
Meatu	Meatu District - rainfall	ND	ND	ND
	Shinyanga regional HQ- temperature	$03^0$39'S	$33^0$25'E	1000

Note: ND means data not available; HQ means headquarters

Reporting that the inter-annual rainfall and temperature variability were significant or not significant may not reveal much about variability, which threatens small-scale farmers, pastoralists and particularly agro-pastoralists. In order to uncover more about rainfall and temperature variability, the study analyzed six-month rainfall trends from November to April. The study also analyzed trends in number of dry and hot years and trends in number of rainy days.

For temperature variability, the analysis focused on trends in number of hot and cold years. This study adopts a definition of a rainy day as defined by the Tanzania Meteorological Agency (TMA) to mean a day whereby at least 1.0 mm of rainfall is measured (Kahimba *et al*., n.d). Below that amount, it is not considered as a rainy day. The study also defines a dry year as one that gives a negative annual rainfall anomaly; otherwise, it is a wet year. A hot year on the other hand, is defined in this study as one, which gives positive annual temperature anomaly; otherwise, it is a cold year.

2.7 Results and Discussion

2.7.1 Trends in annual rainfall and temperature

Results for inter-annual rainfall anomaly trends measured at Kiomboi meteorological station are presented in Fig. 2.1. The curvilinear relationship between anomaly in millimetres and time in years was better because the scatter plots (Appendix 19 and 20) were so scattered suggesting that the linear relationship was not appropriate. The analysis showed that the long-term mean was 852.2 mm per year for the period between 1994 and 2008. This is a typical trend for the semi-arid regions as defined in this study in which the lower limit for mean annual rainfall is 400 mm and the upper limit is 900 mm. In addition, the curvilinear trend reveals that the annual rainfall was decreasing at Kiomboi meteorological station between 1994 and 2001. This was followed by an increasing trend for the period between 2001 and 2008. The P-value was 0.3 ($P > 0.05$) implying that the change was not statistically significant.

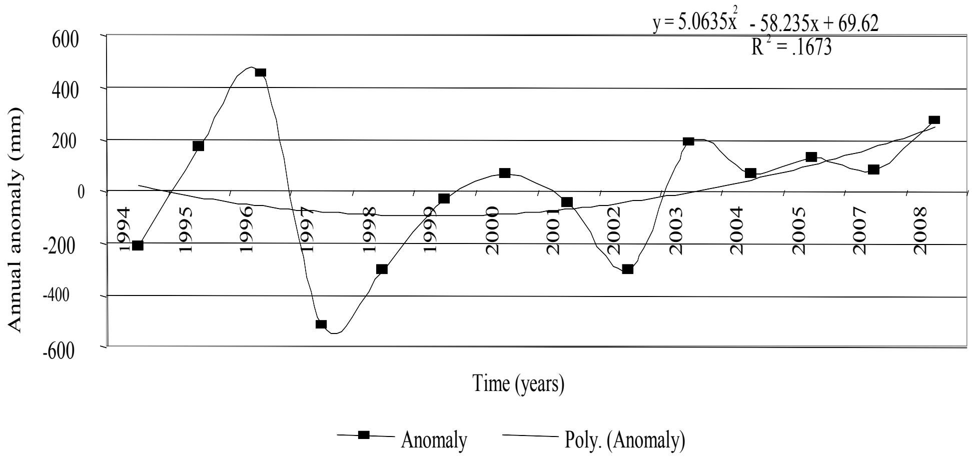

Figure 2.1: Kiomboi annual rainfall anomaly trends [1994-2008].

Note: Poly (anomaly) means anomaly with many curves and that the relationship is not linear

The results of the regression analysis where the anomaly was regressed against time (years) showed that the coefficient of determination (R^2) was 0.17, which implies that 17% of the inter-annual rainfall variability was associated with change in time, while the rest of the variance can be explained by other factors. The annual rainfall decreased from 1994 to 2001 and thereafter increased up to 2008. The increasing trend which occurred after 2001 as shown in Fig. 2.1 can be beneficial, but only if the increase was significant and those rainfall patterns were consistent. Consistent rainfall patterns suggest that it rained at the time farmers and agro-pastoralists expected it to rain. Furthermore, rainfall variability can be beneficial when the increasing annual rainfall trend exceeds the range for semi-arid regions. The values for mean annual rainfall and R^2 in Iramba District suggest that the rain-fed farming system was at risk. The dominant farming systems in semi-arid regions likely to be affected as reported by UDSM (1999) include maize and legume system; agro-pastoralist system; livestock/sorghum/millet system; and pastoralist system.

It was difficult to fit the data for maximum temperature in a linear or curvilinear equation because data were so scattered when plotted on a scatter plot. More importantly, data were available for 10 years only indicating that the period was not enough to fit better the data in a linear or curvilinear equation. However, results showed that the mean maximum temperature for Singida regional headquarters, which was used as a proxy for Iramba District, was 27.5^{0}C over the period between 2003 and 2011. In addition, there was higher number of hot years relative to cold ones over the same interval (Table 2.2). Comparing maximum temperature with inter-annual rainfall anomaly presented in this study, the period between 2003 and 2007 had the highest number of dry years compared to wet ones. This implies that the periods of highest temperature were also dry periods. It also implies that the increase in maximum temperature was accompanied by decreasing amount of rainfall in the region and in Iramba District in particular because part of the district is located along the Great East African Rift Valley which is relatively warm (Iramba District Council, 2009).

Table 2.2: Number of hot and cold years in Iramba District based on temperature anomaly

Period	Number of hot years	Number of cold years
2003-2007	3	2
2007-2011	3	2
Total	**6**	**4**

Maximum temperature is normally recorded during the day time, thus its increase can reduce soil moisture through evaporation and evapotranspiration, which in turn can negatively affect crop and pasture development. It is important to note, however, that data for maximum temperature used in this study were collected at the regional headquarters in Singida because TMA does not record temperature at the district level. Hence, when interpreting the results on temperature, caution has been taken because there can be some temperature variability from one district to another within the region.

In Meatu District, annual rainfall anomaly showed a long-term mean of 668.0 mm for the period between 1994 and 2011 (Fig. 2.2). Like in Iramba District, this mean annual rainfall was typical of the semi-arid regions. Based on mean annual rainfall, Meatu District was drier than Iramba District. Yet, the annual rainfall anomaly in Meatu District showed almost a constant trend between 1994 and 2003. The trend from 2004 showed a minimum increasing pattern up to 2011 (Fig. 2.2). The P-value was 0.7 ($P > 0.05$) implying that the increase was not statistically significant at 5% level of significance. The R^2 was 0.0074, translating into 0.7% of the inter-annual rainfall variability that was associated with change in time between 1994 and 2011.

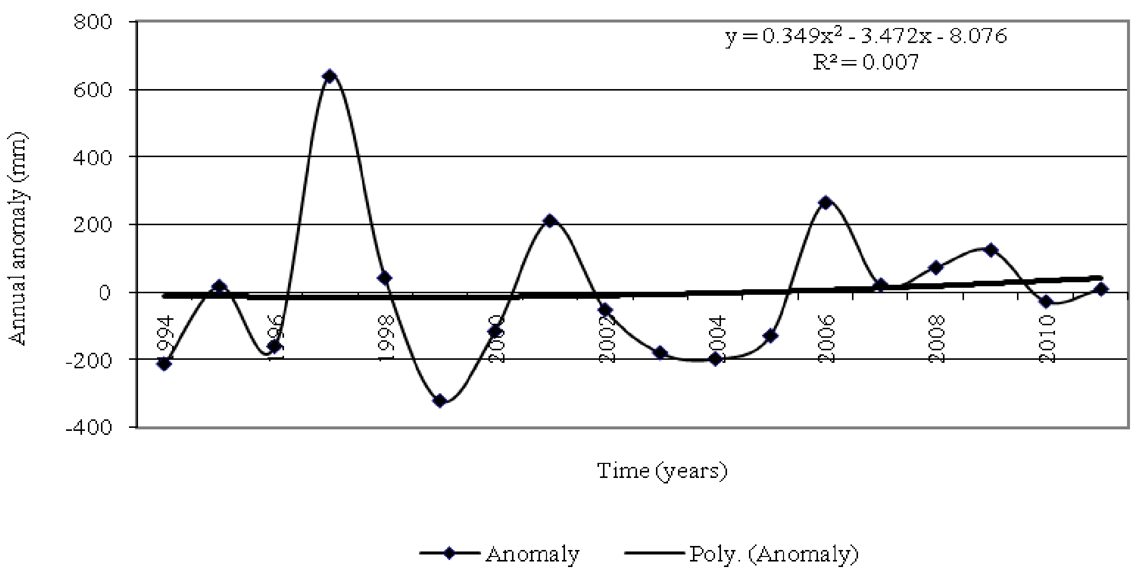

Figure 2.2: Meatu annual rainfall anomaly trends [1994-2011].

Note: Poly (anomaly) means anomaly with many curves and that the relationship is not linear

Considering the R^2 values, it appears that the inter-annual rainfall variability accounted for by change in time was relatively less in Meatu than in Iramba District. Furthermore, the P-value for each district revealed insignificant increase in inter-annual rainfall over time indicating similar rainfall patterns in the study districts. This result is not surprising because both districts are located within a semi-arid agro-ecological zone where annual rainfall is usually less sufficient. Rainfall variability can be high, though not significantly increasing over time. Arguably, these results may not reflect local perception about the degree of drought and rainfall variability because the local people can define drought and rainfall variability differently from the measured ones. Insignificant increase in inter-annual rainfall anomaly was also reported by Nicholson (2000) in semi-arid southern Africa. Nicholson (2000) on the other hand reported strong inter-annual rainfall anomaly in the semi-arid northern hemisphere, mainly influenced by land-atmosphere feedback mechanism.

As it was the case in Iramba District, it was difficult to fit the data for maximum temperature in a linear or curvilinear trend in Meatu District because the data were also so much scattered when plotted in a scatter diagram, suggesting that the linear or curvilinear trend was not possible. Based on Shinyanga meteorological station, the mean for maximum temperature was 30.6^0C for the period between 1994 and 2011. In addition, temperature anomaly showed more hot years relative to cold years for that period (Table 2.3). The period between 1999 and 2003 showed the highest number of hot years implying that it was the hottest period (Table 2.3). Like in Iramba District, the hottest periods in Meatu District were also dry periods.

Table 2.3: Number of hot and cold years in Meatu District based on temperature anomaly

Period	Number of hot years	Number of cold years
1994-1998	2	3
1999-2003	4	1
2004-2008	3	2
2009-2011	1	2
Total	**10**	**8**

2.7.2 Trends in number of dry and wet years

Table 2.4 presents numbers of dry and wet years measured at Kiomboi meteorological station. A dry year is defined in this study as one whose annual anomaly was negative as opposed to a wet year which had positive anomaly. The results showed that there were 6 dry years and 9 wet years in the period between 1994 and 2008 at Kiomboi meteorological station. A higher number of dry years was recorded between 1994 and 2003. The number of wet years was higher for the period between 2004 and 2008. However, there was no clear trend on dry and wet years for the period between 1994 and 2008.

Table 2.4: Number of dry and wet years measured at Kiomboi in Iramba District

Decade	Dry years [Negative anomaly]	Wet years [Positive anomaly]	Years with missing data
1994-1998	3	2	0
1999-2003	3	2	0
2004-2008	0	5	0
Total	**6**	**9**	**0**

Table 2.5: Number of dry and wet years measured in Meatu District

Decade	Dry years [Negative anomaly]	Wet years [Positive anomaly]	Years with missing data
1994-1998	2	3	0
1999-2003	4	1	0
2004-2008	2	3	0
2009-2011	1	2	2
Total	**9**	**9**	**2**

Meanwhile, the analysis of rainfall data in Meatu District showed a similar number of dry and wet years in the period between 1994 and 2011 and, like in Iramba, there was no clear trend (Table 2.5). This was expected because, as reported earlier in this study, annual rainfall anomaly trend showed a slow increasing trend for the period between 1994 and 2011 and so the number of dry and wet years was likely to remain constant throughout the period under consideration. Nonetheless, the number of dry and wet years alternated up and down or down and up. An alternating pattern for dry and wet years in the district suggests presence of rainfall variability. Dry years were, in principle, bad ones because the amount of rainfall was below the long-term mean. In other words, dry years received lower rainfall. An increasing number of dry years can suggest increasing number of bad years measured at a particular rainfall station. These results were in contrast with a study conducted by Lema and Majule (2009) in Manyoni District, Singida Region, which reported an increasing frequency of dry years. Moyo *et al*. (2012) also reported recurrence of drought in semi-arid SSA including Zimbabwe. This implies that rainfall variability in semi-arid areas differs by location and generalization is not possible.

2.7.3 Trends in mean monthly rainfall and temperature

Table.6 presents trends in mean monthly rainfall measured at Kiomboi meteorological station during the six-month crop growing period from November to April. Clear trends are also presented in Appendix 8. The results in Table 2.6 showed that the highest amount of rainfall during the crop growing season had been shifting from December (1994-1998) to March (1999-2003) and back to January (2004-2008). April and December showed a continuous decrease in amount of rainfall throughout the period under consideration, while the rest of the months showed fluctuating trends.

Table 2.6: Mean monthly rainfall at Kiomboi meteorological station

Month	1994-1998	1999-2003	2004-2008
November	71.0	123.6	67.3
December	195.6	139.1	112.9
January	140.2	192.4	149.9
February	158.8	60.1	134.7
March	151.8	202.2	135.3
April	120.8	87.6	66.6

Both shifts of heavy rains and fluctuating decreasing trends during the crop growing season suggest presence of seasonal rainfall variability. A clear decreasing trend in the amount of rainfall in April suggests earlier rainfall cessation, which shortens the length of the crop growing season, hence affecting proper maturity of crops and pastures. The clear decreasing trend in December implies that rainfall was decreasing during the critical crop growing period. The implication of both effects (which occur in December and April) is to reduce the productivity of crops and pastures. Rowhani *et al.* (2011), for example, have reported a decrease in productivity for maize, rice and sorghum in Tanzania due to climate variability.

The results in Table 2.7 also showed that the highest temperature at Singida meteorological station was recorded in November for the period between 2003 and 2007. November also recorded the highest temperature for the period between 2008 and 2011 implying that it was the hottest month throughout the period between 2003 and 2011. In addition, March and April showed an increasing maximum temperature trend from 2003 to 2011. December, January and February showed decreasing trend throughout the period under consideration. It was difficult to establish the correlation between maximum temperature measured at Singida meteorological station and rainfall measured at Kiomboi meteorological station because there was inconsistency in time frame regarding rainfall and temperature records. Nonetheless, the data clearly showed that, while rainfall decreased throughout the month of April for the period between 1994 and 2008, maximum temperature increased by 0.1^0C in the same month between 2003 and 2011 at Singida regional headquarters and presumably in the rest of the region, including Iramba district.

Table 2.7: Mean monthly maximum temperature at Singida meteorological station

Month	2003-2007	2008-2011
November	29.6	28.8
December	27.7	27.4
January	27.8	27.4
February	28.3	27.3
March	27.5	27.7
April	26.8	26.9

In Meatu District, rainfall data were available for the period between 1994 and 2011. The results showed that the highest amount of rainfall was recorded in January (1994-1998), March (1999-2003), December (2004-2008), and February (2009-2011); implying a constant shift for the most rainy month (Table 2.8). The trends are also clearly presented in Appendix 9.

Table 2.8: Mean monthly rainfall in Meatu District

Month	1994-1998	1999-2003	2004-2008	2009-2011
November	132.9	64.6	108.4	62.5
December	141.0	77.6	135.0	175.0
January	168.4	108.9	101.2	48.0
February	124.1	74.9	102.1	139.9
March	102.1	138.2	133.3	136.0
April	130.5	88.3	84.3	96.3

The data also showed a clear decreasing trend in the amount of rainfall received in January. The trend was generally also declining for April during this period, especially between 1994 and 2008. The rest of the months showed fluctuating trends. The decreasing trend in January and the mixed trends in the rest of the months suggest that there was seasonal rainfall variability in Meatu District for the period under consideration. The common phenomenon for Iramba and Meatu districts is that there was seasonal rainfall variability in both districts and the crop growing season normally began in November to April.

Like in Iramba District, the highest temperature in Meatu District was recorded in November throughout the study period except for the interval between 1999 and 2003 when February recorded the highest temperature (Table 2.9).

Table 2.9: Mean monthly maximum temperature at Shinyanga meteorological station

Month	1994-1998	1999-2003	2004-2008	2009-2011
November	31.7	31.0	31.4	30.9
December	30.2	29.6	29.9	29.3
January	29.5	29.1	30.3	29.9
February	29.2	31.3	30.3	30.2
March	30.7	30.1	29.6	30.4
April	29.6	29.8	29.9	30.5

Within months, trends showed that the maximum temperature increased in April throughout the period between 1994 and 2011. The rest of the months showed fluctuating trends over the same period suggesting temperature variability in Shinyanga including Meatu District. Interestingly, while on the one hand the amount of rainfall decreased in April, maximum temperature on the other hand showed an increasing trend over the same month between 1994 and 2011. This study argues that, higher temperature can intensify evapo-transpiration and in turn reduce soil moisture available for crops, particularly when it occurs during the growing season. This phenomenon can in turn threaten crop and pasture development and productivity. Water sources may also dry up thus adversely affecting smallholder farmers and agro-pastoralists whose livelihoods largely depend on rain-fed farming system. Seasonal variability of rainfall and temperature was similarly reported by McSweeney (2011) and Rowhani *et al.* (2011) at the national level in Tanzania.

2.7.4 Trends in number of rainy days within crop growing seasons

Table 2.10 presents the numbers of rainy days during crop growing seasons which occurred between November and April. The results from Kiomboi meteorological station showed a fluctuating trend in the number of rainy days for the period between 1994 and

2008. These increased during the period 1994-2003, but decreased in the period between 2003 and 2008. Although annual rainfall anomaly showed a minimal increasing trend during this interval in the case of Meatu District as reported earlier in this study, the mean number of rain days showed no clear decreasing trend throughout the period between 1994 and 2011 (Table 2.11). However, this does not mean that there was no rainfall variability. Rainfall variability coupled with less sufficient annual rainfall can exacerbate poor livelihoods among smallholder farmers and agro-pastoralists.

Table 2.10: Number of rain days at Kiomboi meteorological station

Decade	Number of rain days between November and April	Mean (in rainy days)	Seasonal anomaly	Months with missing data
1994-1998	332	66.4	-2.6	0
1999-2003	341	68.2	-4.5	0
2004-2008	283	56.6	7.1	1
Total	**1115**	**63.7**	**0.0**	**1**

Table 2.11: Number of rain days in Meatu District

Period	Number of Rain Days between November and April	Mean (in rainy days)	Seasonal anomaly	Months with missing data
1994-1998	240	48.0	-1.4	0.0
1999-2003	197	39.4	7.2	0.0
2004-2008	251	50.2	-3.6	0.0
2009-2011	151	30.2	16.4	2.0
Total	**839**	**46.6**	**0.0**	**2.0**

A decrease in number of rain days especially during crop growing season may not necessarily mean that the amount of rainfall decreased concurrently because the amount of rainfall depends on intensity and duration during which the rain falls. This can clearly be seeing in Meatu District (Table 2.11) where the annual rainfall anomaly showed an increasing trend (though insignificant) for the period between 1994 and 2011, while the number of rain days showed a fluctuating decreasing trend. The results indicating a decrease in the number of rainy days in some years are supported by Sarr (2012) who reports a substantial drop in the number of rainy days in semi-arid areas of West Africa, and by Gong *et al.* (2004) who also reported the same in semi-arid regions of China. This implies that the decrease in number of rain days is a widespread phenomenon in semi-arid areas not only in Tanzania, but also in other areas in Africa and the world at large.

2.8 Conclusions and Recommendations

This chapter examined trends in inter-annual anomaly and seasonal variability of rainfall and temperature in Iramba and Meatu districts. It specifically assessed trends in the; number of rainy days, number of hot and cold years, number of dry and wet years and also monthly rainfall variability. Based on the results and discussion, the chapter concludes that the trends of rainfall and temperature variability increased over time from 1994 to 2011. As hypothesized ($P > 0.05$), the increase in inter-annual rainfall variability was not significant indicating similar inter-annual rainfall variability in both districts. Maximum temperature showed not only variability, but also an increasing trend, a typical characteristic of semi-arid areas. The chapter also concludes that, whereas annual anomaly showed weak rainfall variability in both districts, within and between seasonal trends showed considerable rainfall and temperature variability. When analyzing climate variability, it is therefore important to consider both seasonal and inter-annual anomaly so as to have a clear understanding regarding the degree of climate variability and change.

Based on these results and conclusions, the chapter recommends that district authorities should support crop and livestock adjustments in order to buffer impacts of rainfall and temperature variability during critical periods for growing of crops and pastures. In addition to consolidating and improving the local knowledge that smallholder farmers and agro-pastoralists might have regarding climate variability and change, the district authorities should create awareness and education, and also advise farmers regarding appropriate adaptation strategies. Such strategies can be applied to address risks caused by less sufficient rainfall, higher day time temperature, as well as rainfall and temperature variability, which have been demonstrated in this chapter. One of these strategies involves adjustment on the planting dates for various crops in order to overcome variability and shifts of rainfall patterns during crop growing seasons.

Smallholder farmers and agro-pastoralists also require support on alternative livelihood strategies to reduce dependence on rainfall. This can be done through investment on irrigated farming system and provision of credit for purchasing irrigation pumps. Through this support, farmers can irrigate their crops, but livestock keepers can also harvest water for their animals and use even during prolonged drought. This heavy investment calls for serious mediation of the government and full participation of the private sector and other development actors.

For this reason support to smallholder farmers on general husbandry of crops and animals such as supply of improved seeds and breeds, that are short-term and drought tolerant need to be in place and strengthened. The private sector, for example, should be facilitated by the government to provide such services with district authorities providing guidance through policies and guidelines that enable private sector actors to operate efficiently and equitably thereby providing inputs and services that are affordable to smallholders.

The chapter also recommends further study on two pertinent research issues: first, on farmers' perception of climate variability and change in order to increase understanding of the phenomenon, and secondly, on the impacts of climate variability and change on rain fed farming system (RFFS) in semi-arid areas of Tanzania and how the system adjusts to minimize the impact.

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CHAPTER THREE

3.0 Perceived and Measured Climate Variability and Change in Semi-arid Tanzania: Experiences from Iramba and Meatu Districts

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3.1 Abstract

Climate variability and change are not only an environmental, but also a developmental concern of the 21st Century, having prominent impact in semi-arid areas in developing countries. Using people's perceptions and meteorological data trends, this chapter examined rainfall and temperature variability in Iramba and Meatu districts, some semi-arid areas in Tanzania. The chapter contributed to the controversy of climate variability and change in semi-arid areas. Specifically, the study: (i) assessed people's perception of climate variability and change; and (ii) compared people's perception with meteorological data trends. A qualitative phase that involved 63 participants was followed by a household survey of 388 randomly selected households. The results showed high agreement between people's perceptions and meteorological data trends on changing rainfall patterns. Bad years described by increased droughts[4], temperature, and dry spell[5]; had intensified relative to the situation in the 1970s. Crop growing period had decreased by one month in Meatu and by more than a month in Iramba. Rainfall patterns had also increasingly become inconsistent and unpredictable. As hypothesized ($P > 0.05$), the Mann Whitney U Test showed that women and men had the same perception. In addition, the Kruskal-Wallis Test indicated that the poor, not so poor and the rich showed similar perception ($P > 0.05$). These results have implications on crop and livestock production systems. The chapter concludes that climate variability and change are complex phenomena, which can holistically be understood by combining people's perceptions and meteorological data trends for informed decision making.

Keywords: Perception, climate variability, farming, agro-pastoralism

3.2 Introduction

Climate variability and change are the most prominent environmental and developmental challenges of the 21st Century. This chapter examined perceived and meteorological data trends in order to broaden understanding of the phenomena in semi-arid areas of Tanzania. The term semi-arid, is often defined differently[6]. In this chapter it refers to an agro-ecological zone, which receives a mean annual rainfall of between 400 and 900 mm with a mean monthly temperature exceeding 18^0C (Quinn and Ockwell, 2010). Climate variability is likely to exacerbate severe shortage of water and soil moisture in semi-arid areas of Tanzania and everywhere (IPCC, 2007). As such, crop production and

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[4] Drought is a phenomenon that exists when precipitation is significantly below normal recorded levels, causing serious hydrological imbalance that often adversely affects land resources and production systems (IPCC, 2007).

[5] A dry spell is a sequence of at least 15 consecutive dry days with less than a threshold value of rainfall, greater or equal to 1.0 mm per day. This period normally occurs at a certain time during the rainy season. Such a period can sometimes be abnormally long, but it is shorter and not as severe as drought (Mathugama and Peiris, 2011).

[6] Some scholars have defined these areas as ones having mean annual rainfalls of as low as between 200 and 600 mm (Huang *et al.,* 2012; Sarr, 2012). Others give a range between 500 and 800 mm per year (URT, 2007; Mongi *et al*., 2010); while some report mean annual rainfalls, which range between 600 and 800 mm (UDSM, 1999).

pastoralism, which are the major livelihoods sources in semi-arid areas, are likely to meet serious challenges (Galvin *et al.,* 2001). Climate variability and change are broader concepts, which are defined somewhat differently in the literature. For some people, climate change is a change in long-term mean of weather conditions, their drivers of change – natural and anthropogenic sources - and their impacts (IPCC, 2007; 2014). For others, climate change refers only to human induced weather changes (FAO, 2008).

This chapter takes climate change as a long-term change in statistics of weather including rainfall, temperature, winds, extreme weather episodes (IPCC, 2007), and perceptions of the changes as perceived by smallholder farmers, pastoralists and agro-pastoralists. Climate variability, on the other hand, is defined as temporal and/or spatial variations of the mean state and other weather statistics of the climate[7] beyond individual weather events (IPCC, 2007). The causes of climate variability are two-fold: first, natural internal processes and secondly, anthropogenic external forcing (IPCC, 2014). While climate change occurs over a long period, usually a minimum of 30 years, climate variability is a short-term phenomenon which occurs within or between growing seasons, between or within a year and or within a decade (IPCC, 2007).

The debate on climate change, which gained momentum during the 1990s, was inspired by two academic papers published by Mann *et al.* (1998; 1999) in Nature and Geophysical Research Letters respectively. Results in these papers revealed that surface temperature in the northern hemisphere was increasing for the previous 1000 years, and that the 1990s was the warmest decade, and 1998 was the warmest year. This increase in temperature, which causes climate variability and change, coincided with increasing amount of greenhouse gases in the atmosphere from anthropogenic and natural sources. Thus, some

[7] The IPCC (2007) defines climate as average weather quantities of temperature, precipitation and wind. The classical period of time is 30 years

scholars including Wegman *et al.* (2006) supported these results, while recommending further studies to establish mechanisms for dealing with the phenomenon. Yet, scholars including Mclntyre and Mckitrick (2003) robustly opposed the results by posing three major arguments: first, the Earth was not warming; secondly, the Earth could be warming, yet anthropogenic sources were not among the causes; and thirdly, the Earth could be warming and anthropogenic sources could be responsible, but cautioned that the world needed not to act to stop the phenomenon (Carr *et al.,* 2010).

Using meteorological data trends and simulation models, literature has, currently, demonstrated a high degree of agreement that supports occurrence of climate variability and change at all levels (IPCC, 2014). Sub-Saharan Africa (SSA) including Tanzania is more vulnerable to the impacts of the changes relative to other regions on the global. Remarkably, semi-arid areas are more at risk (IPCC, 2007). This vulnerability can be explained by factors including dependency on livelihood options which are sensitive to climate variability and change, dependency on natural resources, untold poverty, weak institutional capacity and little adaptive capacity to the impacts. For instance, 80% of the world's agriculture is rain-fed. In SSA, agriculture depends on rainfall by 95%. Clearly, rain-fed dependence is above 95% in semi-arid areas (IWMI, 2010; Mongi *et al*., 2010), including Tanzania.

In the 2000s, studies on climate variability and change have turned around into assessing people's perception of the phenomena. Some studies combine perceived and measured climate variability and change in order to comprehensively understand the phenomena. A number of studies have shown agreements between perceived and measured climate variability and change (Maddison, 2006; Mongi *et al.,* 2010; Ogalleh *et al.,* 2012; Juana *et al.,* 2013). Others for example Meze-Hausken (2004) portray contrasting results.

Lyimo and Kangalawe (2010) analyzed rainfall variability for the period between 1974 and 2005 in semi-arid areas of Shinyanga Rural District in Tanzania and reported no significant decrease over time, as opposed to perceived changes. In addition, Lema and Majule (2009) reported decreasing measured rainfall and increasing temperature for the period between 1922 and 2007 in Manyoni, one of the semi-arid areas in Tanzania. However, people's perceptions among 400 respondents were widely distributed over variables including temperature increase; change in onset of rainfall; decrease in rainfall and increase in frequency of droughts. Therefore, there is paucity of information on peoples' perception of climate variability and change and that the phenomena may not be necessarily something new in semi-arid areas. What is unclear is its change over time. Thus, this chapter aimed at contributing to the climate variability and change body of knowledge capturing the change element of the phenomena over time. Specifically, it: (i) assessed people's perception of climate variability and change; and (ii) compared perceived and meteorological data trends. The next sections of this chapter are devoted to describing the study area, methodology employed, results and discussion, conclusions and recommendations.

3.3 Descriptions of the Study Districts

The study was conducted in Meatu District found in Simiyu Region and in Iramba District found in Singida Region. Meatu District lies between latitudes 3^o and 4^o South and longitudes 34^o and 35^o East, South of Lake Victoria, and its altitude ranges between 1 000 and 1 500 metres above sea level. The mean annual rainfall is between 400 and 900 mm in the southern and northern agro-ecological zones of the district, respectively. The rainfall regime is unimodal (Meatu District Council, 2009). Iramba District, on the other hand, lies between latitudes 4^0 to $4^03^’$ South and longitudes 34^0 East to 35^0 East. The district is divided into three major agro-ecological zones: Western Great East African Rift Valley, central highland; and the eastern zone. The former zone is drier relative to the other zones (Iramba District Council, 2009).

Generally, the district receives a mean annual rainfall of between 500 and 850 mm. Surface temperature in the district ranges between 15^0C in July and 30^0C in October (Iramba District Council, 2009). While vegetation is widely scattered, replanted trees after deforestation and sometimes clustered in Meatu District, they are mainly natural Miombo woodlands, acacia woodlands and grasslands in Iramba District. The districts were selected for the study for two reasons: first, they are contiguous. This enabled assessment of variations of rainfall and temperature between adjacent districts lying in semi-arid areas. Secondly, while entirely located in semi-arid areas, livelihoods in both districts depend on agriculture and agro-pastoralism, and dependence on rainfall is above 95% (NBS, 2009).

3.4 Methodology

In order to expand the scope and improve analysis of climate variability and change the current study employed cross-sectional and trend analyses (Sandelowski, 2000). Cross-sectional design was necessary in order to analyze the current situation. This design, however, cannot capture the change element over time. In order to address this limitation, the study involved trend analysis of data on measured rainfall and temperature. In addition, a retrospective technique of asking questions was used to capture perceived changes of climate variability and change over the previous 30 years.

Primary data collection and analysis were done in two different stages. Stage one employed Participatory Rural Appraisal (PRA). The methods employed during PRA were Focus Group Discussions (FGDs), historical timeline and pair-wise ranking. Historical timeline was useful for analyzing changes in the climate over time, while pair-wise ranking was useful in prioritizing a list of climatic variables identified during FGDs. Stage two on the other hand, was a household survey that built on the first stage in order to quantify variables that were prioritized in the first one. That means the second stage was informed by the first stage. The results from the two stages were integrated and compared with meteorological data trends.

The study's unit of analysis for the household survey was a household, and either a household head or a spouse was interviewed depending on availability. Purposive sampling techniques were used to select divisions based on different agro-ecological zones. The southern zone in Meatu District is drier relative to the northern and central zones. In Iramba District, the western lowland is drier relative to the central highland and eastern lowland. Criteria for village selection were: frequent droughts, hunger and frequency of receiving food aid. Frequent hunger and food aid were used as proxy indicators for crop failure which were associated with climate variability and change. Based on criteria mentioned above, two villages were selected from Meatu District: one from southern and the other one from northern part. In Iramba District, only one village was selected from the Western zone as no other villages met the criteria pointed above.

3.4.1 Participatory rural appraisal

Qualitative data were collected through PRA techniques in order to enable farmers and agro-pastoralists to share and analyze their perception of climate variability and change (Chambers, 1994a; 1994b). This method used timeline, pair-wise ranking and FGDs that involved household heads and spouses. A total of seven FGDs were conducted (Table 3.1). In total, 63 members participated. A plan was to include 6-12 members per FGD, but participants ranged from 6 to 14. This is because; in some villages some members came without being invited. According to Masadeh (2012), a small increase in size of FGD does not affect the quality of data.

Table 3.1: Information on FGDs and participants involved

Village name	Number of FGDs conducted	Number of male participants	Number of female participants	Mean age (years)	Minimum age (years)	Maximum age (years)
Kidaru	3	6	9	44	25	60
Mwashata	2	10	14	42	29	63
Mwamanimba	2	13	11	49	31	68
Total	**7**	**29**	**34**	**NA**	**NA**	**NA**

Note: FGDs = Focus Group Discussions; NA = Not Applicable

The study learned from one FGD in Kidaru village, which combined men and women that women did not speak freely when mixed together with men in one group, implying that mixed groups could not clearly uncover women's perception. Therefore, the group in Kidaru was then split into men and women to capture perception from each group. The discussions were tape recorded. Trends of bad years were assessed using timeline approach.

3.4.2 Household survey

A household survey was used to collect quantitative data. A structured questionnaire with closed and open-ended questions was administered to a random sample of 388 households using a systematic random sampling technique to determine perception of climate variability and change. To ensure reliability, pre-testing of the instrument was done at Mwakasumbi near Mwashata village in Meatu District. This involved ten respondents. After pre-testing, variables intended to measure responses on change in length of growing season, number of rain days and change in amount of rainfall were removed to ensure that the Cronbach's Alpha value was at least 0.7. An Alpha value of 0.7 and above is considered acceptable (Pallant, 2007; Field, 2009). The variables involved to measure responses, which produced a Cronbach's Alpha value of 0.72, were derived from pair-wise ranking and also from literature. These were: (i) frequency of floods, (ii) rainfall unevenness, (iii) rainfall unpredictability, (iv) strong winds, (v) daytime temperature and (vi) night time temperature, (vii) frequency of droughts, (viii) crop diseases, (ix) livestock diseases and (x) crop insect pests. The responses for these variables ranged from 1 (highly decreased) to 5 (highly increased) for the past ten to thirty years, and their descriptive statistics and reliability analysis are presented in Appendix 6.

Sampling frames were prepared for each village by listing names of all heads of households. In order to minimize bias during sampling, the established list of household heads did not follow any specific pattern (Kothari, 2004). The random sample from each village was selected from the list of names after a certain sampling interval, obtained by dividing total number of households in the village by the identified sample size. Simple random sampling was used to select the first respondent from within a sampling interval. Each of the names of household heads in the first sampling interval was written on a separate piece of paper from which one piece was randomly picked indicating where to start the systematic random sampling. The sample size was determined using equation (i). Relatively larger samples address the issue of heterogeneity, normality and so improve quality of research results (Bartlett *et al.,* 2001). Based on these considerations, the sample size was determined using the following formula as presented by Kothari (2004).

$$n = \frac{z^2 * p * q}{e^2} \qquad \text{Equation (i)}$$

Where:

z = the value of the standard variate at a given confidence level usually 1.96 at 95% confidence level; n = sample size; p = sample proportion, for maximum n, p = 0.5; q = 1-p that is: 1-0.5 = 0.5; and e = precision or margin of error which is normally 0.05 (5%) at 95% confidence level. Substituting the values in equation (i) we got n = 391. However, the sample size used was 388 because three of questionnaires were not filled out properly, and so were not involved in the analysis. During data collection, Kidaru, Mwashata and Mwamanimba had 444; 462; and 315 households respectively making a total of 1201. The following formula was therefore used to determine the sample in each village.

$n_i = n*p_i$...Equation (ii)

Where: p_i = proportion of households in a village; n_i = selected sample per village and n = total number of households in the study area. The proportion (p_i) of selected households in each village was calculated by taking total number of households in a village divided by total number of households in the three villages which was 1201. By substituting the values in equation (ii) the selected number of households per village is presented in Table 3.2. Respondents' characteristics are presented in Appendix 4 and 5.

Table 3.2: Number of households involved in the survey

Village name	Total number of households	Selected households	Selected households (%)	Women involved (%)
Kidaru	444	142	32	42
Mwashata	462	145	31	30
Mwamanimba	315	101	32	43
Total	**1201**	**388**	**32**	**39**

3.5 Meteorological Data

Secondary data, (meteorological data) particularly monthly rainfall and temperature for the period between 1994 and 2011 were collected from Tanzania Meteorological Agency (TMA) responsible for meteorological issues in the country.

3.6 Data Analysis

Tape recorded qualitative data were transcribed into text and then organized into specific themes based on the objectives of the study. Quantitative data on the other hand were first cleaned to eliminate errors and also to ensure consistency. The study recorded responses of ten variables (mentioned earlier), at an ordinal scale of 1 (highly decreased) to 5 (highly increased) to measure perception of climate variability and change. The total scores for each respondent were computed and the analysis focused on whether there were changes in the selected variables relative to the situation in the past ten to thirty years. Frequencies of responses were also computed using SPSS to uncover variations in perceptions of climate variability and change.

Based on the size of land and ownership of cattle, ability to hire labour, and also based on the households' food security, (Nombo *et al.,* 2013) categorized households in the study area into the poor, not so poor and the rich. Other indicators of wealth are shown from Appendix 16 to18. The current study used this categorization to test the hypothesis that perception of climate variability and change was the same for the poor, not so poor and the rich ($P > 0.05$). This was done using the Kruskal-Wallis H test, which is a non-parametric test appropriate for comparing median differences for ordinal data, in this case respondents' total scores, when the groups compared are more than two (McCrum-Gardner, 2008).

In addition, the Mann-Whitney U Test was used to test the hypothesis that men and women's perceptions of climate variability and change were the same ($P > 0.05$). This is also a non-parametric test, which is appropriate to compare median of two independent groups such as men and women when data are recorded at an ordinal level (Pallant, 2007; McCrum-Gardner, 2008). With regard to meteorological data, dry and hot seasons were calculated using seasonal anomaly. Seasonal anomaly, in this study, is defined as a deviation from a seasonal mean, and that dry and hot seasons were shown by negative anomaly.

3.7 Results and Discussion

3.7.1 Perception from qualitative methods

Tables 3.3 and 3.4 present qualitative results from FGDs on climate variability and change. The results showed that onset of rainfall had changed in Meatu from September during the 1970s to November and sometimes to December. Cessation had shifted from end of May during the 1970s to April. In Iramba, onset of rainfall had shifted forward to December while it used to occur in November in the 1970s. Similarly, cessation of rainfall had shifted from May in the 1970s to March, April or sometimes early May. Results also showed that while rainfall was sufficient in the 1970s, it had become less sufficient for the needs of crops, livestock and humans over time (Table 3.3). Participants in both districts also reported increasing air temperature, which was difficult to separate it from drought (Table 3.4).

Pair-wise ranking showed that the most factors, which threatened crop and livestock production was drought followed by unpredictable rainfall, early cessation and late onset of rainfall, strong winds and insufficient rainfall in that order (See Appendix 13). The changes in rainfall patterns, particularly on onset and cessation of rainfall, from the 1970s were in line with quantitative data (See Appendix 14 and 15).

Table 3.3: Changes related to rainfall

Indicator	Situation in 2013			Situation in the 1970s		
	Kidaru	**Mwashata**	**Mwamanimba**	**Kidaru**	**Mwashata**	**Mwamanimba**
Onset of rainfall	November/December or January	November/December	December and rarely end of November	November/ December	September or October	September or October
Cessation of rainfall	March/April or early May	April/rarely May	April/ rarely May	End of May/ mid-June	End of May, mid-June or early July	End of May and sometimes mid-June
Sufficiency of rainfall	Not sufficient for the needs of crops and livestock	Not sufficient	Not sufficient for the the needs of crops and livestock	Was somewhat sufficient	Was sufficient	Was somewhat sufficient
February dry spell	Extended back to January, February and sometimes to mid-March	Two weeks up to whole month, and extended back to January	The whole month, and it has extended back to January	Whole month	8-day dry spell	8-day dry spell
Dry season	May to December/January	May to November/ December	May to November	Mid-June to early October	July to September	June to October
Change of water in the rivers	Rivers Ndurumo, Msua, and Gongwa are all seasonal	River Simiyu is drying up in some parts during dry seasons	River Semu, Badi and Lyussa are all seasonal	River Ndurumo somewhat dried up during dry season	River Simiyu did not dry up throughout the year	Rivers somewhat dried up during dry seasons

Table 3.4: Characteristics and frequency of bad years between 1970s and 2012

Year	Climatic related events by village		
	Kidaru	**Mwashata**	**Mwamanimba**
1974/75	Insufficient rainfall and hunger	Insufficient rainfall and hunger	Drought, rainfall was somewhat erratic, crop failure followed by hunger
1983	Insufficient rainfall, drought, eruption of crop pests and hunger	-	-
1984	Insufficient rainfall, high day time temperature and drought followed by hunger	Erratic rainfall, high day time temperature, crop failure followed by hunger	Strong wind, erratic rainfall, poor harvests and total maize failure followed by hunger
1985-89	High rainfall variability and high day time temperature	High rainfall variability, high day time temperature and increased strong winds. These carried away clouds when it wanted to rain	High variability of rainfall, insufficient rainfall and drought, scarcity of pastures and water for human and livestock needs
1993	Floods and eruption of crop pests followed by hunger	-	-
1998/99	Floods and eruption of crop pests followed by hunger due to poor harvests. Water and pastures were not affected	Higher amount of rainfall than normal, but no floods, poor harvests, but water and pastures for livestock were not affected	Crop failure due to excessive moisture, but no considerable floods except in very low lands, eruption of crop diseases. Pasture and water for human and livestock were not affected
2003	Drought and hunger	-	-
2005	Drought, erratic rainfall during growing seasons and high day time temperature	Strong wind, high day time temperature, highly erratic rainfall followed by hunger due to crop failure	Insufficient rainfall, high day time temperature,, strong wind followed by hunger due to crop failure
2011/12	Drought, high day time temperature, erratic rainfall during growing seasons	Insufficient rainfall and highly erratic, eruption of crop diseases especially in Maize, hunger, some cattle died due to lack of pastures	Insufficient rainfall, drought, high day time temperature, crop diseases, scarcity of pastures, water and hunger and death of cattle due to lack of pastures

The February dry spell had increased from 8 days in the 1970s to more than a month in Mwashata and Mwamanimba, and had extended back to January. Similarly, in Kidaru, the dry spell had also extended back to January and sometimes to mid-March. Water sources, particularly rivers, had increasingly become seasonal compared to the situation in the 1970s due to increased warming, which in turn increased evaporation from water sources. Late onset of rainfall, early cessation and widening of the dry spells as shown in Table 3.3 suggest that the length of the growing season had decreased by a month in Mwamanimba and Mwashata in Meatu, and by more than a month in Kidaru in Iramba. Similar results were reported by Mongi *et al.* (2010) in Tabora Tanzania; Mathugama and Peiris, (2011) in India; Moyo *et al.* (2012) and Kori *et al*. (2012 in semi-arid areas of Zimbabwe and South Africa respectively. These results have negative impact on rain-fed agriculture and livestock production (Rowhani *et al.,* 2011), especially in semi-arid areas (IPCC, 2007).

Discussions during FGDs showed that unimodal rainfall patterns and the dry spell that used to occur in February were not new in semi-arid areas. However, an increasing period for the dry spell extending back from February to January and sometimes to mid-March suggests that the rainfall regime is becoming bimodal. Nonetheless, late onset and early cessation disqualify this regime to be considered bimodal. Collectively, these had intensified climate variability which in turn increased the number of bad years (Table 3.4). A bad year as defined by the farmers in this study is one whereby the amount of rainfall is less sufficient, erratic and unpredictable. It is essentially dry and hot characterized by crop failure, water scarcity for humans and for pasture development. Normally, this kind of a year culminates into hunger. Based on these results, crop and pasture failure had become common in the study area. Lyimo and Kangalawe (2010) reported similar results in Shinyanga Rural District, which is also located in semi-arid areas of Tanzania.

Less sufficient rainfall and droughts began to intensify in the late 1980s (Table 3.4). In addition, frequency of droughts and high day time temperature had seriously increased during the 2000s. On the other hand, frequency of floods had almost remained unchanged. Kidaru village for example, reported two flood events for the past 20 years, while Mwashata and Mwamanimba did not experience substantial floods in the past 30 years (Table 3.4). What appears to be a serious challenge includes increased rainfall uncertainties, prolonged and frequent droughts, rainfall unpredictability, high day time temperature, shortening of growing seasons and increased strong winds that carry away clouds when it is about to rain. Moreover, these problems are interlocked such that it was difficult to separate them, making climate variability and change a complex phenomenon. This complexity is also reflected through increased frequency of bad years particularly in the 2000s (Table 3.4). One of the women FGD participants at Kidaru reported:

> "...Drought has become serious especially since the 2000s...sorghum and bulrush millet, which are drought resistant crops, are now frequently failing due to drought...in 2011/12 we received three rainy days only and therefore the crops failed...this year (2013) is likely to be the same..." (Women FGD participant, Kidaru, 23rd May, 2013).

That quotation demonstrated concern of farmers' perceptions regarding increased number of bad years. The study clearly observed that perception of the phenomena was the same in both districts. Similarly, FGDs showed that men's and women's perceptions were similar on occurrence of rainfall and temperature variability since the 1970s. Literature also reports the same about similarity of men and women's perception of the phenomenon (Swai *et al.,* 2012a; Legesse *et al.,* 2013; Juana *et al.,* 2013). A study by Swai *et al.* (2012b) on the other hand, reports differences between men and women's perceptions of climate change and variability. These results can be due to wrong interpretation of the quantitative data because men and women's perceptions of change in temperature, wind and drought differed only by one percent, implying that the perception was almost similar. However, women perceive more risk of climate variability and change, and other risks due to different gender roles which expose them (women) to higher risks (Gustafson, 1998; Nombo *et al.,* 2013).

3.7.2 Quantitative responses

Like qualitative results, quantitative data showed highly increased droughts compared to the situation in the past 30 years as this was reported by 62% of respondents (Table 3.5). The median scores in Table 3.5 also clearly portray increased droughts. Similar results were reported by Afifi *et al.* (2014) in northern Tanzania suggesting that drought had become a serious risk in Tanzania, but also in other low income countries (IPCC, 2014). Looking at the median, Table 3.5 suggests that occurrence of floods remained unchanged for the past 30 years. This was reported by 60% of respondents (Table 3.5). The rest variables in Table 3.5 showed moderate increase including crop pests and crop and livestock diseases. Crop pests and crop and livestock diseases were reported during FGDs, that they were highly associated with changes in the climate. Berg *et al.* (2011) also reported increased crop diseases and insect pests in Sweden as a consequence of climate change.

Table 3.5: Percentage responses on current variability compared to the situation in the past 10 to 30 years (n=388)

Variable	Percentage responses					
	HD	DM	NC	IM	HI	Median score
Frequency of flood	22	11	60	6	2	3
Rainfall unevenness	13	18	5	33	32	4
Rainfall unpredictability	10	12	4	28	47	4
Strong wind	11	13	15	29	32	4
Day time temperature	3	11	4	37	46	4
Night time temperature	3	10	7	41	40	4
Frequency of droughts	4	4	4	26	62	5
Diseases in crops	5	13	10	36	35	4
Diseases in livestock	8	16	11	39	27	4
Insect crop pests	8	16	8	37	31	4

Scores: HD = highly decreased (1 score); DM = decreased moderately (2 scores); NC = no change (3 scores); IM = increased moderately (4 scores) and HI = highly increased (5 scores)

The Kruskal-Wallis Test was performed to test the hypothesis that perceptions of the poor, not so poor and the rich were the same ($P > 0.05$). The results for testing this hypothesis are presented in Table 3.6.

Table 3.6: Household responses on climate variability by wealth status (n=388)

Wealth category	n	Median	Chi-square	Degree of freedom	P-Value
Poor	192	36	2.537	2	0.281
Not so poor	152	36			
Rich	44	36			

The results showed that there was no significant difference in perceptions for the three wealth categories (Table 3.6). Since the sample was selected from smallholder farmers and agro-pastoralists, a similarity in responses based on wealth status suggests that livelihoods of the poor and of the rich depended on the climate and that the respondents were able to perceive occurrence of climate variability and change.

The Mann-Whitney U Test was used to compare median of perceptions between men and women. The results showed that there was no significant difference in the median of perception scores between men and women (Table 3.7). This can be translated into similar perceptions of climate variability and change between men and women. Similar results were reported during FGDs. This is supported by Legesse *et al.* (2013) who reported similar men and women's perceptions of climate variability and change in Ethiopia.

Table 3.7: Responses on climate variability and change between men and women (n=388)

Respondents' sex	n	Median	Mann-Whitney U	Wilcoxon W	Z	P-Value
Male	235	35	17565	45295	-0.384	0.701
Female	153	36				

3.7.3 Comparison between meteorological data and people's perception

The results presented in Table 3.8 clearly show that January and April experienced a decreasing rainfall trend for the period between 1994 and 2011 in Meatu. Similar results were also reported by Kabote *et al*. (2013). The results in this study also showed higher standard deviations implying that rainfall patterns were inconsistent in each month during crop growing seasons. It can also be interpreted that some months received much rains while others received very low rains. These results were in line with people's perception, which revealed that the dry spell that used to occur in February had extended back to

January and that the growing season had decreased. The results were also in line with people's perception regarding increasing rainfall unpredictability that coincided with higher standard deviations in monthly rainfall.

Rainfall in December and April also showed a clear decreasing trend for the period between 1994 and 2008 in Iramba (Table 3.9). These results suggest two important things: first, the decreasing trend in April implies early cessation compared to the situation in the past. Secondly, the decreasing trend in December suggests that rainfall had become less sufficient during critical crop growing period. This can increase water scarcity resulting into crop failure and poor pasture development.

Like in Meatu, the meteorological data trends in Iramba showed higher standard deviations suggesting inconsistent rainfall patterns (Table 3.9). Early cessation, which reduces crop growing period and less sufficient rainfall were also portrayed by people's perception. The seasonal means of rainfall in Meatu and Iramba for a period between 1994 and 2011 were 669.6 mm and 777.4 mm respectively. This is an insufficient amount of rainfall for requirements of many crops, given inconsistency of rainfall patterns demonstrated by higher standard deviations. For example, rainfall requirement for maize is 500 to 2 000 mm, sorghum 250 to 1 200 mm, cotton 850 to 1 100 mm, paddy 1 200 to 1 800 mm and sunflower 600 to 1 000 mm per annum (TARO, 1987a-f).

Table 3.8: Measured rainfall variability during growing seasons in Meatu District

Period	November		December		January		February		March		April	
	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev
1994-1998	132.9	90.9	141.0	106.5	168.4	113.1	124.1	88.4	102.1	42.8	130.5	23.2
1999-2003	64.6	31.5	77.6	15.1	108.9	46.3	74.9	34.9	138.2	62.1	88.5	69.6
2004-2008	108.4	83.5	135.0	42.1	101.2	53.2	102.1	48.0	133.3	92.5	84.3	43.5
2009-2011	62.5	20.2	175.0	16.8	48.0	36.4	139.9	49.1	136.0	23.8	96.3	76.9

Table 3.9: Measured rainfall variability during growing seasons in Iramba District

Period	November		December		January		February		March		April	
	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev
1994-1998	71.0	68.9	195.6	197.6	140.2	68.1	158.8	49.5	151.8	112.8	120.8	56.1
1999-2003	123.6	84.8	139.1	54.0	192.4	97.2	60.1	26.4	202.2	57.1	87.6	45.3
2004-2008	67.3	50.6	112.9	59.3	149.9	65.7	134.7	57.5	135.3	100.4	66.6	69.1
2009-2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = Data not available

Arguably, less sufficient and inconsistent rainfall patterns have serious implications on decisions of farmers and agro-pastoralists regarding the cropping calendar and types of crop varieties to be adopted. Meteorological data trends also showed that in a period of 15 years, the number of dry seasons[8] was 8 in Iramba District, and in a period of 18 years dry seasons were 11 in Meatu District (Table 3.10). During dry seasons, measured rainfall was less than the seasonal mean which was 777.4 and 669.6 mm per season in Iramba and Meatu districts respectively. Farmers and agro-pastoralists referred to dry seasons as bad years.

Although meteorological data results on rainfall patterns and decreasing amount of rainfall in some months confirmed people's perception in the study area, contrasting results were reported in Ethiopia whereby meteorological results did not confirm rainfall decreasing trends. In this situation, people's perception was influenced by environmental degradation, decrease in soil fertility, and increased demand for staple food due to population increase (Meze-Hausken, 2004). While people's perception showed increased frequency of bad years in the past 10 years from 2012, there was no consistency for measured dry seasons in Meatu District, and lack of data in Iramba District made it difficult to observe frequency of measured dry seasons. This perception can be explained that lack or inadequate amount of rainfall in the period when it is expected to rain was reported by the farmers as a bad year or dry season.

Hot seasons in which the temperature exceeded seasonal mean of 27.5^0C and 30.6^0C, were 6 and 8 in Iramba and Meatu districts respectively (Table 3.10). Although people's perception showed increasing temperature, meteorological data trends did not demonstrate a clear trend on hot seasons. This can be explained that temperature may not be too high,

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[8] A six-month period from November to April having negative rainfall anomaly

but people's perception of temperature increase in the study area can be due to prolonged and excessive drought and dry spells as reported during FGDs. On the other hand, failure of meteorological data to demonstrate increasing trend in temperature in this study can be due to lack of data in some months and some periods since the 2000s.

Interestingly, Table 3.10 shows that dry seasons were also hot seasons in Meatu District, implying overlapping of drought and temperature variables, which in turn increased complexity of climate variability and change. The inability of meteorological data to affirm increased frequency of dry and hot seasons can also be explained by unavailability of meteorological stations at the village or ward level, or it can be due to lack of data in some periods during the past decade. Environmental changes e.g. deforestation and soil erosion as reported by Meze-Hausken (2004) can also influence people's perception.

Table 3.10: Meteorological data trends in number of dry and hot seasons

Period	Iramba		Meatu	
	Dry seasons	Hot seasons	Dry seasons	Hot seasons
1994-1998	2	NA	2	2
1999-2003	2	NA	4	4
2004-2008	4	4	3	2
2009-2011	NA	2	2	0
Total	**8**	**6**	**11**	**8**

NA = Data not available

3.8 Conclusions and Recommendations

This chapter examined people's perception and meteorological data trends in order to broaden understanding of climate variability and change. The chapter contributes to the concern whether climate variability and change had intensified or not in selected semi-arid areas of Tanzania. Specifically, the chapter: (i) assessed people's perception of climate variability and change, and (ii) compared perception with meteorological data trends. Based on the results and discussion, the chapter makes three conclusions: first, people's perception showed complexity and increasing climate variability and change since the 1970s. Frequency of bad years had increased putting people's livelihoods at risk. Secondly, as hypothesized, men and women's perceptions of climate variability and change were the same ($P > 0.05$). Similarly, the poor, not so poor and the rich had the same perception about the phenomena ($P > 0.05$).

Thirdly, there was high agreement between perception and meteorological data trends on inconsistent rainfall patterns, shift of dry spell from February to January and sometimes to March, increasing duration of dry spell, early cessation of rainfall, less sufficient rainfall and decreasing crop growing season. However, perception of increased frequency of droughts was not confirmed by meteorological data trends, mainly due to missing meteorological data in some months in the previous decade. Lack of meteorological stations at the village level also contributed to unclear meteorological data trends regarding dry and hot seasons in comparison with people's perception.

Based on the conclusions, the chapter makes three recommendations: first, when examining climate variability and change, researchers should combine people's perception and meteorological data trends so as to broaden understanding of the phenomena for informed appropriate decision and policy making. Secondly, Tanzania Meteorological Agency (TMA) and district authorities need to strengthen record keeping for meteorological data, and install at least one meteorological station per ward. During the research, meteorological stations were widely scattered, and temperature was recorded only at the regional level. This may not reveal the whole picture because climate variability can occur at a small scale, like ward level. Thirdly, TMA and district authorities should ensure sustainability of the meteorological stations. Finally, the chapter recommends an in-depth study on how the rain-fed farming system (RFFS) is affected by climate variability and change and how the system adjusts in semi-arid areas to cushion associated impacts.

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CHAPTER FOUR

4.0 Rain-fed Farming System at a Crossroads in Semi-arid Areas of Tanzania: What Roles Do Climate Variability and Change Play?

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4.1 Abstract

Positive changes in rain-fed farming system (RFFS) in response to climate variability and change are also positive impact. They are crucial for a sustainable system in semi-arid areas. Such positive changes can support smallholder farmers' livelihoods. Using participatory rural appraisal (PRA) and household survey, this chapter examined the roles of climate variability and change in triggering changes in the RFFS. Specifically, the chapter: (i) assessed dominant crop and livestock farming system; (ii) assessed the change element in crop and livestock production systems; and (iii) examined factors for the changes in RFFS. A random sample of 388 households was used. Qualitative data analysis was done through content analysis. Binary logistic regression was used to assess factors that explain changes on RFFS. The results showed that dominant crops were different in each village. Secondly, some changes in crop varieties were noted and in livestock grazing arrangements as well. Unlike the hypothesis ($P > 0.05$), the results demonstrated that warming (ß = -10.61, Wald = 36.26, $P \leq 0.001$) showed highest significant impact on likelihood of adopting new crop varieties relative to other factors. Similarly, drought (ß = 2.16, Wald = 6.82, $P \leq 0.009$) showed highest impact on the likelihood of changing a grazing place. Yet, the changes were constrained by factors like natural resources conservation policies, failure of crop varieties to withstand warming and drought, price for improved crop varieties and poor or lack of proper land use management. Therefore, the RFFS was at a crossroads with implications on system sustainability and livelihoods. The government and private interventions should support farmers and agro-pastoralists to manage risks related to climate variability and change.

Keywords: Climate change, agro-pastoralism, livelihoods, semi-arid, Tanzania

4.2 Introduction

Climate change, as a concept is defined in almost every academic work that addresses concerns of climate variability and change (O'Brien *et al.,* 2006; IPCC, 2007; FAO, 2008). The most cited definition of climate change is that of the IPCC (2007), which defines climate change as a long-term change in statistics of rainfall, temperature and extreme weather episodes. Climate variability on the other hand, is defined as temporal and/or spatial variations of the mean state and other weather statistics of the climate beyond individual weather events (IPCC, 2007). These phenomena have potential impacts on sectors including water, food and nutrition, agriculture, human health, ecosystem, and infrastructure (IPCC, 2014). The impacts are differentiated by geographical location, gender and wealth status. Women are more affected because of asymmetrical gender relations (Nombo *et al.,* 2013). On the other hand, semi-arid agro-ecological zones are more vulnerable mainly due to unfavourable climatic environment and over dependency on the agricultural sector and natural resources, which are sensitive to climate variability and change (Senkondo *et al.,* 2004; Sarr, 2012; Milan and Ho, 2014).

Rainfall is more variable in semi-arid areas[9] (UDSM, 1999; Huang *et al.,* 2012). Literature defines semi-arid areas based on its climate especially rainfall. However, based on range of rainfall the definition is not consistent. As such, some scholars do not differentiate semi-arid from arid areas (Huang *et al.,* 2012; Sarr, 2012). Thus, this study takes the range of rainfall in semi-arid areas to be between 400 mm and 900 mm per year. Semi-arid areas are also characterized by drought, inadequate soil moisture, soil infertility, higher day time temperature and higher evaporation that exceed precipitation (Senkondo *et al.,* 2004; Vette, 2009; Mongi *et al.,* 2010).

Agriculture and pastoralism are major farming systems in semi-arid areas. Farming system[10] - composed of sub-systems - has been defined as a broader and complex relationship of farm enterprises (FAO, 2008; Dixon *et al.,* 2001; Behera and Sharma, 2007). This means that it is a set of inter-related, interacting and interdependent elements acting together to support livelihoods and is capable of reacting as a whole to climatic and non-climatic factors. This chapter takes a system that entirely depends on rainfall as a rain-fed farming system (RFFS). Its elements that basically interact together and, which are managed by farming households include crops, animals, soils, labour, capital, land and technologies used (Dixon *et al.,* 2001; Behera and Sharma, 2007). Thus, any adjustment in any of these elements, modification, adoption or emerging of new crops, crop varieties,

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[9] Some scholars have defined these areas as ones having a mean annual rainfall of as low as between 200 and 600 mm (Huang *et al.,* 2012; Sarr, 2012). Others give a range between 500 and 800 mm per year (URT, 2007; Mongi *et al*., 2010); while some report mean annual rainfalls, which range between 600 and 800 mm (UDSM, 1999).

[10] See Behera and Sharma (2007) for more definitions of farming systems and its classification

cropping and grazing arrangements and their interactions there in, is considered to be a change in this chapter.

The impact of climate variability and change on RFFS is overarching in Africa and Tanzania in particular (IPCC, 2007; Sarr, 2012). In addition, the phenomena interact with non-climatic factors like economic (market, input, and credit), political factors (institutions), social and cultural (tenure, taboos, local beliefs, marital institutions, religion and food preference), household priorities (food and income), biological (pests and diseases) and resource factors (land, knowledge and labour) (Behera and Sharma, 2007) in affecting the RFFS. Arguably, positive changes in RFFS in response to climate variability and change are positive impact that are important for ensuring that the system and people's livelihoods are sustainable. In other words, positive impacts are opportunities as opposed to negative impacts that threaten RFFS.

Studies on the impact of climate variability and change are numerous in Sub-Saharan Africa (SSA) and more specifically in Tanzania, but most of them focus either in livestock (Galvin *et al.,* 2001) or in agriculture (Paavola, 2008; Mongi *et al*., 2010; Lema and Majule, 2009; Swai *et al.,* 2012; Juana *et al.,* 2013; Legesse *et al.,* 2013). On the other hand, studies which focus on impact for both agriculture and livestock, like Meena *et al*. (2008) and Mbilinyi, *et al.* (2013), in response to climate variability and change are limited in the country. This means that most of the existing studies divide RFFS into single components with an idea that results from the components can be added to one another (Darnhofer *et al.,* 2008). This approach tends to overlook important things including factors that affect the entire RFFS and, therefore, can hardly help to understand changes in the system and how to deal with them comprehensively. While information on the change process of RFFS in response to climate variability and change is scarce; crop failure, scarcity of water and pasture are on the increase (Lema and Majule, 2009).

Using system thinking approach, which views a farm as one system, and that change in one part affects other system organization (Darnhofer *et al.,* 2010); this chapter examined the role of climate variability and change in triggering changes in RFFS in semi-arid areas. Specifically, the chapter: (i) assessed dominant crop and livestock farming system; (ii) assessed changes in crop and livestock production systems; and (iii) examined major predictors of the changes in RFFS. Results from this study are important in choosing policy interventions in crop and livestock production systems to manage risks of climate variability and change. The next sections describe the study areas, methodology and discuss the results. Finally, it winds up by presenting conclusions and recommendations.

4.3 Study Areas

This study was conducted in Meatu District in Simiyu Region and in Iramba District in Singida Region. As described by Kabote *et al*. (2013), Meatu District lies between latitudes 3^o and 4^o South and longitudes 34^o and 35^o East, and its altitude ranges between 1000 and 1500 m.a.s.l. The district's vegetation is characterized by shrubs and thorny trees scattered or clustered in some areas. Most parts in the southern zone of the district have bare soils especially during dry seasons compared to the northern zone. On the other hand, Iramba District lies between 4^0 to $4^0.3^{'}$ latitudes South and 34^0 to 35^0 longitudes East. Vegetation is mainly natural including miombo woodlands, acacia woodlands and grasslands. More trees are found on hills compared to flat terrains in the low-lands.

The mean annual rainfall in Meatu District ranges between 400 and 900 mm in the southern and northern agro-ecological zones of the district, respectively and rainfall regime is unimodal. Iramba District on the other hand, receives a mean annual rainfall of between 500 and 850 mm. Surface temperature in the district ranges between 15^0C in July and 30^0C in October (Iramba District Council, 2009). Excluding district headquarters at Kiomboi in Iramba and Mwanhuzi in Meatu, the other areas are rural, dominated by smallholder farmers and agro-pastoralists.

The districts were selected because: (i) crop failure has increasingly become common each year. This necessitates the district authorities to provide food aid for the people to address hunger problem. (ii) The districts are contiguous. This was important to assess variations in rainfall and temperature between adjacent districts lying entirely in semi-arid areas dominated by different ethnic groups. (iii) Livelihoods in both districts depend on crop production and agro-pastoralism. Moreover, dependence on rainfall exceeds 95% (NBS, 2009). The study involved three villages including Kidaru in Iramba District, Singida Region; and Mwashata and Mwamanimba in Meatu District, Simiyu Region (Fig. 4.1). These villages lie entirely in semi-arid agro-ecological zone in which rainfall is already uncertain even without climate variability and change (Kabote *et al.,* 2013). The criteria for village selection were based on the history of frequency of drought, crop failure, hunger and history of receiving food aid, which have increasingly become common in the past ten years. This information was provided by the district agricultural officers.

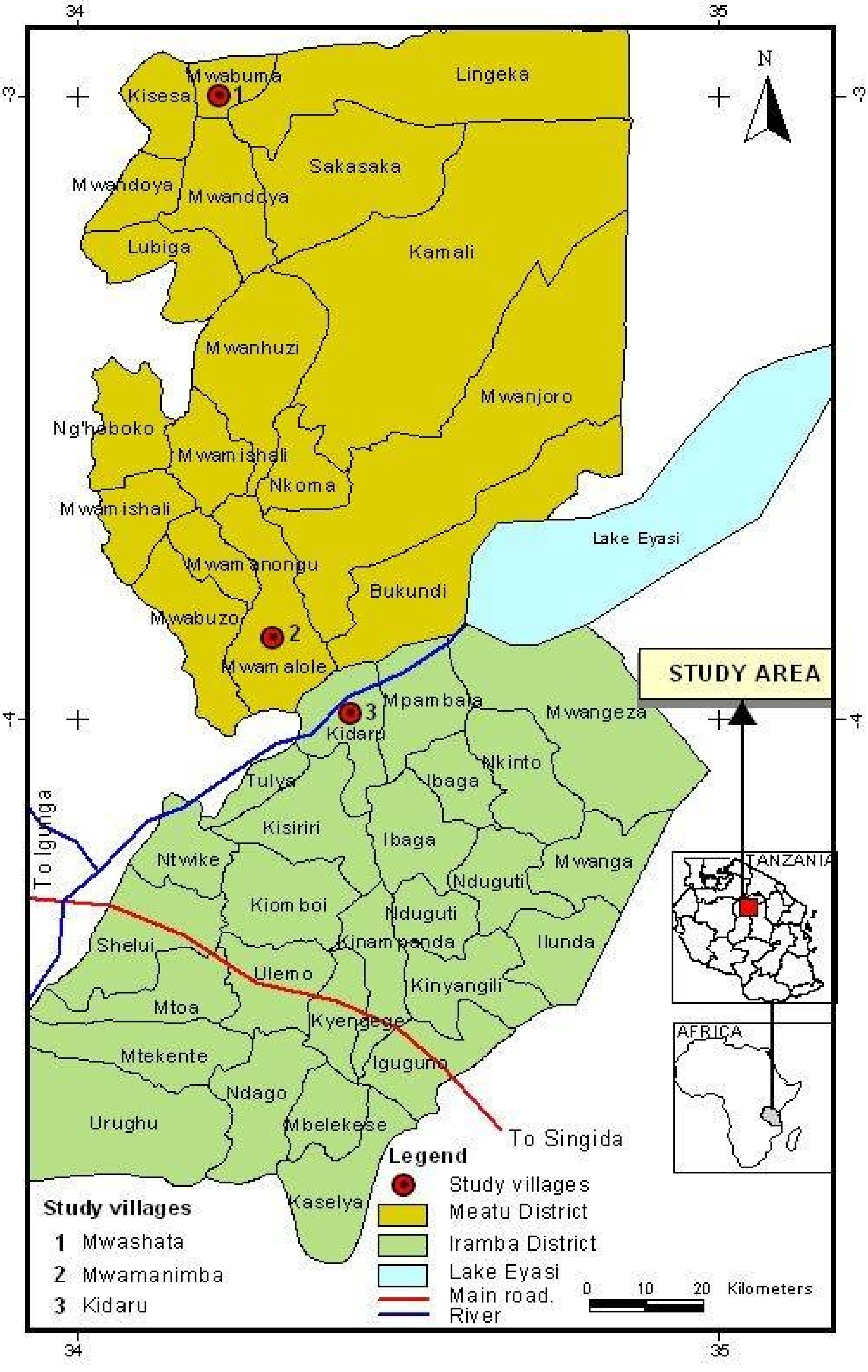

Figure 4.1: Map of Tanzania showing study villages.

4.4 Methodology

The study adopted a cross-sectional design in order to examine the current situation (Mann, 2003). Data collection and analysis took place in two stages. Participatory rural appraisal (PRA), mainly focus group discussions (FGDs), preceded, household survey. Thus, the first stage informed the second stage (Bryman, 2006). The results from the two stages were integrated so as to expand the scope and improve quality of the results (Sandelowski, 2000). This approach is known as exploratory sequential research design (Gilbert, 2010). The study used a household as a unit of analysis during the survey because of its responsibility in decision making on resource use (Darnhofer *et al.,* 2010). Respondents were visited at home, and either the household head or spouse was interviewed depending on availability.

4.4.1 Participatory rural appraisal

Participatory rural appraisal (PRA), mainly focus group discussions (FGDs), involved household heads and spouses, farmers and agro-pastoralists. Different age groups starting from 25 years up to 60 years and above were involved in FGDs to capture views from different age groups. Focus group discussions aimed at enabling participants to take part in the analysis of the issues under study (Chambers, 1994). The study involved a total of seven FGDs, encompassing 63 participants. The plan was to have 6-12 members per FGD (Masadeh, 2012) for effective participation and good quality of data, but participants ranged from six to 14 because some members came without being invited. There were separate groups for men and women to capture views from each group because, traditionally, women in the Sukuma[11] community do not speak freely in the presence of men participants. The study learned in Kidaru that women could also not speak freely. This also justified a need to have separate men and women groups. Discussions were tape

[11] Ethnic group that dominates in Shinyanga, Mwanza, Geita,Tabora and Simiyu Regions including Meatu District

recorded. The consent of the respondents was sought before they were tape recorded to ensure that the process took place in a natural setting such that the use of a tape record did not affect the results. Agriculture and livestock extension officers were consulted only for clarification of some technical issues. Characteristics of FGDs participants are presented in Table 4.1. Respondents' characteristics are presented in Appendix 4 and 5.

Table 4.1: Characteristics of FGDs participants

Village name	Number of FGDs conducted	Number of male participants	Number of female participants	Mean age (years)	Minimum age (years)	Maximum age (years)
Kidaru	3	6	9	44	25	60
Mwashata	2	10	14	42	29	63
Mwamanimba	2	13	11	49	31	68
Total	**7**	**29**	**34**	**NA**	**NA**	**NA**

Note: FGDs = Focus Group Discussions; NA = Not Applicable

4.4.2 Household survey

A structured questionnaire was administered to 388 randomly selected respondents drawn using systematic random sampling techniques. As explained in chapter three in this thesis, ten respondents in Mwakasumbi village participated during pre-testing of the questionnaire to ensure validity and reliability. Sampling frames were prepared for each village by listing names of all household heads. The listing did not follow any specific arrangement in order to minimize bias during sampling (Kothari, 2004). A random sample from each village was selected from the list of names after a certain sampling interval that was obtained by dividing the total number of households in the village by the predetermined sample size in that village. Simple random sampling was applied to select the first respondent whereby each name in the first interval was written on a piece of paper and then put together in a basket from which one paper piece was picked. The name on the piece of paper that was picked from the basket earmarked the beginning of the systematic sampling. In order to minimize sampling error and improve quality of research results, a sample should be neither too small nor too big (Bartlett *et al.,* 2001). Interviews to fill the questionnaires were done at respondents' homes after prior information. The questions asked were closed ended to capture climate and non-climatic factors which explained adoption of improved crop varieties and changes in grazing arrangements. The sample size was determined using the formula as presented by Kothari (2004).

$$n = \frac{z^2 * p * q}{e^2} \quad \text{……..Equation (i)}$$

Where:

z = the value of the standard variate at a given confidence level usually 1.96 at 95% confidence level; n = sample size; p = sample proportion, for maximum n, p = 0.5; q = 1-p that is: 1-0.5 = 0.5; and e = precision or margin of error which is normally 0.05 (5%) at 95% confidence level. Substituting the values we get n = 391. However, the sample size used was 388 because, 3 copies of questionnaires were not filled properly and therefore were discarded. Based on the total number of households, which was, during data collection 444 in Kidaru; 462 in Mwashata and 315 Mwamanimba villages respectively, making a total of 1201 households, the following formula was used to estimate the sample in each village.

$$ni = n*pi \quad \text{...Equation (ii)}$$

Where: pi = proportion of households in a village; and n = total number of households and n_i = selected sample per village. The proportion (pi) of households in each village was calculated by taking number of households in a village divided by total number of households in the three villages which was 1201. By substituting the values in equation

(ii) we get the following number of selected households in each village as presented in Table 4.2.

Table 4.2: Number of households involved in the survey

Village name	Total number of households	Selected households	Selected households (%)	Women involved (%)
Kidaru	444	142	32	42
Mwashata	462	145	31	30
Mwamanimba	315	101	32	43
Total	**1201**	**388**	**32**	**39**

4.4.3 Data analysis

The analysis of qualitative data involved transcriptions of tape recorded information into text before being organized into specific themes based on the objectives of the study. The responses from FGDs by age-wise were synthesized together in understanding the impact of climate variability and change on the rain-fed farming system (RFFS). The change in RFFS was assessed qualitatively during FGDs through retrospective questions that aimed to understand any adjustment in response to climate variability and change in any part of RFFS. The indicators to assess the changes in RFFS included emergence of new crops, adoption of improved crop varieties, adjustment in cropping and grazing systems and water sources for the livestock.

Quantitative data were analyzed using the Statistical Package for Social Sciences (SPSS). Based on size of land and ownership of livestock especially cattle, ability to hire labour, and also based on the households' food security, Nombo *et al*. (2013) classified households in the study area into the rich, the poor and the not so poor. Therefore, the current study used this classification to quantify the magnitude of some variables. A binary logistic regression as explained by Chan (2004) and Peng *et al.* (2002) was used to test the hypothesis that climate and non-climatic factors have the same impact ($P \geq 0.05$) on adopting improved crop varieties and also on changing grazing arrangements like where to graze the livestock.

Interpretation of the output from the model focused on β-coefficients for measuring the directions of the impact (positive or negative) of predictor variables; Wald statistics for measuring the magnitudes of the impact; p-values for testing significance of the impact, and odds ratios (EXP(B) values) for predicting the number of times various predictor variables have chances relative to one another regarding adoption of improved varieties and change of grazing arrangements. The binary logistic regression model used is shown in equation (iii). Fitness of the model is presented in Appendix 10 and 11.

$\text{Log}\,[Pi/1\text{-}Pi] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_{13} X_{13}$............................Equation (iii)

Where:

Log [Pi/1-Pi] = Natural logarithm of the odds for adopting improved varieties for maize and sorghum or change on grazing arrangements; β_0 = Constant; β_1 to β_{13} = Logistic regression coefficients of the predictor variables, X_1 = insufficient rainfall, X_2 = increased warming, X_3 = increased drought, X_4 = rainfall unpredictability, X_5 = early cessation, X_6 = extension services, X_7 = market, X_8 = respondents' sex, X_9 = food preference, X_{10} = respondents' age, X_{11} = respondents' years of schooling, X_{12} = household size and X_{13} = occupation.

For change on grazing arrangements, the predictor variables were: X_1 = insufficient rainfall, X_2 = increased drought, X_3 = agriculture expansion, X_4 = government policies, X_5 = respondents' sex X_6 = respondents' age, X_7 = years of schooling and X_8 = household size. The variables entered in the model were derived from farmers' perceptions (Appendix 13). Only maize and sorghum were involved in this analysis because FGDs reported change in varieties for these crops for the past 30 years. Both dummy and continuous predictor variables were used while the two dependent variables were binary (Appendix 12).

4.5 Results and Discussion

4.5.1 Dominant crop and livestock farming systems

The qualitative results collected during FGDs showed that the dominant crops differed by villages whereby sorghum was grown mainly at Mwamanimba, bulrush millet at Kidaru and maize at Mwashata and Mwamanimba. These results were in line with quantitative results presented in Table 4.3. The association between types of crops grown per village was significant ($p \leq 0.01$). According to Healey (2005), the Phi-values[12] greater than 0.3, which are shown in Table 4.3, indicate strong association. This difference was mainly due to differences in the amount of rainfall received in the villages. This is supported by the moisture requirements for each crop presented in Table 4.4. The northern part of Meatu where Mwashata is located, receives up to 900 mm of annual rainfall compared to Kidaru and Mwamanimba, which on average receive annual rainfall of 550 mm and 400 mm respectively (Iramba District Council, 2009; Meatu District Council, 2009). For the period between 1994 and 2011, meteorological data showed that seasonal rainfall in Meatu and Iramba for a six-month period from November to April ranged between 669.6 mm and 777.4 mm respectively (Kabote *et al.,* 2013).

[12] The Phi-values between 0.00 and 0.1 would suggest weak association, whereas the Phi-values between 0.11 and 0.30 would mean moderate association (Healey, 2005).

Table 4.3: Percentage responses on dominant crops grown during 2012/13 (n=388)

Type of crop	Variable	Kidaru (n=142)	Mwamanimba (n=101)	Mwashata (n=145)	Chi-square	P-Value	Phi-Value
Maize	Grown	37	85	96	135.934	0.000	0.592
	Not grown	63	15	4			
Sorghum	Grown	38	65	9	85.400	0.000	0.469
	Not grown	62	35	91			
Sweet potatoes	Grown	16	78	72	123.430	0.000	0.564
	Not grown	84	22	28			
Bulrush millet	Grown	74	4	3	214.359	0.000	0.743
	Not grown	26	96	97			
Cotton	Grown	4	93	69	218.394	0.000	0.750
	Not grown	96	7	31			
Sunflower	Grown	65	19	35	56.081	0.000	0.380
	Not grown	35	81	65			

Table 4.4: Crops and water requirements

Common name	Scientific name	Rainfall requirements (mm)
Maize	*Zea mays (* L.)	500-2 000
Sorghum	*Sorghum bicolor* (L.) Moench	250-1 200
Paddy rice	*Oryza sativa* (L.)	1 200- 1 800
Sweet potatoes	*Ipomoea batatas* (L.) Lam	500-1 600
Bulrush millet	*Pennisetum glaucum* (L.) R. Br	275-1 500
Cotton	*Gossypium hirsutum* (L.)	850-1 100
Sunflower	*Helianthus annuus* (L.)	600-1 000
Green gram	*Vigna radiata* (L.)	600-800

Sources: Tanzania Agricultural Research Organization (TARO), 1987a; 1987b; 1987c; 1987d; 1987e; 1987f; Kaliba *et al.,* 1998; Saadan *et al.,* 2000; Chapagain *et al.,* 2006)

Based on the moisture requirements reported presented in Table 4.4, seasonal rainfall favoured sorghum in Mwamanimba, maize in Mwashata, bulrush millet and sunflower in

Kidaru and Mwamanimba. Other climatic factors that affected crop production are presented in Appendices 13 to 15. The results also showed that agro-pastoralism was widely practised, especially, in Mwamanimba in Meatu (Table 4.5).

Table 4.5: Percentage responses on dominant livestock (n = 388)

Livestock	Variable	Wealth status			Chi-square	P-Value	Phi-Value
		Poor (n=192)	Not so poor (n=152)	Rich (n=44)			
Cattle	Keep	42	71	68	32.661	0.000	0.290
	Do not keep	58	29	32			
Goat	Keep	37	54	61	15.074	0.001	0.197
	Do not keep	63	46	39			
Sheep	Keep	23	33	57	19.124	0.000	0.222
	Do not keep	77	67	43			
Donkey	Keep	6	8	16	5.209	0.074	0.116
	Do not keep	94	92	84			
Pigs	Keep	8	15	25	9.783	0.008	0.159
	Do not keep	92	85	75			
Poultry	Keep	49	64	66	8.734	0.013	0.150
	Do not keep	51	36	34			

This was not surprising because agro-pastoralism is common in semi-arid areas where climatic conditions do not favour crop production (Vetter, 2009). The p-values in Table 4.5 show that there was significant association between livestock keeping, except for keeping donkeys, and wealth status. Similar results were reported by Nombo *et al*. (2013). The association showed that the majority of the rich kept livestock compared to the poor and the not so poor households. Using the Phi-values shown in the last column in Table 4.5, it can be deduced that the association between livestock keeping and wealth status was moderate because the Phi-values ranged from 0.11 to 0.29 (Healey, 2005).

4.5.2 Changes in crop and livestock production systems

Results from FGD showed that sunflower was adopted between 2008 and 2010 as a cash crop in Mwashata and Mwamanimba, and in the 1990s in Kidaru village. This crop had replaced cotton in Kidaru because, as reported in the previous section in this chapter, the village received less amount of rainfall, which was appropriate for sunflower (600 mm to 1000 mm), but not for cotton that needs 850 mm to1100 mm of rainfall per year (TARO, 1987e; 1987d; Chapagain *et al.,* 2006). Climatic conditions, in addition to price failure for cotton following adoption of free market policies established in the 1980s and 1990s, accelerated adoption of sunflower. Both men and women FGD participants at Mwashata, which was also repeatedly mentioned in FGDs in other villages, can be summarized as follows:

> "...It is possible to experience crop failure every year due to drought and rainfall unpredictability...rainfall may start earlier, but it can also end earlier in April compared to the situation in the 1970s when it used to end in May or in early June..." (Mwashata, 22nd January 2013).

The quotation implies that the changes in rainfall patterns had occurred. At Mwamanimba for example, FGDs reported that drought occurred consecutively since 2003. At Kidaru, on the other hand, FGDs reported that drought occurred eight times while at Mwashata it was reported that drought occurred seven times over the same period. This stimulated adoption of drought resistant crops like bulrush millet particularly since the 1980s. This went hand in hand with declining interest in maize because of being sensitive to drought. On the other hand, bulrush millet had disappeared in Mwashata and Mwamanimba because it is less preferred by the Sukuma relative to the Nyiramba people, and also due to bird infestation in Meatu (Nombo *et al.,* 2013).

Discussions during FGDs also showed that some households had adopted improved crop varieties of maize and sorghum (Table 4.6) as a response to climate variability and change, especially drought. Sources of improved crop varieties were mentioned to include District Agricultural and Livestock Departments and private agro-dealers[13] in Bariadi, Mwanhuzi and Kiomboi. The price for purchasing improved varieties from private agro-dealers was high making most of the smallholder farmers unable to adopt it. In many cases, harvests in one year were used as seeds in the next year implying that the use of improved crop varieties, though essential to minimize crop failure, was minimal and so supporting smallholder farmers in terms of improved crop varieties is critical to manage risks of climate variability and change.

As reported in chapter two in this thesis, and also as presented in Appendices 14 and 15, FGDs demonstrated changes in onset of rainfall mainly from September or October in the 1970s to November or December in the 2013. End of rainfall had also changed mainly from May or June in the 1970s to March or April in the 2013. This is supported by Kabote *et al*. (2013) who implicated decreasing meteorological rainfall trend in April with early cessation of rainfall in Meatu and Iramba. These changes in rainfall patterns had affected the whole cropping system including what crop variety to plant, when to plant up to harvesting period. This was justified by men FGD participants at Mwamanimba that reported the following:

"...In the 1970s, we planted sorghum in September or October and harvested in July...we planted maize from December to February and harvesting period for maize began in April...today we are not sure on which date we can start planting sorghum or maize because the rainfall onset had become more variable..." (Mwamanimba, 25th January 2013).

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[13] Retail distributors of agricultural inputs such as seeds, tools, pesticides and fertilizers

Table 4.6: Adoption of improved crop varieties

Type of crop variety	Kidaru village		Mwashata village		Mwamanimba village	
	Existing situation	**Situation in the 1980s**	**Existing situation**	**Situation in the 1980s**	**Existing situation**	**Situation in the 1980s**
Maize	Varieties include *Kagiri* (short), Kilima (medium), Dekalb (DK) (short), *Pundamilia* (medium) and *Tembo* (long)	Long-term varieties include hybrid (H 614) and Ukiriguru composite (UCA)	Varieties include *Katumbili* (short), *Pundamilia* (medium), and *Simba* (medium). These take 2 to 3 months to attain maturity	Long-term variety mainly *gembe,* which took about 4 months to attain maturity.	Varieties include *katumaini and, kagri (short) and katumbili (medium).* These take 2 to 3 months to attain maturity	Local variety mainly *gembe,* which took about 4 months to attain maturity
Sorghum	Varieties include *mkombitunna* in Nyiramba language (goose like against bird attack)	Long-term varieties including *korongo, tembe, kakera* and *kalolo*	Short-term varieties including *malawi, ng'hulya and ngudungu*	Long-term variety mainly ng*'holongo* which took about 6 to 7 months to attain maturity	Short-term varieties including s*erena, miningamhera, and pato*	Long-term variety mainly *ng'holongo* that took about 6 to 7 months to attain maturity

That quotation justified that changes in the rain-fed farming system (RFFS) were inevitable to minimize crop failure due to changes in rainfall patterns. In addition, FGDs reported that crop insect pests, diseases and the February dry spell[14], did not affect maize yields when planted during February in the 1970s. The qualitative results also demonstrated that the dry spell had extended back to January thus interrupting the crop growing period (Mongi *et al.,* 2010). Uncertainties in the cropping calendar due to climate variability and change is also reported by Darnhofer *et al*. (2010).

The household survey data presented in Table 4.7 explicitly showed that 66% of the rich households adopted improved maize varieties. This can also be interpreted that the poor and the not so poor were more at risk of being affected by climate variability due to inability to adopt improved varieties. However, there was no significant association between adoption of maize varieties and wealth status at 5% (Table 4.7). The same Table also shows that 64% of the rich and 53% of the not so poor did not adopt improved varieties of sorghum. This implies that majority including the poor and not so poor, were unable or unwilling to adopt improved varieties of sorghum. There was also no significant association between adoption of improved varieties of sorghum and wealth status at 5% (Table 4.7). Notably, FGDs reported that even improved varieties of sorghum were not able to withstand drought. This suggests a need for different crop varieties.

[14] A dry spell is a sequence of at least 15 consecutive dry days with less than a threshold value of rainfall, greater or equal to 1.0 mm per day. This period normally occurs at a certain time during the rainy season. Such a period can sometimes be abnormally long, but it is shorter and not as severe as drought (Mathugama and Peiris, 2011).

Table 4.7: Percentage responses on adoption of improved varieties (n=388)

Type of crop	Variable	Wealth status Poor (n=192)	Not so poor (n=152)	Rich (n=44)	Chi-square	P-Value	Cramer's V - value
Maize	Adopted	46	49	66	8.637	0.071	0.105
	Not adopted	24	24	25			
	Neutral	30	27	9			
Sorghum	Adopted	24	20	27	9.374	0.052	0.110
	Not adopted	46	53	64			
	Neutral	30	27	9			

Note: Neutral means, improved varieties were occasionally used

Qualitative results also revealed that livestock deaths had increased relative to the situation in the 1970s. This was due to anthrax and rift valley fever. Insufficient knowledge on disease control among agro-pastoralists exacerbated livestock deaths leading to decrease in the number of livestock. In addition, seasonal movements of agro-pastoralists usually led by adult men, leaving behind women, girls and elders, to other regions like Rukwa, Tabora, Kigoma, and Morogoro Regions in search for pasture and water contributed to the decrease in number of livestock as well. Similar results in increased mobility were also reported by Afifi *et al*. (2014) in northern Tanzania.

In addition, long-standing drought increased distance, duration and frequency of movements of agro-pastoralists. For instance, duration to stay away with the livestock searching for water and pasture had increased from two months in the 1970s to six months or more by 2013. Similar results are also reported by Mongi *et al.* (2010). Consequently, small herds, ox-plough and weak livestock could only be found in the villages throughout the year. Mobility also involved bigger herds of goats and sheep (500 and more), which was not the case in the 1970s. In addition to seasonal movements to overcome lack of grazing pastures, qualitative results showed that agro-pastoralists adopted practises like purchase of grazing areas, grazing in own household plots, grazing in conserved areas in Mwashata and Mwamanimba in Meatu, and grazing up the hills in the conserved forest along the Great East African lift valley in Kidaru. Communal conservation of pasture areas locally known as Ngitiri disappeared in Meatu due to increased demand for land caused by agriculture expansion responding to climate variability and change.

Qualitative results also showed that, at Kidaru, natural resource conservation policies allowed grazing up the hills, but not agriculture activities to avoid deforestation and environmental degradation in general. On the other hand, conservation reserve policies prohibited grazing activities in the game reserve in Meatu District. Thus, conflicts and killings were reported between agro-pastoralists and conservation authorities in Mwamanimba and Mwashata villages. Yet, the game reserve had increasingly become potential for grazing livestock as a consequence of increasing frequency of long-standing drought and agriculture expansion since the 1970s. To stress this, one of the men FGD participants in Mwamanimba summarized his views by saying:

> "…grazing livestock in the Maswa Game Reserve is part of life…this will stay forever unless pasture and water scarcity problems are addressed…"

That quotation can be interpreted that stopping grazing activities in conserved areas in Meatu was difficult. This suggests strengthening of institutions and interventions that govern use of pasture and water in conserved areas. The long-standing drought had also prompted agro-pastoralists to dig water holes in lowlands and along the rivers in search of water for the livestock and also for domestic use since the 1980s. Interestingly, FGDs reported that depths for the water holes increased over time definitely due to increased frequency of long-standing drought. Mattee and Shem (2006) and Mati *et al*. (2005) also reported presence of water holes for livestock in semi-arid northern Tanzania and in

Kenya. The results also showed that rivers had increasingly become seasonal; making water scarcity a serious problem even during wet seasons.

4.5.3 Changes in interaction between crop and livestock production systems

As reported in the previous section in this chapter, seasonal movements of livestock occurred in response to factors like drought, population increase and agriculture expansion. Movement of livestock occurred between January and July in Kidaru and Mwashata mainly to address lack of agricultural land exacerbated by increased human population and agricultural expansion. This was justified by men FGD at Mwamanimba as follows:

> "...Unlike in the 1970s, when we grazed our livestock within or nearby our village...we are now moving our livestock seasonally to give way for agricultural activities...in the 1970s, we grazed anywhere without any problem, but now we are sometimes purchasing places for grazing..." (Men FGD, Mwamanimba, 26th January 2013).

That quotation implies that, unlike during the 1970s, crop production interacted with seasonal movements of the livestock because of decreasing grazing places. It was difficult to separate agricultural expansion and climate variability and change that triggered the interactions. Livestock were taken off to open a window for crop production. During the dry season (July to December), livestock were taken back in the study area. At that period, crop residues provided feeds for the livestock, but only from the own household farm.

In Mwamanimba, on the other hand, livestock were moved from the village during dry seasons when pasture and water were scarce. Moving back to the village was during growing seasons in which livestock had to feed mainly in the own household farm. Unlike in Mwashata and Kidaru, the driving factor for seasonal movements of livestock in Mwamanimba was mainly lack of pasture as a direct consequence of increased frequency of drought. Since the 2000s, seasonal movements had become more complicated. This practise reduced household labour force from men and boys who were involved in the mobility. Similar results are reported by Rademacher-Schulz *et al*. (2014) in northern Ghana. This can negatively affect food production contributing to poor nutrition for women, elders and children who did not participate in the mobility. Poor nutrition for women has implications on child nutrition and health. However, seasonal migration to urban areas, which does not involve livestock movements, supports livelihoods in Peru (Milan and Ho, 2014).

Although FGDs supported by Rademacher-Schulz *et al*. (2014) reported decrease in herds of livestock due to deaths caused by diseases, observation revealed that the herds were still bigger with some households owning more than one thousand cattle. This, in addition to drought and poor land use management system; whereby there was no land allocated for different uses like agriculture, grazing and human settlement, put crop and livestock production systems at a crossroads. Therefore, men and boys in agro-pastoralist households were temporally or sometimes permanently separated from their families, in a way to searching water and pasture. Unlike in the 1970s when livestock grazed anywhere within a village, the situation had changed due to dwindling of grazing areas. Crop residues after harvesting period had increasingly become an important source of livestock feeds. As such, interactions between crop and livestock keeping seemed to be important for supporting livelihoods in the study area. Seasonal movements affected both men and women, but women appeared to be more affected. Men and women FGD participants at Kidaru justified by reporting that:

> "...men and women are affected by seasonal movements of husbands and boys who take the livestock up the hills where they can be injured by wild animals...last year two boys were injured...women, children and the aged left at home, can live in hardship when famine occurs..." (Mixed men and women FGD participants, Kidaru, 31st May, 2013).

In addition, as men and boys stay longer away from the family, gender relations in the long-run are subject to change due to change in gender roles. Women in absence of the husbands are likely to perform men's roles (Nombo *et al.,* 2013). This can disadvantage women because they are already overburdened by domestic chores due to unequal gender relations (IPCC, 2014). Nevertheless, perhaps because of ignoring gender dimension in their studies, some scholars have concluded that seasonal movements of livestock in semi-arid areas is critical for optimal utilization of pastures (Mattee and Shem, 2006; Rota, 2009). In addition, for many years, Tanzania's national policies have been pushing for sedentarization with argument that such movements pose serious environmental degradation and desertification.

4.5.4 Major predictors of the changes in the rain-fed farming system

The previous section in this chapter demonstrated that both climate and non-climate factors contributed to changes in the rain-fed farming system (RFFS) particularly adopting improved crop varieties and practising new grazing places. Using binary logistic regression model, it was essential to determine which one between climate and non-climatic factors played a great role on triggering the changes. The dependent variables were adoption of new crop varieties and changing a grazing place (Table 4.8). The Hosmer and Lemeshow test ($P > 0.05$) showed that the model fitted well the data (Appendices 10 and 11).

Table 4.8: Percentage responses on adopting new crop varieties and changing a grazing place

(a) Adopting new crop varieties (N = 388)			
Variable	**Kidaru (n = 142)**	**Mwamanimba (n = 101)**	**Mwashata (n = 145)**
Adopted	39	69	76
Did not adopt	61	31	24
(b) Changing a grazing place (N = 181)			
Changed	52	76	69
Did not change	48	24	31

The results in Table 4.8 show that adopting new crop varieties was prominent at Mwashata followed by Mwamanimba. Notably, as reported in section 4.5.2 in this chapter, adoption of new crop varieties was higher in maize and sorghum relative to other crops in the study areas. On the other hand, changing a grazing place was prominent at Mwanimanimba relative to other villages (Table 4.8) because of lack of pastures. Descriptive statistics for independent variables entered in the model are presented in Table 4.9.

Table 4.9: Independent variables entered in the model for adopting new crop varieties and changing a grazing place

(a) Adopting new crop varieties (N = 388)

Variable	**Caused adoption (%)**	**Did not cause adoption (%)**
Insufficient rainfall	62	38
Increased warming	69	31
Increased drought	68	32
Rainfall unpredictability	58	42
Early cessation of rainfall	62	38
Extension services	32	68
Market access	5	95
Food preference	57	43
Occupation	13	87

(b) Changing a grazing place (N = 181)

Variable	**Caused changes (%)**	**Did not cause changes (%)**
Insufficient rainfall	74	26
Increased drought	78	22
Agriculture expansion	79	21
Government policy	3	97

Note: The sample size for changing a grazing place is for the households that kept cattle

The empirical results showed that, out of 13 variables entered in the binary logistic regression model, increased warming showed highest significant contribution to the likelihood of adopting improved crop varieties (maize and sorghum) at 0.1%. Similarly early cessation was significant at 0.1%. Other variables which showed significant contribution include increased drought and insufficient rainfall, which were significant at 1%. Food preference and respondents' sex were significant at 5%. The rest variables were not significant at 5% level of significance (Table 4.10), though had some influence as reported in the previous sections in this chapter and also as demonstrated by Maddison (2008).

Table 4.10: Results of the logistic regression on the likelihood of farm households adopting new crop varieties (n=388)

Variables entered in the model	ß	S.E	Wald	p-value	Odds ratio
Insufficient rainfall	1.61	0.59	7.26	0.007	5.00
Increased warming	-10.61	1.76	36.26	0.000	0.00
Increased droughts	3.35	1.17	8.06	0.005	28.38
Rainfall unpredictability	2.16	1.19	3.29	0.070	8.72
Early cessation	2.50	0.81	9.45	0.002	12.25
Extension services	2.93	1.58	0.01	0.993	2.48
Market	7.25	3.93	3.39	0.065	1.40
Respondents' sex	1.55	0.70	4.90	0.027	4.74
Food preference	2.53	1.10	5.28	0.021	12.64
Respondents' age	0.01	0.02	0.48	0.484	1.01
Years of schooling	-1.12	0.12	1.07	0.300	0.88
Household size	-0.03	0.10	0.08	0.765	0.97
Occupation	1.36	0.72	3.49	0.062	3.90
Constant	-3.05	1.53	3.98	0.046	0.04

The positive sign on ß-coefficients implies that such variables increased respondents' likelihood to adopt new crop varieties as opposed to the negative sign. Using Wald statistic values, Table 4.10 shows that warming had highest impact (ß = -10.61, Wald = 36.26, $P \leq 0.001$) on the likelihood of adopting improved crop varieties relative to other factors including non-climatic factors. The odds ratio for warming was 0.000 suggesting that for every unit increase in surface temperature there would be no change on the respondents' likelihood to adopt new improved varieties.

Arguably, warming overlapped with variables like drought and early cessation of rainfall such that it was difficult to disentangle them. This posed serious challenges to smallholder farming as an enterprise. Using meteorological data, Kabote *et al.* (2013) also reported similar results. Serious rainfall variability that negatively affects farming activities has also been reported in various places over the globe (IPCC, 2014), like India (Murali and Afifi, 2014) and Ghana (Rademacher-Schulz *et al.,* 2014).

Quantitative results in Table 4.11 showed that, out of 8 variables entered in the model, increased drought was significant at 1% while agricultural expansion and insufficient rainfall were significant at 5%. Using Wald statistic values, the results also showed that drought had the highest impact (ß = 2.16, Wald = 6.82, $P \leq 0.009$) on the likelihood of adopting new grazing places, far away as opposed to the 1970s, when agro-pastoralists grazed the livestock anywhere within or nearby the village of domicile. The results also showed that the odds ratio for drought was 8.70. This can be interpreted that drought had over eight times likelihood of causing changes in grazing places relative to other variables.

The rest variables were not significant at the 5% level of significance. The demand for agricultural land was high due to increased population. Nonetheless, it was difficult to disentangle agriculture expansion, drought and insufficient rainfall because farmers expanded their farm size in response to climate variability and change (Table 4.11). Nombo *et al*. (2013) also reported that smallholder farmers had to expand their farm size to minimize the impact of climate variability and change in Meatu and Iramba.

Table 4.11: Results of the logistic regression on the likelihood of changing grazing system (n=181a)

Variables entered in the model	ß	S.E	Wald	p-value	Odds ratio
Insufficient rainfall	1.69	0.70	5.82	0.016	5.44
Increased drought	2.16	0.83	6.82	0.009	8.70
Agriculture expansion	2.43	0.98	6.18	0.013	11.32
Government policy	1.65	1.41	1.37	0.242	5.21
Respondents' sex	-0.91	0.73	1.56	0.214	0.40
Respondents' age	-0.01	0.02	0.14	0.710	0.99
Years of schooling	0.08	0.09	0.71	0.399	1.08
Household size	0.01	0.04	0.12	0.730	1.01
Constant	-1.46	1.31	1.24	0.266	0.23

[a]Sample size (n) involves only households who kept cattle

Arguably, pastures had decreased because of dwindling grazing places as a consequence of climate variability and change. This required smallholder farmers and agro-pastoralists to change their grazing arrangements and therefore the distance to move with the livestock seeking for pastures increased, which in turn reduced time required by agro-pastoralists to engage in crop production. This had definitely caused food insecurity. Rademacher-Schulz *et al.* (2014) also reported that increased mobility among smallholder farmers caused food insecurity in Ghana.

Notably, adopting new crop varieties and changing grazing arrangements to cushion the impact of climate variability and change was unavoidable for a positive impact on the rain-fed farming system (RFFS), making it sustainable in supporting livelihoods. However, different paths had emerged because of constraints. For instance, existing crop varieties failed to withstand warming and drought, which intertwined with agriculture expansion. Moreover, some smallholder farmers did not adopt improved crop varieties because the price was up, and so they were unable to purchase them. Such farmers kept on using traditional crop varieties which are not drought resistant. Also, in addition to poor or lack of proper land use management system, conservation policies particularly in Meatu, reported in this chapter, were protective on use of pasture and water in conserved areas resulting into conflicts between agro-pastoralists and authorities. To that effect, although the system needed to adjust in a way to bring about positive impact, other paths different from the ones expected had emerged. In other words, the constraints exerted forces in different directions and therefore the system was at a crossroads.

4.6 Conclusions and Recommendations

This chapter examined the roles of climate variability and change in triggering changes on the rain-fed farming system (RFFS). Specifically, it dwelt on the changes and predictors of the changes in crop and livestock production systems. Based on the results of this chapter, the following conclusions are made: firstly, unlike the hypothesis ($P > 0.05$), climate variability and change showed significant impact on adopting crop varieties and changing grazing arrangements relative to non-climatic factors. Warming, drought and agriculture expansion showed the highest impact on adopting improved crop varieties and on changing grazing arrangements compared to non-climatic factors. Nevertheless, the changes on adopting improved crop varieties and new grazing arrangements were constrained by issues like natural resource conservation policies, inability of existing improved crop varieties to withstand climatic changes and high price for improved crop varieties.

Secondly, climate variability and change have increased the need for crop-livestock interactions, but poor land use management constrained these interactions, meaning that climate variability and change have overarching impact on the RFFS. This was clearly observed through use of the system thinking approach, which takes on board climatic and non-climatic factors in affecting different elements of the RFFS. Based on the fact that the RFFS needed adjustment and the constraints that acted in an opposite way, the chapter concludes that the RFFS was at a crossroads.

Based on the conclusions, the following recommendations are made: first, interventions promoted by the government and Non-governmental Organizations (NGOs) on crop and livestock production should focus on promoting about more drought and disease resistant crop varieties (especially sorghum, bulrush millet and sunflower), which can withstand climate variability and change. This is important because existing crop varieties had failed to withstand climatic changes. Secondly, other interventions should focus on creating awareness and education among agro-pastoralists on the importance of minimizing the herds to a manageable and productive size while improving pasture management to address scarcity of water and dwindling of grazing areas.

Thirdly, other interventions need to focus on harmonizing the use of pasture and land among agro-pastoralists and resource conservation policies. This is important in order to address conflicts on resource use that had already happened. Fourthly, due to intensification of drought especially since the 2000s, there is a need for interventions to focus on construction of water reservoirs and irrigation structures, meaning that a change from RFFS to irrigated farming system is inevitable. This should be accompanied by creating awareness on use of good agronomic practices and sustainable land use planning to address land use related conflicts. Finally, the chapter recommends further studies on changes in gender relations, nutrition and health, farmer's risks and marriage dynamics associated with climate variability and change in the study area and other semi-arid areas. Further studies should also focus on impacts of climate variability and change between male and female headed households.

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CHAPTER FIVE

5.0 Gender Relations and Climate Variability and Change in Rain-fed Farming System in Selected Semi-arid Areas of Tanzania

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5.1 Abstract

Climate variability and change have overarching impact on rain-fed farming system (RFFS). However, the impact on gender relations is not clearly understood. Using Connell's theory and the Harvard Analytical Framework, this chapter examined impacts of climate variability and change on gender relations in Iramba and Meatu districts. A qualitative approach was employed to demonstrate comprehensive relationships between gender relations and climate variability and change. The results showed that unequal division of labour in response to climate variability and change overburdened more women and children relative to men in both districts. In addition, men in-laws in Meatu controlled livestock and land resources when husbands were away due to climate variability and change. On the other hand, women in Iramba controlled livestock in absence of the husbands, but not land. In addition, the use of ridges in sweet potatoes production conserved moisture and improved household food and income. Women in both districts had full control over income from own plots. Yet, in Meatu, biased cultural norms allowed men, but not women, to control household income. Therefore, climate variability and change perpetuated and increased unequal gender relations, which in turn exacerbated the impact of climate variability and change. To that effect, interventions to address the impact should be gender sensitive and context specific.

Keywords: Gender relations, climate variability and change, semi-arid, Tanzania

5.2 Introduction

In the past two decades, since the 1990s, climate variability and change have increasingly become issues of concern in development particularly in Sub-Saharan Africa (SSA) because of low adaptive capacity. Serious impacts of the phenomena are reported in crop yield, food security and food systems, health, water and energy sources, ecological systems, migration and conflicts (Nelson *et al.,* 2002; Brody *et al.,* 2008; Goh, 2012). According to IPCC (2014) climate change has relatively higher impact on livelihoods of the poor relative to non-poor. The rain-fed farming system[15] (RFFS) refers to the system of crop and livestock production that depend entirely on rainfall. The system is particularly at risk when one considers semi-arid areas[16] (IPCC, 2007).

Climate variability and change are short-term and long-term changes in statistics of rainfall, temperature, relative humidity, winds and extreme weather events (IPCC, 2007).

[15] The concept of farming system is broader but can be defined as a set of inter-related, interacting and interdependent elements acting together to support livelihoods and is capable of reacting as a whole to climatic and non-climatic factors (Dixon *et al.,* 2001; Behera and Sharma, 2007)

[16] Semi-arid agro-ecological zones are characterized by erratic and low mean annual rainfall. Drought, inadequate soil moisture, soil infertility, higher day time temperature, higher evaporation that exceed precipitation are also common features in these areas (Vette, 2009; Mongi *et al.,* 2010)

Climate variability differs from climate change in that it is a short-term change that includes temporal and spatial variations of the mean state of the climate beyond individual weather events (IPCC, 2007). Although the phenomena pose widespread impacts, the magnitude of the impacts differs by ecological zones, wealth status and by gender (Nelson *et al*., 2002; Brody *et al.,* 2008; Carvajal-Escobar *et al.,* 2008; UNDP, 2009; Arora-Jonsson, 2011; Djoudi and Brockhaus, 2011; Nellemann *et al.,* 2011; Bauriedl, 2013).

Gender is taken in this study to mean socially constructed roles, behaviours, attributes, aptitudes and relative power between men and women in a given society (Baten and Khan, 2010). On the other hand, gender relations relate to specific forms of social, culture (ideas, beliefs and norms) and power relations between men and women (Reeves and Baden, 2000; Shayo, 2004). Gender is not natural; it changes over time depending on circumstances. Their changes are determined by factors like economic, legal, political, environmental and climate change. Being a woman or a man, there are restrictions or opportunities that are connected with it in a specific society. It is widely accepted that gender relations subordinate women in many societies. However, they are context specific such that they differ between rural and urban areas and between households (Nelson and Stathers, 2009).

Studies show that economic impact of climate variability and change are relatively known than social particularly gendered impacts (Kabubo-Mariara and Karanja, 2007; Kurukulasuriya and Ajwad, 2007; Kabubo-Mariara, 2009; Apata *et al.,* 2011). Nonetheless, in the past one and a half decade since the 2000s, scholars have increased interest on examining long-term and short-term impacts of climate variability and change with gender perspectives (Mulinge and Getu, 2013). Despite these efforts, the impact of climate variability and change on gender relations in Tanzania, not only in the rain-fed farming system, but also in other systems is still unclear (Nelson and Stathers, 2009). Therefore, an analysis of gender relations in response to climate variability and change is needed especially in semi-arid areas in order to inform development actors who are interested in transforming asymmetrical gender relations.

Gender analysis has traditionally been inspired by feminist theories. These theories suitably uncover gender inequality at societal and institutional levels. The central goal of these theories is to transform inequalities into gender equality. Thus, emphasis is put on women's social, economic and political rights, definitely due to their subordinate position in society (Lorber, 2010). Gender inequality, according to these theories, is rooted in gender differences and patriarchy ideology (Thompson, 2003; Brody *et al.,* 2008; Lorber, 2010). Feminist theories, though offering an insight regarding inequality in society, do not provide a clear systematic framework for analyzing gender relations. Therefore, this leads to a need for an organized theoretical framework to analyze gender relations.

A social theory of gender and power that was developed by Robert Connell in 1987 provides a systematic framework for analysis of gender relations (Connell, 1987). This can be done based on three social structures: (i) division of labour that relates to allocating different occupations to men and women; (ii) division of power that relates to power relations between men and women; and (iii) structure of cathexis, which is based on biased social norms between men and women (Reeves and Baden, 2000). The analysis of gender relations based on those social structures can uncover asymmetrical gender relations in the rain-fed farming system (RFFS) in which transformative policy interventions can focus (Maharaj, 1995). Connell's theory argues that gender relations at societal level remain intact over a long period of time as society slowly changes. It also posits that changes at the institutional level occur rapidly, but changes in gender relations at this level occur gradually (Maharaj, 1995; Wingood and DiClemente, 2000).

Connell's theory has been applied by Wingood and DiClemente (2000) to analyze existing gender relations in reproductive health. However, Wingood and DiClemente (2000) did not use this theory to capture changes in gender relations possibly because it was not the scope of their study. A study by Mwaipopo (2004) analyzed gender relations in Tanzania's agricultural sector using three social structures including gender division of labour, gender division of power and norms that sanction these divisions. However, this study by Mwaipopo (2004) did not clearly mention use of the Connell's theory of gender and power. The current study was inspired by the Connell's theory in order to systematically examine impacts of climate variability and change on gender relations in RFFS. The study takes intensification of climate variability and change, as stimuli that can exert changes on social structures and eventually posing impacts on gender relations.

Available literature (Amsalu and Wana, 2013; Mulinge and Getu, 2013; Mushi, 2013; Nombo *et al.,* 2013) only provides a vague conclusion that the impact of climate variability and change is gendered. Yet, information about impacts on gender relations is limited and patchy (Nelson and Stathers, 2009) especially in RFFS, which is sensitive to climate variability and change. This makes difficult to draw robust conclusion for informed policy interventions in Tanzania to address gendered impact of climate variability and change. Therefore, this chapter aimed to answer the following questions: (i) how are gender relations impacted in response to climate variability and change? (ii) Who are most disadvantaged by the impacts on gender relations between men, women and children and why.

The results from this study contribute to knowledge on contextual understanding of gendered impacts of climate variability and change in RFFS in semi-arid areas of Tanzania. The results will also provide insights on the need to plan interventions for climate variability and change adaptation strategies with the aim of transforming asymmetrical gender relations that can exacerbate the impacts of the phenomena. The next sections of this chapter are devoted to explaining the study area, outlining the methodology, presenting and discussing the results. Finally, the chapter winds up by presenting conclusions and recommendations.

5.3 The Study Area

5.3.1 Location of study districts

Meatu District lies between latitudes 3^o and 4^o South and longitudes 34^o and 35^o East, South of Lake Victoria, and its altitude ranges between 1 000 and 1 500 meters above sea level (m.a.s.l). The mean annual rainfall is 400 mm in the southern and 900 mm in the northern parts. The rainfall regime is unimodal. In this rainfall pattern, rains begin in November and cessation occurs in April (Mtongori and Innes, 2010). Vegetation is widely scattered and replanted trees after deforestation are sometimes clustered in Meatu District.

Iramba District on the other hand, lies between latitudes 4^0 to $4^0.3^{'}$ South and longitudes 34^0 to 35^0 East. The district is divided into three major agro-ecological zones: western Great East African Rift Valley; central highland; and the eastern zone. The former zone is relatively drier compared to the other zones (Iramba District Council, 2009). The district receives mean annual rainfall of between 500 and 850 mm. Surface temperature in the district ranges between 15^0C in July and 30^0C in October (Iramba District Council, 2009). Vegetation is mainly natural Miombo woodlands, acacia woodlands and grasslands in Iramba District. The districts involved in the study were contiguous and different types of ethnic groups in the districts were important in terms of giving variations in gender relations and climate change.

5.3.2 Location and justification for village selection

Three villages situated in semi-arid areas of Tanzania were involved. These were Mwashata and Mwamanimba found in Meatu District in Simiyu Region. The district is dominated by the Sukuma ethnic group. The third village was Kidaru that is found in Iramba District along the Great East African Rift Valley in Singida Region. This district is dominated by the Nyiramba ethnic group. The rain-fed farming system in the selected villages is dominated by sorghum *(Sorghum bicolor)*, cotton *(Gossypium hirsutum)*, maize *(Zea mays)*, bulrush millet (*Pennisetum glaucum)* and sweet potatoes *(Ipomoea batatas)*. Livestock on the other hand, include cattle, goats, sheep, poultry, donkey and pigs. A substantial number of agro-pastoralists is found in Mwamanimba (Kabote *et al.,* 2013).

The criteria to select the study villages were: frequent drought, frequent hunger and frequency of receiving food aid. Frequent hunger and frequency of receiving food aid were used as proxy indicators for crop failure associated with climate variability and change. For example, since 2000, Kidaru received food aid from the district authority and from Non-governmental Organizations eight times. Over the same period of time, Mwashata received food aid from the district authority seven times whereby Mwamanimba received food aid almost each year.

5.4 Methodology

5.4.1 Research design, sample and data collection methods

This chapter adopted a qualitative research approach in order to generate extensive amounts of descriptive data. The design also enabled holistic examination of the gender relations and climate variability and change (Creswell *et al.,* 2007). Sixty three household heads and spouses from agricultural and agro-pastoralist households participated in FGDs (Table 5.1). The study tape recorded discussions from focus groups (FGDs) and interviews with key informants. One of the FGDs in Kidaru encompassed men and women, but women could not participate freely and therefore the group was split into men and women to capture views from each group. Consequently, men and women were in different groups in Mwashata and Mwamanimba.

Table 5.1: Characteristics of FGDs participants

Village name	Number of FGDs conducted	Number of male participants	Number of female participants	Mean age (years)	Minimum age (years)	Maximum age (years)
Kidaru	3	6	9	44	25	60
Mwashata	2	10	14	42	29	63
Mwamanimba	2	13	11	49	31	68
Total	**7**	**29**	**34**	**NA**	**NA**	**NA**

Note: NA = Not Applicable

Initially, the plan was to have 6 to 12 participants per FGD, but members ranged from 6 to 14. This is because one participant in one of the men FGDs in Mwamanimba and two participants in Mwashata participated without being invited. Literature on size of FGDs is mixed though recommends 6 to 12 for effective participation and good quality of data (Masadeh, 2012). Participants' age ranged from 25 to 68 years in order to capture different views from different age groups.

During FGDs, the study identified six key informants who were not in the FGDs and who's some of the household members had either migrated to other areas in search of casual labour, or were away for the purpose of moving their livestock in search of water and pasture. The thinking was that when particularly household heads are away, division of labour and control over resources can change in a long run. Therefore, the key informants generated in-depth qualitative data in order to make sense of the changes in gender relations associated with climate variability and change. The interviews with the key informants were face-to-face. A checklist of open-ended questions guided the interviews (Creswell *et al.,* 2007). The guide was designed such that key informants could share their experience regarding climate variability and change and how gender relations were impacted.

5.4.2 Data analysis

Tape recorded information was transcribed into text to address the research questions and the analysis focused on the content and meaning of the text. The Harvard Analytical Framework[17] was used to guide data collection and gender analysis. Three variables were involved in the analysis: first, activity profile in rain-fed farming system (RFFS) focusing on who does what among men, women and children, and if this had changed over time in response to climate variability and change (March *et al.,* 1999; Kangisher, 2007), including who is advantaged or disadvantaged by the changes.

Activities in RFFS focused on cropping calendar and livestock grazing patterns. Second, the study identified and analyzed productive resources including land and livestock and who has access to and control over the resources among men, women and children and the

[17] Sometimes known as the gender roles framework or the gender analysis framework, it was developed by researchers at the Harvard Institute for International Development in the USA in collaboration with women's office (USAID) of women in development. The framework can be used to collect data at the individual and at the household level making men's and women's work visible (March *et al.,* 1999).

changes which had occurred over time. Access to resources implies that one is able to use the resource, while control over resources means that one has ability to make decisions about resource use, including whether it can be sold (March *et al.,* 1999). Third, the study analyzed climate variability and change, which are believed to trigger changes in the activity profile, access to and control over resources. The factors for the changes were assumed to be an opportunity or a threat for gender relations in the rain-fed farming system.

5.5 Results

5.5.1 Climate variability and change and division of labour

Table 5.2 summarizes results from focus group discussions (FGDs) indicating periods when the rainfall started and when it ended in the 1970s compared to the situation in 2013. Results from this Table show that onset and cessation of rainfall had changed. Rainfall patterns after onset had increasingly become inconsistent compared to the situation in the 1970s. An eight day dry spell that used to occur in February in the 1970s had increased in duration.

Table 5.2: Changes in rainfall patterns

	Situation in the 1970s		Situation in 2013	
Village	**Onset**	**Cessation**	**Onset**	**Cessation**
Kidaru	November/December	May/June	November/December/ January	March/April/ May
Mwashata	September/October	May/July	November/December	April/May
Mwamanimba	September/October	May/June	December	April/May

The dry spell had increased to one month and its period of occurrence had moved backward from February to January. In addition, rainfall had increasingly become less sufficient, day time temperature and frequency of drought had also increased as reported in chapter two in this study. Inconsistent rainfall patterns and less sufficient rainfall particularly in April and December in Iramba; and in January and April in Meatu were also reported by Kabote *et al*. (2013). Participants during FGDs stressed that frequency of drought had increased seriously since the 2000s. Late onset of rainfall, early cessation and widening of the February dry spell had shortened crop growing period by a month in Meatu and by more than a month in Iramba.

The results reported during FGDs about changes in rainfall patterns since the 1970s were in line with results reported by one of the key informants in Meatu District. This can be summarized as follows:

> '…less sufficient rainfall is a major problem …rainfall may start well and stops earlier than expected…the situation was good in the 1970s when I almost harvested enough for the household…currently…hunger has increasingly become common and my household sometimes gets food aid …households who own livestock are somehow better off because they can sell their animal stocks and purchase food stuff for their families...' (A 63 years old man, Mwashata, 22nd January 2013).

Based on that quotation it can be deduced that rainfall patterns had become unpredictable resulting into crop failure and frequent hunger that had to be addressed through food aid and selling of assets including livestock. This implies that households, mainly female headed ones not owning livestock, were likely to be at risk relative to livestock keepers. Therefore, strategies to address crop failure in response to changes in rainfall patterns are critical and need to be gender sensitive. This is supported by Nombo *et al.* (2013) who reported that none livestock keepers are more affected by the impacts of climate variability and change compared to livestock keepers.

Results from FGDs (Table 5.3) also showed that women and girls were more involved in food crop production especially production of sorghum, maize, sweet potatoes, sunflower and bulrush millet relative to men who were more involved in cash crops like cotton in Meatu and Sunflower in Iramba.

Table 5.3: Activity profile in crop production

Task	Kidaru	Mwashata	Mwamanimba
Clearing the land for agriculture	Men and boys	Men and boys, but sometimes all[a]	Men and boys
Tilling the land	All	All	All
Seed preparation	Women	Women	Women
Seed sowing	All	Women and children	Women and children
Weeding	All	Women and children	Women
Harvesting and transportation of agricultural produce	All	All	All
Processing of agricultural produce and storage	All	All	Women and children
Selling of agricultural produce	Men	Men	Men
Cutting and ferrying firewood	Women and girls	Women and girls	Women and girls
Fetching and ferrying drinking water	Women and girls	Women and girls	Women and girls

Note: Both food and cash crops were included. All means men, women and children; children means boys and girls; [a]reported by women FGD in Mwashata

However, in many cases, existing cultural norms allowed an overlap of division of labour between men and women especially on tilling the land, harvesting and transportation of agricultural produce from the farm to home. Interestingly, men were mainly involved in transporting agricultural produce using an oxcart. Head carrying was mainly women's responsibility. Tilling the land by a plough was men's role, but women were mainly involved in using a hand hoe. Weeding was women's and children's role, boys and girls, however; men were particularly involved in production of cash crops like cotton and sunflower. In addition, seed preparation was women's responsibility, but in case seeds had to be purchased, men were involved in providing the cash.

Such division of labour as presented in Table 5.3 was not absolutely something new. This is supported by Lorber (2010) who stresses that division of labour in many societies is gendered. This unequal gender division of labour is sanctioned by existing cultural norms, which traditionally subordinate women. Yet, with increasing frequency of drought that led to crop failure and in turn food insecurity and hunger, changes had occurred. These changes were justified during FGDs at Mwamanimba as follows:

> '…my husband rarely stays at home since 1997 because he has to go to seek casual labour somewhere else for the family members to have something to eat…our children have missed father's care… my husband is currently away and so I have become the mother and the father of the family…I have to sell firewood and graze someone's cattle to sustain my family…' (A 36 years old woman, Mwamanimba, 2nd March 2013).

That quotation justified that men's mobility in response to climate variability had increased. Thus, women and girls played their roles and those of migrated male heads and boys at the household level. For instance, women and girls were involved in using a plough to till the land that was traditionally men's role. This occurred due to mobility for men and boys in search of pasture and water for the livestock or migrated to urban centres especially Kiomboi and Singida in Iramba or Mwanhuzi, Bariadi and Shinyanga in Meatu in search of casual labour. These issues including mobility were also repeatedly mentioned by other key informants. Therefore, women and children particularly young boys and girls were involved in off-farm activities as summarized in the following narration. This was likely to affect strategic needs, especially education, for children.

> '…in 1998 my husband left me when I was pregnant and came back when the new born was three months old…currently he is away and I am caring for 5 children whom I have to make sure they have something to eat and also they are able to go to school…I get little money to purchase food and pay for other requirements like school fees through doing farm work for other households…my children are also doing farm work for other families…'(A 58 years old woman, Kidaru, 23rd May 2013).

Changes in gender division of labour were also reported in livestock production as presented in Table 5.4. The results showed that grazing livestock was traditionally children's role, mainly boys, though girls were also involved particularly in Meatu. Men and boys were largely involved in seasonal movements of livestock mainly cattle in search of pasture in Kidaru and Mwashata or in search of water and pasture in Mwamanimba. Men were also involved in digging water holes in lowlands and along rivers in search of water for livestock. This occurred when the herd of livestock was small and that it was not necessary to involve it in the seasonal movements. Women on the other hand, dug water holes along rivers and streams in search of water for domestic use and for small livestock particularly goats and sheep. Climate variability and change had increased water scarcity for livestock and for domestic use and therefore added extra responsibilities and labour for men and women.

Table 5.4: Activity profile in livestock production

Activity	Kidaru	Mwashata	Mwamanimba
Digging trenches in search of water for livestock use	Men and boys	Men and boys. Women take care of goats and sheep	Men and boys and sometimes women take care of goats and sheep
Seasonal labour migration during hunger period (Searching casual labour)	Men	Men	Men
Grazing livestock	Boys and girls	Boys and girls	Boys and girls
Seasonal movement of livestock in search of water and pasture	Men and boys	Men and boys	Men and boys
Milking	Men	Men and women	Men and women

Men were helping women to fetch water and fuelwood resources because the distance to collect them had increased. Some men were involved in collecting these resources for business purposes. Existing unequal gender division of labour seemed to aggravate the impacts of climate variability and change on women who had assumed men's responsibilities because of increased men's mobility.

Climate variability and change were manifested through, among other things, increased frequency of drought. As such, distance for seasonal movements of livestock had gradually increased from within the district in the 1970s to moving beyond region boundaries. Frequency of movements had also increased. The direction of mobility included Rukwa, Morogoro, Mbeya and Tabora Regions. Depth of water holes to access water for livestock had increased from one metre in the 1980s up to 10 metres in the 2000s. Lake Victoria Environmental Management Programme (LVEMP) formed community groups to deal with soil and moisture conservation in Meatu. This helped men and women to get information and knowledge about moisture conservation.

Based on those changes, women and girls were involved in grazing small stocks including goats and sheep and also older or weak and farm draught animals which were not involved in seasonal movements. In addition, digging water holes for livestock, which were not involved in movements; and grazing those animals were additional responsibilities for women and girls. Furthermore, travelling long distances in search of pasture and water were extra responsibilities for men. Despite additional tasks that had occurred for men and women, more tasks in livestock as it was in crop production had occurred for women relative to men.

5.5.2 Division of power for productive resources

Results from FGDs showed that men, women and children had access to land resources, livestock and agricultural produce and income. As mentioned earlier in the previous section, access to resource means that one was able to use the resource while control over the resource means that one was able to make decisions about resource use including whether the resource can be sold (March *et al.,* 1999). However, control of those resources was dominated by men as reported by FGD participants at Mwashata:

> "...we (men) control household income, livestock and land...in rare cases we can share control with our wives and boys but not girls...some of us (men) spend the household income for drinking local brew..." (Men FGD participants, Mwashata, 22nd January, 2013).

That quotation justified that control over household resources was a male domain. Unlike in the past, increased crop failure due to drought made women to have their own agricultural plots. Women had full control over the produce and income from their own plots relative to the family income which was mainly controlled by men.

Increased mobility among men to minimize impacts of climate variability and change can be interpreted that this was an opportunity for women to decide on how to use the household land resources, income and livestock. Yet, this study found that the decision to sell or rent the land or sell livestock in times when it was necessary had to involve men in-laws (husband's farther or brothers) in Meatu. In Iramba, women could use livestock remained at the household after others had been moved, including selling to generate household income. However, renting the family land needed presence of the husbands.

5.5.3 Gender bias and climate variability and change

The results from FGDs also showed that, traditionally, sweet potatoes, bambaranuts, green gram, groundnuts and pigeon peas were labelled as 'women crops'. Production of women crops involved mainly women in the past. On the other hand, cash crops including cotton and sunflower were labelled as 'men crops'. Sweet potatoes had increasingly become a famine crop in addition to sorghum and millet following increased drought. As a result, men participated in sweet potatoes production. Some of women's crops such as green gram and groundnuts had become potential for generating household income in Meatu due to failure of cash crops like cotton. Thus, green gram and groundnuts were likely to become men crops in future so that men can be able to control the income accruing from those crops. This kind of bias perpetuated women subordination, and that, it sanctioned asymmetrical gender relations with implications on gendered impacts of climate variability and change.

Those results clearly show that off-farm tasks including selling firewood, grazing someone's cattle, mobility and selling livestock and food aid helped households to minimize impacts of climate variability and change. The impacts of climate variability and change include crop failure even for drought resistant crops like sorghum and bulrush millet, perpetuation of hunger and food insecurity each year, inability to support children's education, child labour, scarcity of pasture, water and energy resources and conflicts between agro-pastoralists and conservation policies. These impacts are gendered with potential impact on gender relations regarding to who is doing an extra role in response to climate variability and change at the household level. Unequal gender division of labour which is also perpetuated by climate variability and change suggests that women are disadvantaged relative to men.

5.6 Discussion

5.6.1 Social impact on gender relations

Climate variability and change occurred through increased rainfall unpredictability; increased frequency of drought; increased duration of dry spells and warming. This was also reported by Kabote *et al*. (2013). Such climatic changes increased men's and boys' mobility in search for water and pasture for livestock and also for searching food and income. Some were unable to help wives and children back home. This increased hardship among women in the study area. Similar results on mobility were reported by Raleigh and Jordan (2010) in West Africa and in Nepal and by Afifi *et al.* (2014) in northern Tanzania. The pattern of migration in this study was partly circular in the sense that it was seasonal, but some men never came back for about five years. This has implication on the number of female headed households and also on living in destitute for women, children and the aged. Circular migration that involves seasonal migration was also reported by Milan and Ho (2014) in Peru.

Although men and boys mobility was an important strategy to overcome food and income shortage and lack of pasture and water for livestock, it had decreased household labour expected from men and boys. Thus, some men's tasks at the household level were performed by women. This implies that additional tasks for women had emerged. For example, women in addition to domestic chores engaged in using a plough during land tilling, which was traditionally a men's role. Mobility had also decreased men's work force in crop production. This implies that women's work force had definitely increased leading to the argument that crop production had increasingly become women's role.

The presence of 'women plots' in response to climate variability and change suggests that women were stretched to work on their own and on the family plots. Although this helped women to have full control over income accruing from their own plots, it increased women workload in both food and cash crop production. This translates into overburdened women relative to men counterparts. This is supported by Nellemann e*t al.* (2011) who reported that women play many tasks like productive, reproductive and community roles. In addition, literature stresses that women provide between 75% and 80% of agricultural work force in Sub-Saharan Africa (SSA) compared to 65% in Asia and 45% in Latin America (Denton, 2002; Nellemann e*t al.,* 2011; Speranza, 2012). Therefore, increased women's roles and responsibilities in response to climate variability and change suggest an extra burden being added on already overburdened women. In other words, the impacts of climate variability and change exacerbate asymmetrical gender relations. Increased women's workload can also negatively affect women's health including reproductive health. Women performing men's roles in response to climate variability and change as reported in this study was also reported by Kakota *et al*. (2011) in Malawi.

Traditionally, men and boys were responsible for grazing livestock. However, climate variability and change caused overlapping of tasks between men and women in managing livestock. For instance, women and girls were engaged in grazing goats, sheep and ox-plough animals which were not involved during seasonal movements. This had also been reported in Ethiopia (Mulinge and Getu, 2013), in Uganda (Kabonesa and Kindi, 2013), in Kenya (Njiru, 2013) and in Zimbabwe (Mare, 2013). In this situation, women and girls were victims in terms of increasing tasks and hence, an increase in workload relative to men. The increase in women's workload was not only due to additional roles and responsibilities, but also due to increased time in accomplishing the tasks caused by dwindling work force from men and boys. These changes in gender division of labour perpetuated and increased unequal gender relations, which in turn exacerbated the impacts of climate variability and change particularly among women and girls relative to men and boys.

Logically, the absence of men at the household level due to increased mobility opened opportunities for women to control land, livestock and income. In Iramba for instance, wives were able to sell livestock to support household needs like purchase of food stuffs and supporting children to access education. This implies that women in Iramba District had gained control over livestock and so had to decide their use in absence of husbands. However, the decision to rent the household land to someone else, when necessary, had to wait presence of the husband. This implies that, unlike control over livestock, control over land resources remained under men domination even when men were away. This was due to intact of cultural norms, which gave rights for men to control land.

Like in Iramba, both men and women in Meatu District had access to land resources and livestock. Yet, women in male headed households (MHHs) had no opportunity to control these resources even when men were away as opposed to female headed households (FHHs). Therefore, excluding FHHs, the decision to sell or rent household land involved men in-laws in case the husband was away due to increased mobility. This difference in controlling productive resources in Iramba and Meatu districts was hinged on cultural norms embedded in the patriarchy ideology for the Nyiramba and Sukuma ethnic groups in Iramba and Meatu respectively. That means, cultural norms, which gave rights for men to control productive resources, though can be negotiated differently from household to household (Nelson and Stathers, 2009), were respected and therefore were intact in the Wasukuma relative to the Wanyiramba. As a consequence, gender relation between men and women in Meatu relative to Iramba regarding control over land and livestock was absolutely under men domination. These unequal gender relations as Denton (2002) posits exacerbated the impacts of climate variability and change on women than on men.

This study stresses that changes in gender relations at the household level can determine, in the long run, changes in gender relations at the societal level. This implies that interventions to transform asymmetrical gender relations need to focus at the household level. According to the Connell's theory of gender and power, the household is a lower level where change in gender relations can occur (Maharaj, 1995; Wingood and DiClemente, 2000). On the other hand, society for example that of the Sukuma in Meatu and Nyiramba in Iramba, is a higher level for which gender relations exist and where they remain intact over a long period of time. Since women are key decision-makers for domestic chores, men's mobility can be an opportunity for women to control productive resources for the benefit of the household and this can empower women (Nelson and Stathers, 2009). This empowerment is necessary for transforming unequal gender relations. Such transformation can in the long-run, spill over from the household to the society level.

The results from this study showed that household income from cash crops like cotton and sunflower and livestock selling remained under men's control. Women had full control over income from their own plots only. Therefore, a shift from women's to men's crop occurred when a crop became potential for income generation. Crops like sweet potatoes, green gram and groundnuts which did not connote for household income generation were traditionally women crops. Sweet potato was traditionally a woman crop. However, the use of ridges driven by increased drought to conserve moisture increased yields and household income accruing from sweet potatoes. Therefore, men helped women to make ridges using an ox-plough. Nonetheless, men were likely to have control over the crop especially in Meatu District so that they could also control the income accruing from it. This is because; existing cultural norms, which were biased, gave rights for men to control household income from different sources. This implies that income imbalance in terms of control as argued by Wingood and DiClemente (2000) perpetuated asymmetrical gender relations. Existing income imbalance between men and women, in addition to crop failure that increased since the 2000s due to excessive drought exacerbated impacts of climate variability and change on women relative to men.

Unlike in the past when women were passive participants in local gatherings, women in the soil and moisture conservation groups in Mwashata had an opportunity to work and socialize with men. This can help women to participate in decision making structures at higher levels. Yet, socializing children at the household level was women's responsibility relative to men counterparts due to increased men and boys' mobility. This implies that, because of increasing climate variability and change (Denton, 2002; IPCC, 2007), children were likely to miss some values obtained through socialization from the male gender. While these changes can minimize inequality in gender division of labour in agriculture and livestock production − assuming the mothers will treat boys and girls equally – it may also result into missing good identities expected from the male gender and which are essential in shaping boys and girls into adult males and females respectively. On the other hand, as long as gender is a societal issue, gender biases and stereotypes could still exist in society.

5.7 Conclusions and Recommendations

This chapter examined changes in gender relations in response to climate variability and change in the rain-fed farming system (RFFS) in semi-arid areas of Tanzania. It also analyzed the gendered impacts with regard to changes in gender relations. Based on the discussion, the study concluded as follows:

First, men's mobility in response to climate variability and change created a space in terms of responsibilities and labour for which women had to fill. Therefore, in addition to traditional women's roles, which are productive, reproductive and community roles, women adopted extra responsibilities, some of which were traditionally men's roles. Such extra roles included the use of the plough in tilling the land, digging water holes to access water and grazing livestock which were not involved in seasonal movements. Men had also adopted some extra responsibility related to mobility. However, women and girls' workload in crop and livestock production had increased relative to men's workload. This affirms perpetuation of unequal gender relations leading to the conclusion that women were negatively affected by changes in division of labour.

Secondly, control over livestock, land and income was mainly under men. Yet, in both districts, women controlled income accruing from their own plots. In Iramba, women had control over livestock in the absence of husbands, but not control over land. On the other hand, men dominated control over land and livestock in Meatu. Despite changes in control over livestock in Iramba, the changes were very gradual with negative impacts on women than men counterparts. Gaining power on control over livestock in Iramba, full control over income accrued from women plots in both districts and participation of women in community groups were positive gender relation transformations. However, this was gradual and differed by locations depending on cultural norms between ethnic groups. This conclusion agrees with the Connell's theory, which succinctly argues that changes in gender relations take place gradually at the institutional level. This leads to the conclusion that gendered impacts of climate variability and change with regard to control over resources were both negative and positive and that women were more affected relative to men especially in Meatu District, which is dominated by the Sukuma ethnic group.

Based on the conclusions, the chapter recommends that when district authorities and Non-governmental Organizations (NGOs) are addressing the impact of climate variability and change in rain-fed farming system (RFFS), interventions should be gender sensitive and context specific. These efforts should specifically consider transforming biased cultural norms, which subordinate and discriminate women with regard to gender division of labour and control over resources.

Secondly, the issue of technology improvement to adapt to climate variability and change is essential because, as demonstrated in this thesis, improved technology e.g. shift from a hand hoe to a plough is powerful in transforming gender relations. This is because it has potential to challenge existing biased norms between men and women. This in turn can reduce the time spent to till the land and so reducing workload among women that was on the increase. Irrigated farming with gender perspective is critically recommended. Therefore, the government of Tanzania should provide support on the use of technology to address unequal gender relations.

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CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary of Major Results and Conclusions

6.1.1 Meteorological data trends for rainfall and temperature

Meteorological data trends are discussed in chapter two to address the first specific objective of this study. The chapter examined inter-annual variability of rainfall and temperature as well as seasonal variability in a six-month crop growing period starting from November to April. The results demonstrated that there was no significant increase ($P > 0.05$) in inter-annual rainfall variability for the period from 1994 to 2011 and from 1994 to 2008 in Meatu and Iramba districts respectively. In addition, the long-term means showed a typical characteristic of a semi-arid area in both districts. On the other hand, maximum temperature was higher in Meatu than in Iramba.

The number of hot years exceeded the number of cold years in both districts, but there was no clear trend on these variables during the period between 1994 and 2011. Similarly, there was no clear trend on number of dry and wet years in both districts. Nonetheless, the number of wet years exceeded the number of dry years in Iramba as opposed to Meatu where the numbers of dry and wet years were similar. While there was no clear trend on the number of rainy days in Iramba, Meatu showed a fluctuating decreasing trend. The six-month crop growing period starting from November to April was used to measure seasonal variability of rainfall and temperature. Results demonstrated that there was a clear decreasing trend of rainfall in April and December in Iramba. January and April also showed a clear decreasing trend in Meatu. On the other hand, April experienced increasing maximum temperature in both districts. This overlapped with a rainfall decreasing trend in that month.

The study concludes that both study districts showed similar trends with regard to inter-annual rainfall. Although the study districts are both located in semi-arid areas, generalization with regard to seasonal variability was difficult due to different trends demonstrated in this study. It is also clear that the length of crop growing period had decreased as demonstrated by meteorological rainfall data, which showed a rainfall decreasing trend in April in the study area. Crop production is more at risk particularly in Iramba because December, which is a critical crop growing period, also experienced a clear rainfall decreasing trend. Increasing temperature trends in April in both districts that coincided with rainfall decreasing trends can increase evaporation from water bodies and also evapo-transpiration from plants and thus increasing possibilities of crop failure.

6.1.2 Perception and meteorological data trends

Perception and measured climate variability and change are discussed in chapter three to address the second specific objective. The chapter assessed people's perceptions through qualitative and quantitative methods and then compared with results from meteorological data trends, which represented measured climate variability and change. People's perception and measured climate variability and change showed that the phenomena had occurred in both districts and farmers were able to recall changes since the 1970s. The indicators of the changes include late onset and early cessation of rainfall, less sufficient rainfall and increased day time and night time temperature which coincided with increased frequency of droughts, especially since the 2000s. Others were: increased rainfall unpredictability; increased wind speed; increased duration and shifting of the dry spell from February to January in Meatu and to March in Iramba; increased seasonality of water bodies; increased diseases in crops, livestock and increased insect crop pests.

As hypothesized, the poor, not so poor and the rich showed almost similar responses, with regard to perception of climate variability and change ($P > 0.05$). Similarly, men and women's perceptions were almost the same ($P > 0.05$), except that women showed more perceived risks of climate variability and change impacts relative to men. This means that measures to address impacts of the phenomena need to be gender sensitive to have a meaningful outcome. People's perception and measured climate variability and change agreed to a large extent. This increased understanding of the phenomena. For instance, meteorological data trends for each month, during the six-month period between November and April, showed high standard deviations implying that rainfall patterns were inconsistent. This can pose problems to the farmers in planning farming activities. The meteorological data trends were in line with people's perceptions that rainfall had increasingly become unpredictable. Meteorological data trends were also in line with farmers' perceptions in that they demonstrated early cessation of rainfall through constant decreasing amount of rainfall in April throughout the time under consideration. Decreasing amount of rainfall in December was also in line with perception that rainfall was less sufficient during critical crop growing period. While people's perception demonstrated increased frequency of drought since the 2000s, measured meteorological data trends did not show a clear trend on number of dry and hot years in this period. This was largely due to lack of data in some months during the last decade.

Despite discrepancy in people's perceptions and measured climate variability and change, especially on drought and increased temperature, the study concludes that the indicators of the phenomena overlapped, making climate variability and change complex phenomena. All indicators used to measure climate variability and change, except inter-annual anomaly, showed that the phenomena had intensified compared to the situation in the 1970s.

6.1.3 Rain-fed farming system and climate variability and change

Changes as a proxy indicator for impacts on the rain-fed farming system (RFFS) in response to climate variability and change are discussed in chapter four to address the third specific objective. The chapter adopted farming system thinking whereby different sub-systems of the farming enterprise that include crops, animals, soils, labour, land and technologies used were viewed as one system. According to this theoretical thinking, change in one sub-system affects other elements of the system organization. Changes in RFFS in response to climate variability and change can be negative or positive. Positive changes are important in order to keep the system sustainable in supporting people's livelihoods. The likelihood of changing sub-systems of RFFS was determined using binary logistic regression and the predictor variables captured climate variability and change and non-climatic factors.

Unlike the hypothesis ($P > 0.05$), the results showed that warming had significant impact ($ß = -10.61$, Wald = 36.26, $P \leq 0.001$) on likelihood of farmers adopting improved crop varieties in sorghum and maize. Other indicators which had significant impacts included increased frequency of drought, rainfall unpredictability and early cessation of rainfall. Food preference and respondents' sex also showed significant impact. Respondents' sex showed significant impact because women showed relatively higher perceived risk of climate variability and change relative to men.

Similarly, unlike the hypothesis ($P > 0.05$), drought and agriculture expansion showed significant impact on likelihood of changing a grazing place. Drought showed the greatest impact ($ß = 2.16$, Wald = 6.82, $P \leq 0.013$). There was also inter-dependence of livestock farming and crop production systems in that livestock were seasonally moved out of the villages to pave way for crop production and brought back after harvesting period. In this arrangement, crop residues were used as animal feeds. Yet, changes in RFFS particularly adopting new crop varieties were constrained by lack of improved varieties that could withstand severe drought. Grazing of livestock, on the other hand, was constrained by natural resources conservation policies and poor land use management system that did not set aside grazing land, farming and settlement land.

Based on these results, the study concludes that the results were in line with the farming system thinking in that they demonstrated complex relationships regarding components of RFFS and climatic factors particularly drought, less sufficient rainfall and unpredictability, warming, late onset and early cessation of rainfall; and non-climatic factors especially price of agricultural produce, population increase, food preference, bird infestation, crop and animal pests and diseases.

The study also concludes that, although many factors affected RFFS, climate variability and change had significant impact. The changes in RFFS mainly affected crop production and livestock keeping negatively. This increased chances for crop and livestock failure and therefore the system was at a crossroads.

6.1.4 Gender relations and climate variability and change

Changes in gender relations in response to climate variability and change in RFFS are examined in chapter five. This covered the fourth specific objective of this study. Using qualitative methods, mainly focus group discussions (FGDs) and key informant interviews, this chapter answered two questions: first, how were gender relations impacted in response to climate variability and change? Second, who were most disadvantaged by the impacts on gender relations between men, women and children and why? The social theory of gender and power developed by Robert Connell in 1987 was used to systematically examine gender relations in RFFS. The theory was also extended to examine changes in gender relations. According to this theory, three social structures were considered: division of labour, division of power and biased norms that reinforced unequal division of labour and power relations.

The chapter demonstrated that climate variability and change increased and perpetuated unequal gender division of labour between men and women. Men's mobility within the districts and outside the districts in search for water and pasture for the livestock was on the increase. Sometimes, men migrated in search for casual labour due to increased hunger caused by crop failure. Therefore, household's labour in RFFS expected from men had decreased. Along with this, men's responsibilities were performed by women. For instance, using a plough to till the land was traditionally men's task, but it was performed by women and girls following increased mobility of men and boys. Men had also adopted new responsibilities related to mobility.

Power relations on the other hand, showed that women in male headed households (MHHs) in Iramba were able to sell livestock and control income accruing to supporting household needs, including purchase of food stuffs and supporting school children to access education. Yet, control of the household's land remained under male domination. On the other hand, power relations in male headed households (MHHs) in Meatu remained intact such that women had no opportunity to control land, livestock and household income even in absence of the men counterparts. This happened because traditionally, these resources are controlled by men. In other words, cultural norms did not allow women to control these resources. Crops which had no potential of income generation like green gram and groundnuts were traditionally labelled 'women crops'. Women had full control over income from their own plots, but no control over the family income. The lack of control over family resources caused serious impacts of climate variability and change on women relative to men such that women and children lived in hardship. Community groups that encompassed men and women were established at Mwashata. These dealt with soil and moisture conservation to address prolonged drought. Importantly, the groups were an opportunity for women to work with men. In addition, the groups helped women to socialize with men and in turn could improve women participation in decision-making at the national level.

The study concludes that climate variability and change increased and perpetuated unequal gender relations. There was an overlap of responsibilities between men and women, but women’s workload had increased compared to men counterparts. In other words, crop production had increasingly become women’s work. Grazing of weak livestock not involved in seasonal movements was also an additional responsibility for women and girls. In addition, norms that reinforced unequal control over resources remained intact though women had full control over income accruing from own plots. In addition, women at Iramba had control over livestock when husbands were away compared to Meatu. This means that control over resources differed by district because each district was dominated by a different ethnic group with different cultural values, beliefs and norms. Therefore, generalization in terms of control over productive resources was difficult.

6.2 Recommendations

6.2.1 Coverage, record keeping and use of climate information

Tanzania Meteorological Agency (TMA) and district authorities should strengthen coverage, record keeping and use of climate information. Improving coverage of meteorological data can be done by installation of a meteorological station to measure rainfall and temperature at ward level, and records should be taken everyday day in a month to avoid missing data. The district authorities should also use meteorological data to create awareness and education, and also advise farmers regarding appropriate adaptation strategies that can be used to address risks associated with climate variability and change particularly crop failure, lack of pasture and scarcity of water.

Secondly, when studying climate variability and change, researchers are advised to take on board seasonal variability by month especially the six-month critical crop growing period that extends from November to April. Combining people's perceptions and measured climate variability and change is also critical in order to improve understanding of the phenomena.

6.2.2 Combining farmers' perceptions and meteorological data

Researchers should combine farmers' perceptions and meteorological data in order to improve an understanding of climate variability and change. In addition, smallholder farmers should also combine the two to improve their adaptive capacity against the phenomena. Researchers are also urged to take a broader picture of climate variability and change. This can help smallholder farmers and other stakeholders to deal with the phenomena comprehensively.

6.2.3 Addressing physical impacts of climate variability and change

The district authorities should minimize physical impacts of climate variability and change on the rain-fed farming system (RFFS). This can be done by introducing land use management system whereby the government should survey the village land and categorize it into agricultural land, grazing land and settlement land. This can help to reduce conflicts between conservation policies and use of land resources by the farmers and agro-pastoralists.

In addition, research institutions and district authorities should help farmers to access improved crop varieties because existing ones in sorghum and maize had failed to withstand excessive droughts. This should go hand in hand with other crops important for livelihoods including bulrush millet, sweet potatoes and sunflower. The same institutions should focus on how agro-pastoralists can minimize their herds to a manageable and productive size in addition to improving pasture management to address scarcity of water and lack of grazing areas. Dependence on rain-fed farming system (RFFS) was at a crossroads, and therefore a shift to irrigated farming system is imperative. Thus, the government and non-governmental organizations (NGOs) should intervene in constructing water reservoirs that can be good sources of water for irrigated farming system. In addition, farmers need to be enthusiastic in changing planting dates for different crops following changes in rainfall patterns and dry spells to avoid risks of crop failure.

6.2.4 Addressing gendered impacts of climate variability and change

Local governments in the study area, central government and NGOs should address impacts of climate variability and change in rain-fed farming system (RFFS) with a gender perspective. Interventions should also be different in different societies. This is because gender relations are context specific, such that they are not universal in different societies. These efforts should focus specifically on transforming cultural norms, values and beliefs, which subordinate and discriminate women with regard to gender division of labour and control over resources. Secondly, including the technology element to address gendered impacts of climate variability and change is essential because, as demonstrated in this study, technology is powerful in transforming unequal gender relations. This is because it has potential to challenge existing biased norms between men and women. Therefore, the uses of improved technology can reduce time spent on farming and so reducing workload for women that was on the increase.

6.3 Areas for Further Research

The study recommends the following areas for further research, which were not the focus of this study:

(i) Although this thesis has demonstrated that climate variability and change had negative impact on RFFS, there is a need to investigate farmer's economic risks associated with climate variability and change in the rain-fed farming system. This should also include examining existing indigenous knowledge to manage specific risks;

(ii) The results demonstrated that climate variability and change could be negatively affecting nutrition among women, children and the elderly, thus examining the relationships between changes in nutrition and climate variability and change is imperative;

(iii) The negative impact on nutrition among different social groups has implication on human health. Therefore, research on relationship between human health especially for women, children and elderly and climate variability and change is essential. Focus should also be on reproductive health and likelihood of succumbing to Human Immunodeficiency Virus (HIV) due to increased men's mobility;

(iv) This thesis has demonstrated increased men's mobility as a consequence of climate variability and change. Thus, it is important to examine relationship between marriage breakdown and climate variability and change; and

(v) In generating more data about gendered differentiated impact of climate variability and change, it is critical to investigate the impact between male and female headed households in agro-pastoralist households. The focus should be on impacts on household wellbeing.

APPENDECES

Appendix 1: A copy of questionnaire used for the research

A: Household identification

1: Respondent's name----------------------Division---------------------Ward--------------

Village name---------------------Date of interview---------------Interviewer's name------

2: Household Biodata and socio-economic information[18]

No.	Sex 1.male 2.Female	Age	Years of schooling	Highest education level reached 1.No formal education 2. Adult education 3. Completed primary education 4. Completed secondary education 5. University 6. Other (Specify)	Total number of household members	Relationship with HH head 1.Household head 2. Spouse 3. Son 4. Daughter 5. Other (specify)	Marital status 1. Married 2. Separated 3. Divorced 4. Widow/widower 5. Never married 6. Other (specify)	Occupation 1.Crop cultivator 2. Livestock keeper 3. Agro-pastoralist 4. Other (specify)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

3: Socio-economic status of the household[19]

1. Low [ ]
2. Middle [ ]
3. High [ ]

Mobility of the household

---

[18] The first row should include information of the respondent (head of household), whereas, the rest should include information of other household members reported by the respondent. Total number of household members should be filled once as reported by the respondent.

[19] A gendered analysis project operating in the study area has already conducted wealth ranking and categorized households into low, middle and high based on indicators of rich and poor established by the people during FGDs. These results will be used during sampling based on the three quintiles. I.e. Respondents will not be asked to respond on question 3, but rather information will be taken from the project data base.

4: Was the household head born in this village?

(a) Born in this village [ ]

(b) Not born in this village [ ]

5: If not, when did he/she migrate into this village? -------------------------------------

6: Why did he/she migrate into this village? --

7: Is/are there any absent household member (s) for a period of more than 6 months? **YES/NO**

8: If yes where are they? ---

9: Why is/are they absent?

(a) Seasonal labour migration (specify) [ ]

(b) For education purposes ..[ ]

(c) Started own household [ ]

(d) Looking for pastures ..[ ]

(e) Looking water for livestock [ ]

(f) Other (specify)---

Farm characteristics and land tenure

10. Do you own land for agriculture? **YES/NO**

11. If yes, how many acres or hectares do you own? --------------------------------------

12: Do you farm all the land you own? **YES/NO**

13: If no, what do you do with the land you own and do not farm? ----------------------

14: Do you also farm land that you do not own? **YES/NO**

15: If yes, under what arrangement? --

B: PERCEPTIONS OF CLIMATE VARIABILITY

16: Have you observed any change regarding rainfall in the past 10 to 30 years? **YES/NO**

17: Have you observed any change regarding surface temperature in the past 10 to 30 years? **YES/NO**

In Q18 to Q27, I am going to ask you about types of changes which have occurred in the past 10 to 30 years regarding rainfall and surface temperature. Indicate the direction of agreement or disagreement and its intensity for each of the following climate variability indicators.

Statement/indicator	Perception of the changes				
	Extremely Decreased [1 score]	Moderately Decreased [2 scores]	Neutral [3 scores]	Moderately Increased [4 scores]	Extremely Increased [5 scores]
18. Frequency of floods have changed in the past 10 to 30 years					
19. Rainfall unevenness has changed in the past 10 to 30 years					
20. Rainfall predictability has changed in the past 10 to 30 years					
21. Wind speed has changed in the past 10 to 30 years					
22. Day time temperature has changed in the past 10 to 30 years					
23. Night time temperature has changed in the past 10 to 30 years [					
24 Frequency of droughts has changed in the past 10 to 30 years					
25. Diseases in crops have changed in the past 10 to 30 years					
26. Diseases in livestock have changed in the past 10 to 30 years					
27. Insect crop pests have changed in the past 10 to 30 years					
Sub-Total Score					
Grand Total Score					

28. Is there any change in on-set of rainfall in the past 10 to 30 years? **NO/YES**

29. If yes, which changes have occurred?

(a) Rainfall now starts earlier [ ]

(b) Rainfall now starts late [...]

30. Is there any change in cessation of rainfall in the past 10 to 30 years? **NO/YES**

31. If yes, which changes have occurred?

(a) Rainfall now ends earlier [ ]

(b) Rainfall now ends late [...]

C: IMPACTS OF CLIMATE VARIABILITY ON RAIN-FED FARMING SYSTEMS

32. What food crops did you grow during 2011/2012 growing season? [Multiple response]

Crop type	Rank according to importance (1 less important to 5 most important)	Size of land cultivated in (Acres/hectares)
(i) Maize [NO/YES]		
(ii) Red Sorghum [NO/YES]		
(iii) White Sorghum [NO/YES]		
(iv) Paddy [NO/YES]		
(v) Sweet potatoes [NO/YES]		
(vi) Cassava [NO/YES]		
(vii) Bulrush Millet [NO/YES]		
(viii) Beans [NO/YES]		
(ix) Others (specify) [NO/YES]		

33. What cash crops did you grow during 2011/2012 growing season? [Multiple response]

Crop type	Rank according to importance (1 less important to 5 most important)	Size of land cultivated in (Acres/hectares)
(i) Cotton [NO/YES]		
(ii) Sunflower [NO/YES]		
(iii) Ground nuts [NO/YES]		
(iv) Green gram (*Choroko*) [NO/YES]		
(v) Simsim (*Ufuta*) [NO/YES]		
(vi) Pegion peas (*Mbaazi*) [NO/YES]		
(vii) Lentil (*Dengu*) [NO/YES]		
(viii) Others [specify]		

34. Is there any change on types of crops or crop varieties you are growing now compared to the situation in the past 10 to 30 years?

a. YES [ ]

b. NO [ ]

35. If yes, what factors have contributed to the changes in Qn 34? [Multiple response]

Variable	Response	
	Yes=1	No=0
Decrease in amount of rainfall		
Increase in amount of rainfall		
Increase in surface temperature		
Increase in frequency of drought		
Increase in frequency of floods		
Increased unpredictability of rainfall		
Late on set of rainfall		
Early cessation of rainfall		
Increased surface temperature		
Others (Specify)		

36. What other factors have contributed to the changes in Qn 34? [Multiple response]

Variable	Response	
	Yes=1	No=0
Extension services		
Rules and regulations (policy)		
Access to improved seeds		
Market access		
Increased household size		
Farm size		
Other (specify)		

37. In case of any change in Q34, which type of food crops have you gained interest and which ones have you lost interest in the past 10 to 30 years? [Specify varieties in each case]

Type of crops	Gained interest	Type of variety gained interest	Lost interest	Type of variety lost interest
(i) Maize	[NO/YES]		[NO/YES]	
(ii) Red Sorghum	[NO/YES]		[NO/YES]	
(iii) White Sorghum	[NO/YES]		[NO/YES]	
(iv) Paddy	[NO/YES]		[NO/YES]	
(v) Sweet potatoes	[NO/YES]		[NO/YES]	
(vi) Cassava	[NO/YES]		[NO/YES]	
(vii) Bulrush Millet	[NO/YES]		[NO/YES]	
(viii) Beans	[NO/YES]		[NO/YES]	
(ix) Others (specify)	[NO/YES]		[NO/YES]	

38. Which type of cash crops have you gained interest and which ones have you lost interest compared to the past? [Specify types of varieties in each case]

Type of crops	Gained interest	Type of variety gained interest	Lost interest	Type of variety lost interest
(i) Cotton	[NO/YES]		[NO/YES]	
(ii) Sun flower	[NO/YES]		[NO/YES]	
(iii) Ground nuts	[NO/YES]		[NO/YES]	
(iv) Green gram	[NO/YES]		[NO/YES]	
(v) Simsim	[NO/YES]		[NO/YES]	
(vi) Pegion peas	[NO/YES]		[NO/YES]	
(vii) Lentils	[NO/YES]		[NO/YES]	
(viii) Others (Specify)	[NO/YES]		[NO/YES]	
	[NO/YES]		[NO/YES]	

39. Do you own livestock? YES/NO

40. What type of livestock do you own?

Type of livestock	Number of livestock kept
Cattle	
Goat	
Sheep	
Donkey	
Pigs	
Other [specify]	

41. Do you keep livestock which are not yours? YES/NO

42. If yes, specify types of livestock, their number and relationship with the person who gave you the livestock---

43. Have your livestock size changed in the past 10 to 30 years?

(a) YES [ ]

(b) NO [ ]

44. If yes, what was the situation in the past 10 to 30 years in terms of types of livestock and number kept?

Type of livestock kept	Number of livestock
Cattle	
Goat	
Sheep	
Donkey	
Pigs	
Other [specify]	

45. What factors have contributed most to the changes in size of livestock? [Multiple response]

(a) Decrease in amount of rainfall [YES/NO]

(b) Increase in amount of rainfall [YES/NO]

(c) Increase in surface temperature [YES/NO]

(d) Increase in frequency of drought [YES/NO]

(e) Increase in frequency of floods [YES/NO]

(f) Increased unpredictability of rainfall [YES/NO]

(g) Late on set of rainfall [YES/NO]

(h) Early cessation of rainfall [YES/NO]

(i) Increased surface temperature [YES/NO]

(j) Others (Specify) ---

46. What other factors have contributed to changes in the size of livestock?

(a) Extension services [YES/NO]

(b) Rules and regulations (policy) [YES/NO]

(c) Livestock pests and diseases [YES/NO]

(d) Selling to buy food [YES/NO]

(e) Lack of grazing areas [YES/NO]

(f) Other (specify)

47. Where do you graze your livestock? [Multiple response]

Grazing area	During wet season	Distance to the grazing area [estimate]	During dry season	Distance to grazing area [estimate]
Open access grazing place in the village	[NO/YES]		[NO/YES]	
Open access grazing area in another village	[NO/YES]		[NO/YES]	
In my own land	[NO/YES]		[NO/YES]	
Village ngitiri	[NO/YES]		[NO/YES]	
Game reserve	[NO/YES]		[NO/YES]	
Community forest	[NO/YES]		[NO/YES]	
Individual ngitiri	[NO/YES]		[NO/YES]	
I do purchase grazing land from colleagues	[NO/YES]		[NO/YES]	
Given grazing land by colleagues	[NO/YES]		[NO/YES]	
Others [specify]	[NO/YES]		[NO/YES]	

48. Have you changed the grazing place for your livestock in the past 10 to 30 years?

(a) YES [ ]

(b) NO [ ]

49. If yes, what was the situation in the past 10 to 30 years? [Multiple response]

Grazing place	During wet season	Distance to the grazing area [estimate]	During dry season	Distance to grazing area [estimate]
Open access grazing area in the village	[NO/YES]		[NO/YES]	
Open access grazing area in another village	[NO/YES]		[NO/YES]	
In my own land	[NO/YES]		[NO/YES]	
Village ngitiri	[NO/YES]		[NO/YES]	
Game reserve	[NO/YES]		[NO/YES]	
Community forest	[NO/YES]		[NO/YES]	
Individual ngitiri	[NO/YES]		[NO/YES]	
I do purchase grazing land from colleagues	[NO/YES]		[NO/YES]	
Given grazing land by colleagues	[NO/YES]		[NO/YES]	
Others [specify]	[NO/YES]		[NO/YES]	

50. What factors have most contributed to change the grazing arrangement? [Multiple response]

Variable	Response	
	Yes=1	No=0
Decrease in amount of rainfall		
Increase in amount of rainfall		
Increase in surface temperature		
Increase in frequency of drought		
Increase in frequency of floods		
Increased unpredictability of rainfall		
Late on set of rainfall		
Early cessation of rainfall		
Increased surface temperature		
Others (Specify)		

51. What other factors have contributed to change grazing areas?

Variable	Response	
	Yes=1	No=0
Extension services		
Rules and regulations (policy)		
Livestock pests and diseases		
Lack of grazing places		
Agriculture expansion		
Other (specify)		

52. Where do you get water for your livestock? [Multiple response]

Water source	During wet season	Distance to the water source [estimate]	During dry season	Distance to the water source [estimate]
Open access water source e.g. River in the village	[NO/YES]		[NO/YES]	
Open access water source e.g. River in another village	[NO/YES]		[NO/YES]	
From my own pit/well	[NO/YES]		[NO/YES]	
Others [specify]	[NO/YES]		[NO/YES]	

53. Have you changed the place you get water for your livestock in the past 10 to 30 years?

(a) YES [ ]

(b) NO [ ]

54. If yes, what was the situation in the past 10 to 30 years? [Multiple response]

Water source	During wet season	Distance to the water source [estimate]	During dry season	Distance to the water source [estimate]
Open access water source e.g. River in the village	[NO/YES]		[NO/YES]	
Open access water source e.g. River in another village	[NO/YES]		[NO/YES]	
From my own pit/well	[NO/YES]		[NO/YES]	
Others [specify]	[NO/YES]		[NO/YES]	

55. What factors have most contributed to change areas where you get water for the livestock? [Multiple response]

(a) Decrease in amount of rainfall [YES/NO]

(b) Increase in amount of rainfall [YES/NO]

(c) Increase in surface temperature [YES/NO]

(d) Increase in frequency of drought [YES/NO]

(e) Increase in frequency of floods [YES/NO]

(f) Increased unpredictability of rainfall [YES/NO]

(g) Late on set of rainfall [YES/NO]

(h) Early cessation of rainfall [YES/NO]

(i) Increased surface temperature [YES/NO]

(j) Others (Specify) --

56. What other factors have contributed to change areas where you get water for the livestock?

(a) Extension services [YES/NO]

(b) Rules and regulations (policy) [YES/NO]

(c) Increase in number of livestock [YES/NO]

(d) Human population pressure [YES/NO]

(e) Other (specify) --

Thank you for your cooperation

Appendix 2: A copy of the checklist of items used for focus group discussion

1. Establish variability of rainfall patterns for the past 30 years in terms on-sets and cessations, sufficiency of rainfall to raise different food and cash crops from planting to harvesting. Also sufficiency of rainfall for pastures and water for livestock throughout a year
2. Identify bad and good years for the past 30 years and events associated with those bad and good years
3. Analyze climatic factors which can cause bad or good years. Identify what are the most perceived climatic factors that cause bad years. Compare these factors with non-climatic factors to establish the most threat to the cultivators and livestock keepers.
4. Assess changes of food and cash crops/varieties grown for the past 30 years and climatic factors associated to the changes. What other factors have exerted the changes? Who is most affected by the changes between men and women, boys and girls? How and why?
5. Explore changes in cropping calendar for three most important food and cash crops in the past 30 years and climatic and non-climatic factors associated to the changes. Who is most affected by the changes between men and women, boys and girls? How and why?
6. Explore changes in the activity profile in the past 30 years based on farm preparation, land tilling, planting, weeding, harvesting, processing and selling. Who has access to and control over land and livestock resources between men and women? Who is most affected by the changes between men and women, boys and girls? How and why?
7. Explore changes in type and number of livestock kept for the past 30 years

8. Explore changes in grazing areas and water sources for the livestock in the past 30 years and factors associated to the changes [climatic and non-climatic]

9. Who is responsible for doing the following farming activities?

Farming activity	Responsible person					
	Men only	Women only	Boys only	Girls only	Men and women	Boys and girls
Land preparation						
Preparation of seeds						
Planting						
Weeding						
Harvesting						
Processing and storage						
Selling cash/food crops						

10. How has the situation changed in the past 10 to 30 years?

11. Who has access to the following resources and how has the situation changed in the past 30 years? What caused the changes?

Resources	Access to resources [men, women, boys, girls, men and women, boys and girls]
Land	
Livestock	
Household income	

12. Who is responsible for grazing livestock and how has the situation changed in the past 30 years?

Thank you for your cooperation

Appendix 3: A copy of checklist of items used for key informant interviews

1. How do you organize crop production and livestock keeping in absence of your husband, who is away in search of pasture and water for the animals or in search of casual labour? (For women)

2. What changes have occurred in division of labour, access to and control over land resources, livestock and household income following increased climate variability and change in relation to absence of your husband? (For women)

3. What problems do you encounter while engaging in seasonal movements of animals? How do you overcome such problems? (For men)

4. What changes had occurred in division of labour, access to and control over land resources, livestock and household income following increased climate variability and change? (For men)

5. What addition roles have occurred and what roles had shifted to women or to men? (Men and women)

Thank you

Appendix 4: Percentage of respondents involved by gender

Respondent's sex	Kidaru (n=142)	Mwamanimba (n=101)	Mwashata (n=145)	Total (N=388)
Female	42	30	43	39
Male	58	70	57	61

Appendix 5: Some descriptive statistics on respondents' characteristics

Variable	Minimum	Maximum	Mean	Std. Deviation
Age	18	100	46	14.3
Years of schooling	0.0	14	5	3.3
Number of household members	1	15	7	5.3
Household farm size owned (Acres)	0.0	40	6	7.4
Number of cattle owned	0.0	1000	15	61.1
Number of goats owned	0.0	187	8	19.4
Number of sheep owned	0.0	80	3	7.7
Number of donkeys owned	0.0	8	0.2	0.9
Number of pigs owned	0.0	20	0.5	2.0
Number of chicken owned	0.0	60	7	9.2

Appendix 6: Descriptive statistics and reliability analysis

Variable	Mean[a]	Std.Dev	Item-total correlation	Cronbach's α if item deleted
Frequency of flood	2.2	0.9	0.2	0.7
Rainfall unevenness	3.5	1.4	0.2	0.7
Rainfall unpredictability	3.9	1.4	0.2	0.7
Strong wind	3.6	1.3	0.4	0.7
Day time temperature	4.1	1.0	0.5	0.7
Night time temperature	4.0	1.1	0.5	0.7
Frequency of droughts	4.4	1.0	0.4	0.7
Diseases in crops	3.8	1.2	0.5	0.7
Diseases in livestock	3.6	1.2	0.5	0.7
Insect crop pests	3.7	1.3	0.5	0.7

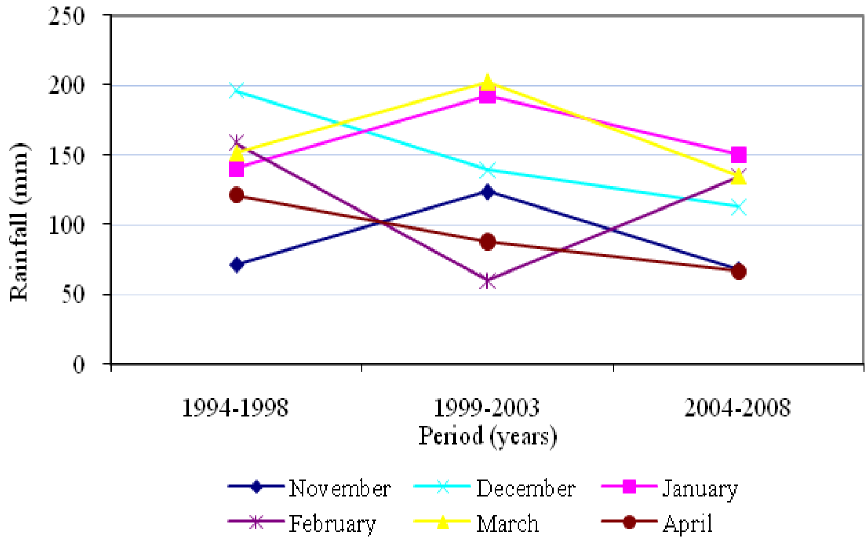
[a] Calculated from scores on a five-point scale whereby:1 = highly decreased; 2 = decreased moderately; 3 = no change; 4 = increased moderately and 5 = highly increased

Appendix 7: Rainfall and temperature seasonal anomaly (November-April)

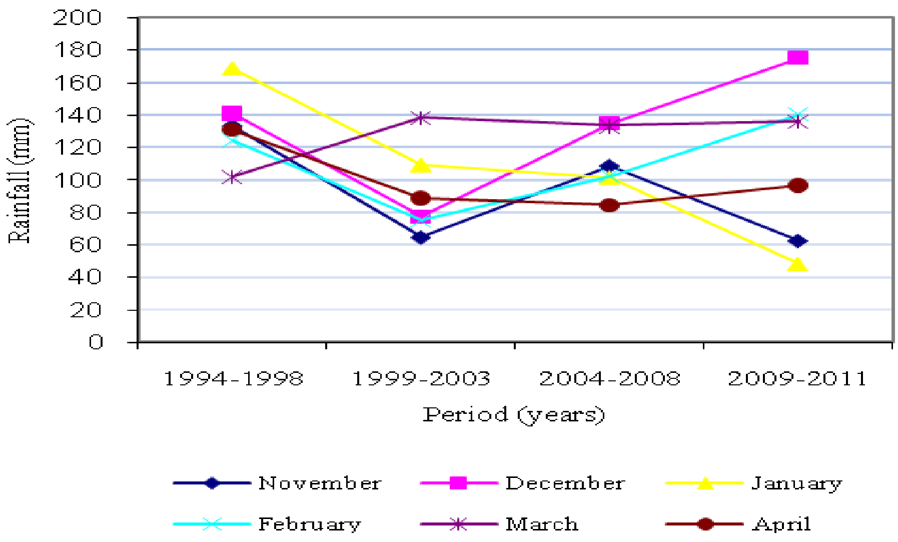
Year	Iramba		Meatu	
	Rainfall (mm)	Temperature (^{0}C)	Rainfall	Temperature (^{0}C)
1994	+233.0	NA	-134.7	0.3
1995	-207.4	NA	+75.2	-0.2
1996	-432.5	NA	-132.0	-0.1
1997	+429.6	NA	+598.6	0.3
1998	+281.7	NA	+241.2	-0.3
1999	+102.4	NA	-188.8	0.2
2000	-12.6	NA	-118.0	0.1
2001	+16.4	NA	+79.9	0.3
2002	+268.9	NA	-128.8	0.5
2003	-236.8	-0.48	-228.8	-0.6
2004	-33.7	0.29	-260.1	0.0
2005	-77.1	-0.25	-17.1	-0.8
2006	NA	0.18	+251.1	0.4
2007	-47.8	0.34	+18.9	-0.1
2008	-284.4	0.48	-20.5	0.4
2009	NA	0.08	+62.6	-0.1
2010	NA	-0.38	-45.8	-0.5
2011	NA	-0.29	-53.5	0.0

NA = Data not available

Appendix 8: Mean monthly rainfall variability in a six-month period in Iramba



Appendix 9: Mean monthly rainfall variability in a six-month period in Meatu



Appendix 10: Model fit for adopting improved varieties

A: Omnibus tests of model coefficients			
	X^2-square	Degree of freedom	p-value
Step	427.448	13	0.000
Block	427.448	13	0.000
Model	427.448	13	0.000
B: Model summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	92.973	0.668	0.904
C: Hosmer and Lemeshow test			
Step	X^2-square	Degree of freedom	p-value
1	4.476	8	0.812

Appendix 11: Model fit for changing grazing areas

A: Omnibus tests of model coefficients			
	X^2-square	Degree of freedom	p-value
Step	38.252	9	0.000
Block	38.252	9	0.000
Model	38.252	9	0.000
B: Model summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	66.650	0.384	0.522
C: Hosmer and Lemeshow test			
Step	X^2-square	Degree of freedom	p-value
1	14.710	8	0.065

Appendix 12: Definition of variables used in the binary logistic regression model

Variable	Definition	Level of measurement
Adopting new crops or crop varieties	Smallholder farmers using new emerging crops or crop varieties	Nominal Yes = 1, No = 0
Changes in grazing place	Moving away from the village of domicile in search for pasture	Nominal Yes = 1, No = 0
Insufficient rainfall	Amount of rainfall received not enough for the crops to attain maturity or for the livestock to have enough pasture and water	Nominal Yes = 1, No = 0
Increased warming	Day time temperature increase	Nominal Yes = 1, No = 0
Increased drought	Long period of no rain within a crop growing period than it is expected	Nominal Yes = 1, No = 0
Rainfall unpredictability	Inability to predict whether it can rain when it is expected to rain	Nominal Yes = 1, No = 0
Early cessation of rainfall	A month in which the rain starts	Nominal Yes = 1, No = 0
Extension services	Knowledge or information obtained by smallholder farmers from agriculture extension officers	Nominal Yes = 1, No = 0
Market access	Ability to purchase improved crop varieties or ability to engage in marketing process to sell the crop produce	Nominal Yes = 1, No = 0
Respondents' sex	Sex of the respondents	Male = 1, Female = 0
Food preference	Most preferred food in relation to type of a crop	Nominal Yes = 1, No = 0
Respondents' age	Age of the respondent	Ratio (Years)
Years of schooling	Number of years the respondent spent in the school	Ratio (Years)
Household size	Number of people living under one household head	Interval (Number of people)
Occupation	Being crop producer only or agro-pastoralist	Crop producer only = 1, agro-pastoralist = 0
Agriculture expansion	Expanding size of cultivated land	Nominal Yes = 1, No = 0
Government policy	Protective government policy to producing a certain crop or a crop variety	Nominal Yes = 1, No = 0
Gender relations	Social, cultural and power relations existing between men and women in society	Division of labour, division of power and social-cultural norms

Note: The variables measured at nominal level were farmers' perceptions

Appendix 13: Pair-wise ranking results on threatening climatic indicators

Variable	Kidaru village				Mwashata village				Mwamanimba village				Overall score	Overall rank based on overall scores
	Male		Female		Male		Female		Male		Female			
	Total score	Rank	Total score	Rank	Total score	Rank	Total score	Rank	Total score	Rank	Total score	Rank		
Insufficient rainfall	4	2	5	1	2	6	3	6	2	7	4	5	20	6
Unpredictable rainfall	4	2	4	2	7	2	6	4	5	4	5	4	31	2
Uneven rainfall distribution	2	5	2	5	4	3	2	7	4	5	3	6	17	7
Drought	3	2	3	4	9	1	7	2	3	6	6	3	37	1
Late onset	2	5	4	2	2	6	4	5	8	1	7	2	27	4
Earlier cessation	1	7	2	5	4	3	7	2	7	2	8	1	29	3
Strong wind	5	1	1	7	1	7	9	1	6	3	0	7	22	5

Appendix 14: Percentage responses on changes in onset of rainfall since the 1970s

Month/period	Onset of rainfall in the 1970s			Onset of rainfall in 2013		
	Kidaru (n=142)	Mwamanimba (n=101)	Mwashata (n=145)	Kidaru (n=142)	Mwamanimba (n=101)	Mwashata (n=145)
September	6	6	32	0	6	2
October	16	41	38	4	4	8
November	45	29	12	31	15	38
December	18	9	3	51	30	27
October/November	6	6	5	5	16	8
November/December	7	8	10	2	2	10
January	2	1	0	7	27	7

Appendix 15: Percentage responses on changes in cessation of rainfall since the 1970s

Month/period	Cessation of rainfall in the 1970s			Cessation of rainfall in 2013		
	Kidaru (n=142)	Mwamanimba (n=101)	Mwashata (n=145)	Kidaru (n=142)	Mwamanimba (n=101)	Mwashata (n=145)
March	0	0	0	18	39	32
April	16	14	7	56	53	55
May	51	57	65	16	3	5
June	25	9	17	7	1	3
March/April	2	1	1	1	4	5
April/May	4	6	4	1	0	0
May/June	2	13	6	1	0	0

Appendix 16: Wealth indicators at Mwashata village

Item/characteristic	Poor	Not so poor	Rich
• Land ownership	• Do not own	• Own 10+ acres	• Own 60+ acres
• Food storage	• Stores less than 20 bags of cereal (food)	• Stores up to 20 bags of cereal (food).	• Stores up to 50+ bags per year
• Livestock ownership	• 10 cows, 9 goats, 5 sheep and 20 hens.	• 10+ cows, 10-30 goats, 5-20 sheep, and 15 hens	• 50+ cows, 30+ goats and 20+ sheep
• Farm implements	• own 3 hand-hoe	own 5 hand-hoe and above	3 ox-plough, 1 ox-cart and 7 hand-hoe
• Hiring of labour	• Unable to hire labour	• Can hire but also sell their labour	• Can hire labour
• Use of tractors in land preparation	• Unable to hire	• Can hire	• Can hire
• Ability to afford medical costs	• Cannot afford /use traditional medicines.	• Can afford medical treatments	• Able to afford medical costs and can go to referral hospital
• Use of traditional methods of helping each other with farming	• Can invite a group of 10 people only to help cultivate their land	• Can invite a group of 30 people	• Can invite group of 30-100 people
• Other livelihood strategies	-	• Own milling machine	• Own milling machine/cow slaughter business
• Housing quality and number owned	• Live in poor quality house. 2 thatch houses	• Own three houses. Can be roofed with corrugated iron sheets	• Own five houses roofed with corrugated iron sheet
• Type of marriage	• Monogamous	• Could be both monogamous or polygamous (i.e., can marry more than one wife)	• Polygamous (Marries up to 3 wives)
• Mode of transport	• Bicycle	• Bicycle and Motorcycle	• Bicycle and Motorcycle
• Type and Number of meals taken	• Eat 2 meals per day (eat sweet potatoes, *ugali* and *mlenda*)	• Eat 2 meals per day (*ugali*, *mlenda* and *dagaa*)	• Eat ugali, mlenda and dagaa as their daily food. Eat 2 times per day
• Type of fuel used	• Use cotton sticks and maize residuals for energy.	Use firewood for energy	Use firewood for energy
Total number of households in Mwashata village = 462 Total number of rich HH=35 (7.6 %) Total number of not poor HH=225 (48.7%), Total number of poor HH= 202 (43.7 %)			

Source: Nombo *et al*. (2013)

Appendix 17: Wealth indicators at Mwamanimba village

Item/characteristic	Poor	Not so poor	Rich
• Land ownership	✓1-15 acres	✓less than 100 acres	✓100 and above acres
• Food storage	✓Enough food for 3 months only	✓Have enough food for half of a year	✓Enough food for the whole year
• Livestock ownership	✓Ranging from 0-5	✓Ranging from 17-60	✓Ranges from 60 and above
• Farm implements	• own only 2 hand-hoe, do not own ox-cart	✓1 ox-plough and 2-4 hand-hoe	✓3-4 ox- plough, 10-24 hand-hoe
• Hiring of labour	✓Use labour power of < 2 people. No ability to hire labour power	✓Has labour power of five people. Ability to hire only few people	✓Labour power is high up to 10 people. Ability to hire many people
• Use of tractors in land preparation	• Unable to hire	• Unable to hire	• Can hire
• Ability to afford medical costs	✓Cannot afford medical costs	✓Sometimes can afford medical costs	• Affords medical costs
• Use of traditional methods of helping each other with farming	• Can invite small number of people for help during farming because of low quality of food as compared to rich and medium quintile. A group of 5-10 people can only be invited	• Ability to invite community members for help during farming 15-20 people	• Can invite a big number of group working up to 100 people
• Housing quality and number owned	✓Has 1-2 houses	✓Living in 2-5 small houses	• Has more than 5 houses
• Mode of transport	• Own only one bicycle	• Use 1-2 bicycle, 1 motorcycle and 1 ox-cart for transport	• Own more than 2 bicycles, 1 or more motorcycle and 1 or more ox-cart for transport
• Type and Number of meals taken	✓Eat 2 meals per day, Can get some milk	✓Eat 3 meals per day, Can get some milk	✓Eat 3 times per day throughout a year, has enough milk
✓Total number of HH in Mwamanimba = 315 Total number of rich HH= 55 (17.46%) Total not so poor HH = 72 (22.8 %), Total number of poor HH = 188 (59.68 %)			

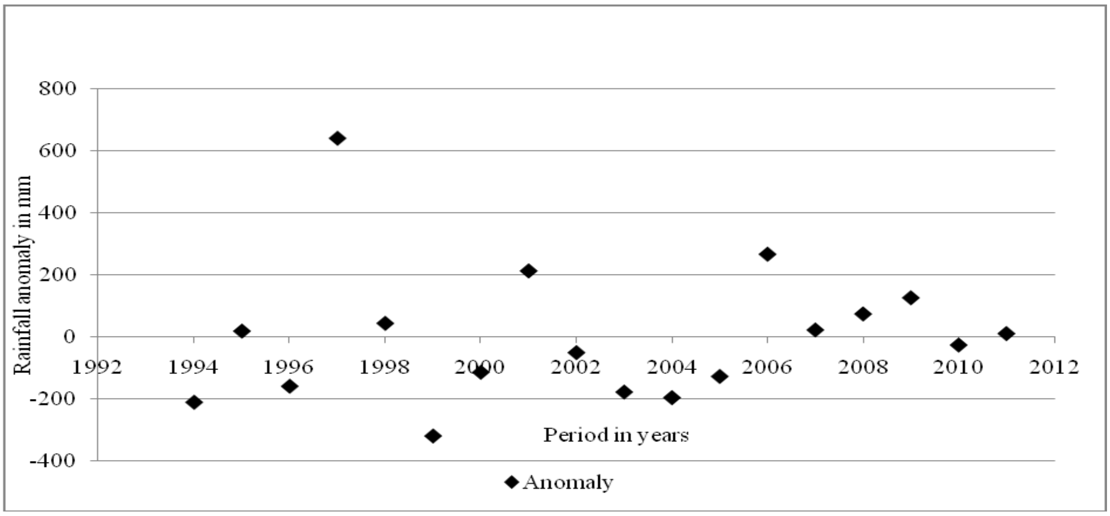
Source: Nombo *et al*. (2013)

Appendix 18: Wealth indicators at Kidaru village

Poor	Not so poor	Rich
Food self-sufficient for less than six months a year	Food self-sufficient for half a year	Produce large surplus from crop production, most of which is marketed
Meet food needs in deficit	Casual work when there is food shortage/problems	Own a number of farming plots (3-7)
No land	Own chicken (5-10) but not goat and cattle	Buys plots from poor farmers
Don't own farming tools eg hand hoe	May plough with hired oxen	Plough with oxen
No animals even chicken	Mainly use family labour	Use hired labou
Hire out family labour on regular basis to work on holdings owned by less poor families	Own a range of hand tools	Own several ploughs, ox carts
Only eat one meal	Children attend school at least through primary school	Own goats, chicken, pigs and cattle
No house "zig zag	Participate in small-scale enterprises to meet cash needs	Use credit
Sell small assets they have children attend lower primary school but have no uniform and some children do not go to school	Have mud house with thatched roof	Have diverse sources of household income (farm and off-farm)
Depend on handouts, and begging	Own a bicycle	Dress well
Have little or no contact with services in community e.g. extension, health	Uses fire wood for cooking energy	Eat two meals a day (fermented milk with stiff porridge)
	Better clothes mainly second hand ones	Send all children to school up secondary level
	Have regular contact with extension service and community health worker	Have an expensive house: iron sheet roof, bricks, concrete floors, bedding, furniture
		Own a solar panels for lightening
		Use fire wood or charcoal for cooking
		Own means of transport (motorcycle, car)
		Can afford to pay for medical treatment
		Contact extension service when seeking information
Total number of HH in Kidaru = 444, proportion of the poor = 48.4%, Proportion of the not so poor = 36.6% and Proportion of the rich = 15%		

Source: Nombo *et al*. (2013)

Appendix 19: Scatter plot for rainfall anomaly in Meatu [1994-2011]



Appendix 20: Scatter plot for rainfall anomaly in Iramba [1994-2008]