UNIVERSITY OF NAIROBI

THE ROLE OF INFORMAL MICROFINANCE INSTITUTIONS IN RESILIENCE OF RURAL LIVELIHOODS TO CLIMATE VARIABILITY; A CASE STUDY OF THARAKA SUB COUNTY, KENYA

BY

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DECLARATION

‘‘I declare that this thesis is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people’s work or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi’s requirement’s’’

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DEDICATION

I dedicate this thesis to my wife Teresia Muthoni Gitonga and children Alex Munene, Francis Maina, and Prettyjoy Kaari, and my parents Alecksus Mburia Kauah and Nancy Kaari Kauah for their motivation and unstinting support.

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ABSTRACT

Successful response to climate variability builds on the proper understanding of the local climatic context and existing strategies such as informal microfinance because the impacts are context specific. However, limited studies have analyzed the contribution of informal microfinance institutions to rural livelihoods climate variability resilience. Also, limited studies have analyzed the factors underlying the contribution of informal microfinance institutions to rural livelihoods climate variability resilience. This gap thus necessitated the research. The specific objectives of the study included to analyze climate variability and trends in Tharaka South Subcounty and assess the structures of informal microfinance institutions in relation to performance. Also, to analyze the effects of climate variability on informal microfinance institutions and analyze the contribution of informal microfinance institutions to rural livelihoods resilience to climate variability. The study used descriptive study design and mixed methods. The multistage sampling design was used to sample 385 respondents for the study. Qualitative data analysis was done using thematic analysis while quantitative data analysis employed descriptive statistics, tabulations, categorical statistics, and Kendall's tau-b correlation. Climate variability was analyzed using descriptive statistics, coefficient of variation, precipitation concentration index, standardized anomaly, and descriptive statistics. Further, climate trends were analyzed using Mann-Kendall (Z) statistical test and the Sens slope estimator test. The analysis revealed that rainfall in the study area is highly variable with the median intra-annual variability being (127%) and inter-annual variability being (24%). The rainfall has a decreasing trend that is not significant ($Z = -0.93$, $P>0.1$). Temperature is also marked by variability and an increasing trend. Climate variability affects rural livelihoods through effect on household's access to capital assets. Informal microfinance institutions were found to enhance households access to capital assets as shown by their positive and significant contribution to access to healthcare ($\tau b = 0.372^{**}$, $P<0.01$), education ($\tau b = 0.448^{**}$, $P<0.01$), inputs of crop production ($\tau b = 0.447^{**}$, $P<0.01$), and inputs of livestock production ($\tau b = 0.473^{**}$, $P<0.01$). Moreover, there was a positive and significant relationship between rural household's climate variability resilience and contribution of informal microfinance institutions to the resilience ($\tau b = 0.91^{**}$, $P<0.01$). However, climate variability affects the performance of informal microfinance institutions. This is shown by the significant negative relationship between vulnerability to climate variability and informal microfinance performance ($\tau_b = -0.109^{**}$, $P<0.01$). The vulnerability of informal microfinance institutions to climate variability is a function of their characteristics and this could be leveraged to inform interventions to cushion them against climate risks. Informal microfinance institutions membership is mainly comprised of the women who constituted 79% of the members. Informal microfinance institutions thus play an important role in promoting gender equity and women empowerment which is key to rural livelihoods resilience to climate variability. Also, since women have been documented to be most vulnerable to climate variability effects, vulnerability to climate variability is thus directly associated with participation in informal microfinance institutions as shown by the significant positive relationship between climate variability and the number of people joining informal microfinance institutions ($\tau_b = 0.239^{**}$, $P<0.01$) per year from 1981 to 2018. The study also found that the structures of informal microfinance institutions determine their performance, and contribution to rural households to climate variability resilience. The characteristics of informal microfinance institutions could thus be leveraged to enhance their performance and contribution to rural livelihoods resilience to climate variability. Informal microfinance institutions are therefore a key strategy for building livelihoods resilience to climate variability in rural areas.

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LIST OF ABBREVIATIONS AND ACRONYMS

°C	Degrees Centigrade
ASAL's	Arid and Semi-arid Lands
CGAP	Consultative Group to Assist the Poor
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CHIRTS	Climate Hazards Group InfraRed Temperature with Station data
CV	Coefficient of Variation
DFID	Department for International Development
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
GGLN	Good Governance Learning Network
GIS	Geographical Information System
IFAD	International Fund for Agricultural Development
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
IUCN	International Union for Conservation of Nature
JF	January February season
JJAS	June July August September season
KM	Kilometer
KM^2	Kilometer's squared
KNMI	Royal Dutch Meteorological Institute
KShs	Kenya Shillings
MAM	March April May season

MJO	Madden-Julian Oscillation
mm	Millimeter
NDVI	Normalized Difference Vegetation Index
OND	October November December season
PCI	Precipitation Concentration Index
SPSS	Statistical Package for Social Sciences
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNHCR	United Nations High Commission for Refugees
USD	United States Dollar
WFP	World Food Program
WHO	World Health Organization

CHAPTER ONE: INTRODUCTION

1.1 Background

Climate variability is the temporal and spatial variation in climate variables including rainfall and temperature above or below the long-term average and other statistics (United Nations, 1992; IPCC, 2007). Based on scientific evidence, climatic patterns are becoming more variable especially in Sub Saharan Africa with significant impacts on rural livelihoods (IPCC, 2007). According to the Government of Kenya (2012a), the projected climatic conditions in Kenya include dry spells that are more frequent and longer and interposed with extreme erratic rainfall episodes. The effect of climate variability in Kenya is thus increasingly blamed for the deterioration of livelihoods in rural areas (Muitimba *et al.*, 2010).

Analyzing the spatial-temporal dynamics of climatic factors is thus imperative to enable understanding of the impacts, guide vulnerability analysis, and thus inform response strategies (Ayugi *et al.*, 2016, Wani *et al.*, 2017, Asfaw *et al.*, 2018; Mohammed *et al.*, 2020). However, limited studies have analyzed long-term trends and variability of climatic variables in East Africa from local to regional levels (Xu *et al.*, 2017). Moreover, most climate studies make use of global, regional, and national level data rather than focus on specific local contexts hence the risk of veiling local level vulnerability (Deressa *et al.*, 2011, Antwi-Agyei *et al.*, 2014). This leads to a poor understanding of climate variability despite its impacts on the environment and the social economy especially in rural areas where climate data is mainly scarce (Xu *et al.*, 2017). There is thus a lacuna in knowledge on climatic variability and trends, especially in specific local contexts.

Local people in Sub-Saharan Africa have however developed strategies for coping and adapting to climate variability through their indigenous knowledge systems (Nyong *et al.*, 2007). Response strategies to climate variability should build on such existing strategies since they reflect the local socioeconomic and environmental context (Mertz *et al.*, 2009; Ziervogel *et al.*, 2006; Tschakert, 2007; Daw *et al.*, 2009). Such strategies include informal microfinance institutions which date back to ancient societies and the pre-colonial period (Aryeetey and Gockel, 1991; Mairura and Okatch, 2015).

Informal microfinance entails providing financial services including savings and lending mostly to poor and low-income people who hardly access formal financial services (Hammil *et al.*, 2008; Thrikawala *et al.*, 2013). They provide more affordable, flexible, and easily accessible financial services enabling the poor to deal with their marginalization by the formal financial sector (Hammil *et al.*, 2008; Tilakaratna, 1996; Allen and Panetta, 2010). However, informal microfinance institutions in Africa are not well defined nor understood that hinders their advancement despite the significant contributions to rural livelihoods (Njeri *et al.*, 2013). Therefore, studies analyzing the structures and performance of informal microfinance institutions and the existing relationships are scanty.

Moreover, climate variability affects the activities of financial institutions just like other economic sectors (Rippey, 2012) with the highest vulnerability being observed in low-income countries (Campiglio *et al.*, 2018). Breeden (2019) noted that the climate risks faced by financial institutions are physical risks and transition risks. Nevertheless, limited studies have analyzed how climate variability affects microfinance institutions (Fenton *et al.*, 2017; Moser and Gonzalez, 2015). Therefore, the risks and opportunities posed by climate variability on microfinance institutions are vaguely understood and there is little incorporation of the existing knowledge into their decision-making processes (Fenton *et al.*, 2017; UNEP, 2002; Finley and Schuchard, n.d.; Breitenstein *et al.*, 2019).

Furthermore, few studies have analyzed the nexus between climate variability effects and vulnerability and informal microfinance institutions. There is thus a lack of adequate knowledge on climate-related risks and opportunities to inform effective response actions in the case of informal microfinance institutions. Besides, limited studies have analyzed how the characteristics of informal microfinance institutions affect their vulnerability to climate variability. There is thus a lack of adequate knowledge on how the structures of informal microfinance institutions could be leveraged to cushion the groups and their members from the negative effects of climate variability.

Microfinance services including microcredit, micro insurance, or micro-savings are imperative tools for addressing the vulnerability of poor people to climate risks since they facilitate their accumulation, diversification, and management of assets (Technoserve, 2014; Komba and Muchopondwa, 2018). This increases the capacity of low-income people to self-insure against future risks and smooth their consumption patterns in the backdrop of income fluctuations during shocks and stresses (Bhattamishra and Barret, 2010; Catholic Relief Services, 2012;

Hohenkammer, 2005). Scheyvens (2015) noted that microfinance institutions help in filling a household's adaptation deficit which is caused by a lack of adequate capital. However, despite their great potential, the contribution of microfinance institutions in building climate variability resilience has been overlooked (Moser and Gonzalez, 2015).

This is especially the case for informal microfinance institutions which have not been considered as a factor in past studies that analyzed factors influencing resilience to climate variability. Therefore, there is a lacuna in detailed analysis on the contribution of informal microfinance institutions to rural livelihoods climate variability resilience especially based on access to capital assets. Besides, few studies have analyzed the factors that determine the contribution of informal microfinance institutions in building rural household's resilience to climate variability.

1.2 Problem Statement

The climatic patterns in Sub-Saharan Africa are becoming more variable with significant impacts on rural households (IPCC, 2007). The effects of climate variability on agricultural production are increasingly blamed for the deterioration of livelihoods in rural areas (Muitimba et al, 2010). However, studies of variability and trends of climate variables, especially in East Africa, are limited (Xu *et al.,* 2017). Existing studies mostly make use of coarse data which leads to poor understanding of climate variability and vulnerability especially in rural areas (Deressa *et al.,* 2011, Antwi-Agyei *et al.,* 2014; Xu *et al.,* 2017). There is thus a lacuna in knowledge on climatic variability and trends, especially in specific local contexts.

Although people in Sub-Saharan Africa have developed and implemented response strategies such as informal microfinance institutions through their indigenous knowledge systems (Aryeetey and Gockel, 1991; Nyong et al, 2007; Mairura and Okatch, 2015). Such strategies have largely been overlooked, including in policies, strategies, and programs for response to climate variability. Informal microfinance institutions in Sub-Saharan have thus not been properly analyzed to enable proper understanding of their structures and performance, and which is key to their development.

Moreover, informal microfinance institutions have hardly been considered as a strategy for building resilience to climate variability, especially based on their critical role in enabling rural communities to access capital assets. Previous studies on the contribution of informal microfinance institutions towards resilience of rural livelihoods to climate variability are scanty.

Besides, past studies past mainly focused on the formal microfinance institutions. There is, therefore, a lacuna in detailed analysis on the contribution of informal microfinance institutions to rural livelihoods climate variability resilience. Also, few studies have analyzed the factors that determine the performance of informal microfinance institutions and their contribution in building rural household's resilience to climate variability.

Furthermore, microfinance institutions are also affected by climate variability (Rippey, 2012) and this is exacerbated by the high vulnerability of their clients, especially in low-income countries (Gutierrez and Mommens, 2011; Fenton *et al.*, 2017; Campiglio *et al.*, 2018). However, few studies have analyzed the effects of climate variability on informal microfinance institutions. There is thus lack of adequate knowledge on climate-related risks and opportunities to inform strategies that could held them to deal with the impacts. Also, limited studies have analyzed the characteristics of informal microfinance institutions in relation to their vulnerability to climate variability. There is thus lack of adequate knowledge on how the structures of informal microfinance institutions could be leveraged to cushion them and their members from the negative effects of climate variability.

1.3 Objectives

1.3.1 General Objective

The overall objective of the study was to analyze the role of informal microfinance institutions in building the resilience of rural livelihoods to climate variability in Tharaka South Subcounty.

1.3.2 Specific Objectives

i. To analyze climate variability and trends in Tharaka South Subcounty.
ii. To assess the structures of informal microfinance institutions and their effect on informal microfinance performance.
iii. To analyze the effects of climate variability on informal microfinance institutions.
iv. To analyze the contribution of informal microfinance institutions to rural livelihoods resilience to climate variability.

1.4 Research questions

i. How is the climate variability, and trends in Tharaka South Subcounty?

ii. How are the structures of informal microfinance institutions and how do they affect informal microfinance performance?
iii. What are the effects of climate variability on informal microfinance institutions?
iv. How do informal microfinance institutions contribute rural livelihoods resilience to climate variability?

1.5 Justification and significance

The detailed analysis of climate variability and trends using high resolution gridded climate data will enable context specific understanding of the dynamics of climate variables in the study area. This will inform proper planning and implementation of strategies, policies, and programs for building resilience to climate variability.

Secondly, detailed and context specific analysis of informal microfinance institutions structures in relation to their performance will inform strategies, policies, and programs aimed at improving their performance. This will enhance their contribution to rural people's livelihoods including their resilience to climate variability. It will also help leverage on informal microfinance institutions to develop effective climate variability resilience building strategies, policies, and programs and that reflect the local socioeconomic and environmental contexts.

Understanding the effect of the characteristics of informal microfinance institutions on their performance and the contribution of informal microfinance institutions to rural livelihoods climate variability resilience is also imperative. This is because it will inform and improve the effectiveness of strategies, policies, and programs aimed at enhancing their performance. It will also inform and improve the effectiveness of strategies, policies, and programs aimed at building the resilience of rural livelihoods through inform microfinance institutions.

In addition, the study will build knowledge on the effects of climate variability on informal microfinance institutions. This will improve understanding of the existing climate-related risks and opportunities and inform development of effective strategies to cushion them against the effects of climate variability. Further understanding how the characteristics of informal microfinance institutions affect their vulnerability to climate variability is imperative in informing strategies aimed at enhancing their ability to mitigate, cope and adapt to the effects.

1.6 Delimitation of the study

The study was limited to Tharaka South Subcounty in Kenya. The study looked at the relationships between the informal microfinance institutions and resilience to climate variability at the point in time. However, the analysis of climate variability and trends covered a period of 38 years for temperature and rainfall, and focused on the monthly, seasonal, and annual scales. The measurements of resilience to climate variability focused on four indicators including access to healthcare, access to education, inputs of crop production, and inputs of livestock production. Analysis of informal microfinance performance focused on savings, loan access, and loan repayment performance. The units of analysis for the study included the informal microfinance institutions and their member's households.

CHAPTER TWO: LITERATURE REVIEW

2.1 Climate variability

Climate variability refers to the variation of climate variables from the long-term average and other statistics in space and time (United Nations, 1992; IPCC, 2007). Ghil (2001) noted that climate variability occurs on all time scales, including monthly, yearly, decanally, centennially, or even millennially and over a given spatial scale from local to regional to global. According to IPCC (2001), climate variability is fluctuation of the magnitude and frequency of climate elements and the happening of extreme weather events, including floods and droughts.

Smit *et al.* (2000) observed that climate variability is essentially part of climate change which causes changes in short-term climate patterns. There is a growing scientific unanimity that climate change will cause more uncertain and erratic weather patterns (Ojwang *et al.*, 2010). Ziervogel and Calder (2003) noted that climate variability manifests as shocks and stresses whereby discrete climate events, for example, floods and droughts can be classed as shocks while more gradual climatic changes over a period above or below the norm can be classed as stresses.

Climate variability is caused by both internal factors within the climate system, internal variability, and external factors outside the climate system, external variability (Ramamasy and Baas, 2007). Internal climate variability results from natural processes within the climate system that result in the transfer of energy from one part of the climate system to another such as the El Nino Southern Oscillation and the North Atlantic Oscillation (Ashford and Wentworth, 2012). External climate variability is caused by external natural processes that change the total amount of energy in the climate system including changes in solar output and volcanic eruptions (Ashford and Wentworth, 2012). External climate variability is also strongly attributed to human activities that emit greenhouse gases hence causing global warming (IPCC, 2014; Innocent *et al.*, 2015).

Parry *et al.* (2012) deduced that Kenya has an intricate climate system that substantially varies regionally, and temporally at seasonal, annual, and decadal scales. Kenya's climate pattern is largely influenced by its location relative to the Indian Ocean and Lake Victoria, diverse topography, the Inter-Tropical Convergence Zone, and the *El Niño* Southern Oscillation (Ojwang *et al.*, 2010). Studies by Marchant *et al.* (2007) and Behera *et al.* (2005) found that climatic patterns in East Africa are also influenced by the Indian Ocean Dipole. Ojwang *et al.* (2010) found that rainfall is the prime climatic factor in Kenya and has a high degree of spatiotemporal variability although the temperature is also a significant factor particularly in the highlands, ASALs, and near large water bodies. Therefore, the ecological and socio-economic impacts of climate variability are mainly due to rainfall variability (Few *et al.*, 2007).

Bryan *et al.* (2013) in a study on adaptation of agriculture in Kenya's households and communities observed that climate variability has been exhibiting a generally positive trend. According to the Government of Kenya (2012a), the projected climatic conditions in Kenya include dry spells that are more frequent and longer and interposed with extreme erratic rainfall episodes. Climate variability in Kenya is thus projected to manifest through more frequent and intense droughts, water scarcity, and desertification (Ojwang *et al.*, 2010).

Recha *et al.* (2012) observed that droughts have become more intense and frequent, and almost an annual occurrence. A study in Yatta District, Kenya (Mburu *et al.*, 2014) found an increasing trend in climate variability as indicated by a steady rise in the coefficient of variation of annual rainfall reported between years 1994 to 2010. Moreover, Boru and Kaske (2014) in a study of climate variability among agro-pastoralists in Gadamoji Division of Marsabit County observed that local people have noticed variability in local climatic patterns including changes in the spacing between rainfall seasons, shortening of the rain periods, change in rainfall onsets and cessation, periods and cycles of failures and an overall increase in local temperature.

2.2 Impacts of climate variability

Changes in the global climate system have adversely impacted ecological and socioeconomic systems (IPCC, 2014). A study on climate, food security, and hunger by WFP *et al.* (2009) found that vulnerability to climate variability in developing countries is mainly due to heavy dependence on climate-sensitive economic activities and the natural resource base, and limited coping and adaptive capacity. Kandji (2006) in an analysis of drought in Kenya noted that vulnerability to climate variability is majorly caused by heavy dependence on rainfed agriculture. Higher vulnerability to climate variability is mainly witnessed among the poor people and marginalized groups due to low access to capital assets, inadequate safety nets, and occupation of hazardous and fragile areas (Haworth *et al.*, 2016; Wilkinson and Peters, 2015). This is especially among poor people in rural areas of arid and semi-arid lands (IFAD, n.d.; Omoyo *et* *al.*, 2015). A study on the reduction of vulnerability of pastoralist communities to impacts of climate variability in Northern Kenya (Okoti *et al.*, 2014) found that climate variability is the main cause of the deterioration in livelihoods observed in rural ASAL areas.

Herrero *et al.* (2010) observed that climate variability in Kenya will hinder an increase in agricultural productivity despite predictions that climate change will cause a general increase in rainfall in East Africa. Besides, Omoyo *et al.* (2015) revealed that maize yield in semi-arid Lower Eastern Kenya varied greatly in response to change in climate parameters implying climate variability impacts crop production. Lema and Majule (2009) found that climate-related factors including rainfall unpredictability and increase in pests and diseases in Tanzania's semi-arid areas are key determinants of crop production. Furthermore, Barasa *et al.* (2015) in a study on the impacts of climate variability on agricultural production in Kakamega County found that 90% of the respondents had observed a reduction in soil fertility.

Recha *et al.* (2012) found that an increase in the length of dry seasons leads to a shortage in the amount of forage, nutritional stress, acute water scarcity, and heat stress on livestock resulting in low food intake hence poor growth, low production, greater susceptibility to diseases and high mortality rates. Similarly, Lyimo and Kangalawe (2011) found that livestock production is adversely impacted by climate variability in Tanzania's semi-arid areas due to declining pasture conditions and drying of water sources which diminishes animal numbers faster than the rate at which they can be replaced hence negatively affecting pastoral livelihoods. Further, Galvin *et al.* (2004) observed that climate variability affects livestock production through a reduction in fodder availability hence negatively affecting the livelihoods of pastoralists in ASALs. Barasa *et al.* (2015) found that 78% of the respondents had observed a reduction in the size, diversity, and genetic quality of livestock due to climate variability.

According to Tunde (2011), climate variability affects the four dimensions of food security including availability, access, utilization, and stability of the food system. Muitimba *et al.* (2010) revealed that famine cycles in Kenya have reduced from every twenty years (1964-1984) to twelve years (1984-1996) to two years (2004-2006), to an annual basis (2007/2008/2009/2010/2011/2012). Galvin *et al.* (2004) observed that climate variability in Kenya will lead to a decline in per capita calorie availability translating into increased malnutrition especially among young children in ASAL areas. Furthermore, Recha *et al.* (2012)

observed that more frequent and intense droughts in semi-arid Eastern Kenya rendered about 2 million people to be permanently dependent on relief food with over 15% of children aged below five years experiencing acute malnutrition. Olusola (2014) in a study of agricultural households in Nigeria found out that impacts of climate variability on livestock and crop production affect their nutritional security. Besides, Agbo *et al.* (2015) gathered that adverse effects of climate variability could lead to a significant rise in food prices due to scarcity thus exacerbating food insecurity.

Climate variability leads to erosion of financial assets, loss of incomes and job opportunities (Johnson *et al.,* 2009) increased cost of living (Gabrielsson *et al.,* 2013), and lack of money to invest in access to education, healthcare, and inputs of agricultural production (Thomas *et al*., 2007). Ziervogel and Calder (2003) deduced that climate variability enhances poverty among rural households in Lesotho through negative effects on the quality and quantity of available capital assets. Ibrahim and Alex (2005) in a study of the impacts of changing environmental conditions in Southern Malawi gathered that persistent and enhanced floods and droughts could aggravate poverty levels thus trapping rural families in a perpetual state of poverty and vulnerability.

United Nations (2009) noted that climate variability and change in the Least Developed Countries will further constrain development and the attainment of development goals. According to DFID (2004), more intense and frequent extreme climate events will reinforce the observed substantial impediment of Africa's development by climate variability. Amare and Waibel (2015) in a study of rural households in Northeast Thailand deduced that climate variability could put various economic sectors at risk and undermine poverty reduction efforts. Furthermore, Shiferaw *et al.* (2014) concluded that the adverse effects of climate variability threaten to diminish the economic and development gains that Sub-Saharan Africa has achieved in the last few decades. Climate variability has an influence on Kenya's general economic performance (Herrero *et al*., 2010) as witnessed in the aftermath of the drought of 2008 to 2011 which led to the country only achieving an annual economic growth rate of 4% against the anticipated 6% and hence an average gap of 3% per annum in economic growth (Government of Kenya, 2012b).

Moreover, climate variability affects the activities of financial institutions (Rippey, 2012) with a higher vulnerability being observed in low-income countries (Campiglio *et al.*, 2018). An impact report by Boston Common (2015) noted that financial institutions have a unique vulnerability to climate risks since they are connected to all market segments through their lending activities. Breeden (2019) noted that physical and transition risks constitute the climatic risks that confront financial institutions. Physical risks are the direct impacts of climate events on resource availability, property, infrastructure, and operations while transition risks are loss of assets value due to change in climate policy, technology, and consumer sentiments in the process of adjustment to a low carbon economy (Drill *et al.*, 2016; Breitenstein *et al.*, 2019; Campiglio *et al.*, 2018; Dafermos *et al.*, 2018; Meel and Blijlevens, 2019).

A study of the effects of climate variability on education in rural Ethiopia (Randell and Gray, 2016) gathered that future climate risks could impede access to education among children and hinder the achievement of development goals in rural Sub-Saharan Africa. Akuegwu *et al.* (2012) found a significant correlation between climate change impacts and academic staff performance in Universities of Cross River State, Nigeria.

Iwasaki *et al.* (2009) in a study of climate change adaptation of fishery livelihoods in Chilika Lagoon in India observed that climate variability increases the exposure of communities to health hazards and jeopardizes their ability to address and recover from health problems. Also, Badjeck *et al.* (2010) in a study of coastal fishing communities in Peru found that a decrease in the accessibility and the capacity to buy food due to climatic disturbances exacerbates the incidence of health problems in communities. WHO (2003) noted that disease incidences in Kenya are influenced by the occurrence of extreme weather events. This is confirmed by Kovats *et al.* (2002) who observed that the Elnino cycle has a positive relationship with the prevalence of malaria in Africa, Asia, and South America. Adverse climate variability impacts on health in Kenya are heightened by the country’s low capacity to respond which is partly caused by the inadequate allocation of resources to the health sector (Government of Kenya, 2008).

Climate variability negatively affects communities by destroying infrastructure upon which their livelihoods depend (IUCN *et al.*, 2004). Hardoy *et al.* (2011) in a study of local disaster reduction in urban areas in Latin America found that extreme events of climate variability have a negative impact on physical capital including the destruction of houses, drainage systems, and water and sanitation facilities. Besides, climate variability through extreme climate events causes damage to health infrastructure and roads (Hewitt and Mehta, 2012). Infrastructural damage due to extreme climate events such as flooding can affect trade by diminishing access to local markets thus reducing the availability of food products and causing an increase in commodity prices (Badjeck *et al*., 2010; Tunde, 2011).

Climate variability erodes social capital and disrupts social networks among the poor impending resource mobilization, and mutual assistance and reciprocity mechanisms (Osbahr *et al.*, 2008; Buechler, 2009). Besides, a study of human mobility in the nexus of climate change (UNHCR *et al.*, n.d.) found that climate variability could enhance the displacement of populations in rural areas by driving human mobility through negative impacts on livelihoods. Meltzoff *et al.* (2005) found that climate variability affects the capacity of local institutions in resources governance and management leading to resource conflicts. Moreover, Stern (2007) concluded that the high vulnerability to climate risks in Sub-Saharan Africa is caused by low institutional capacity. Dube and Sekhwela (2007) in a study of coping strategies in Limpopo Basin, Botswana gathered that erosion of traditional institutional norms and knowledge systems weakens the capacity to respond thus exacerbating the vulnerability to climate variability.

Climate variability has a real and immediate threat to the management of natural resources and the livelihoods of communities that largely depend on them (Jacobs *et al.*, 2015). This is because a decline in the natural resource base and hence resources to use in response to shocks and stresses degrades an ecosystem’s protective capacity leading to increased exposure to climatic hazards (IUCN *et al.*, 2004). Adverse climate variability impacts on trees and forests will increase the vulnerability of the 1.2 billion extremely poor people who directly depend on them (World Bank, 2004). According to Mugo and Gathui (2010) and Parry *et al.* (2012), climate variability constrains access to biomass energy by affecting forest growth and causing forest cover loss.

Climate variability causes water insecurity, and this will escalate as evaporation rates increase and rainfall patterns become more variable (Parry *et al.*, 2012; Ncube *et al.*, 2016). An analysis by Niang *et al.* (2014) concluded that the greater unpredictability of rainfall in Africa is likely to exacerbate existing water scarcity. Moreover, a study by Boru and Kaske (2014) among agro-pastoralists in the Gadamoji Division of Marsabit County found out that local people have perceived increased water shortage due to climate variability.

2.3 Climate variability resilience

Resilience is the ability to prepare, cope, adapt, and pull through climate shocks and stresses (DFID, 2014). Scheyvens *et al.* (2015), therefore, noted that a resilient household maintains its level of wellbeing when confronted with climate shocks and stresses. Resilience is context-specific and depends on the nature of the shock or stress experienced, the prevailing social, economic, environmental, and political context, and the choice of response actions (Frankenberger and Nelson, 2013). Context on the other hand is dynamic and depends on how people respond to shocks and stresses (Alinovi *et al.,* 2010) that in turn leads to contextual changes that should be integrated into resilience-building strategies (Frankenberger *et al.,* 2012).

Perez *et al.* (2015) noted that the characteristics of a resilient socio-ecological system include livelihood diversity, access to assets, community ownership of natural resources, empowerment, capacity to organize, capacity to learn, and access to diverse knowledge. Resilient systems also display a high degree of social cohesion, have built-in functions for management of information relevant for risk management, and have reserve resources for use in response to shocks and stresses (Mazur, 2013).

Piya *et al.* (2016) observed that rural household's climate variability resilience in the Midhills of Nepal was influenced by access to capital assets. Frankenberger *et al.* (2012) deduced that accumulation and diversification of capital assets are critical for enhancing the adaptive capacity of vulnerable households to climate shocks in Africa. The ability of farmers to increase production, enhance incomes, and thus invest in agriculture directly depends on the effective development of capital assets (Ellis, 2000; Carney, 1998; Scoones, 1998). According to Bryan and Berhaman (2013), access to adequate financial capital enables farmers to adapt to climate variability by facilitating access to farm inputs.

Lyimo and Kangalawe (2011) found that access to capital assets in semi-arid Tanzania helps people to pursue diverse and cumulative livelihood strategies and hence adapt and cope with climate variability. Livelihood's diversification either in terms of occupational multiplicity, occupational mobility, and diversification of mainstream sectors, therefore, reinforces the resilience of households to climate variability by avoiding the specialization trap (Antwi-Agyei *et al.*, 2014; IPCC, 2014; Badjeck & Flitner, 2009). Nesha *et al.* (2014) found that management interventions aimed at resilience to climate variability require a holistic, multisector approach and must therefore deal with multiple resource systems. Thornton *et al.* (2007) observed that diversifying livelihood options by raising more livestock varieties and engaging in nonagricultural activities is critical for income and food security in households that depend on livestock.

Boissiere *et al.* (2013) deduced that the development of successful interventions for responding to climate variability in tropical forests of Papua, Indonesia needs a proper understanding of how local people experience and respond since the impacts are location and time specific. Response strategies to climate variability should thus build on strategies that are already being implemented by local people and reflect their socioeconomic and environmental context (Mertz *et al.,* 2009; Ziervogel *et al.,* 2006; Tschakert, 2007; Daw *et al.*, 2009; Ojwang *et al.,* 2010). According to IUCN *et al.* (2004), climate variability resilience-building should begin with activities that focus on ongoing vulnerabilities and be based on the experiences of the community. Additionally, IFAD (n.d.) observed that responses to impacts of climate variability are most effective when local communities are involved fully from planning to the implementing of interventions. Berkes *et al.* (2010) revealed that the traditional ecological knowledge of rural communities constitutes a profound understanding of local climate variability and change. Recognizing and utilizing traditional knowledge in a community is thus key in building their capacity to cope and adapt to impacts of climate variability and change (Berkes and Jolly, 2001; Vasquez-Leon, 2002).

Social networks are key in resilience-building since they facilitate mutual support mechanisms based on which people support each other during difficult times (Perry *et al.*, 2010). Ostrom (1999) noted that strong and diverse social networks enhance the capacity of households and individuals to anticipate and respond to disturbances in their socioecological systems. Social networks enhance social capital and enhance access to information, resources, markets, and resilience-building technologies (Iheke and Agodike, 2016; Wall and Marzall, 2006; Sadri *et al.*, 2018). Besides, a study by Osbahr *et al.* (2008) in Mozambique found that the ability to reciprocate through local connections, family ties, and informal institutions is one of the most significant mechanisms used to buffer households against climate risks disturbance. According to Frankenberger *et al.* (2012), elements of social capital lay the foundation for good governance and peace-building initiatives which is a prerequisite for strengthening resilience especially in areas marked by resource conflicts due to climate shocks and stresses. Governance arrangements that encourage wide-ranging communal action and cohesion are vital in dealing with change and uncertainty (Jones *et al.*, 2010; Ratner, 2013).

Further, Catholic Relief Services (2012) found that the establishment and maintenance of community-based associations is instrumental in helping vulnerable communities deal with the impacts of climate variability. The adaptive capacity of a community to climate variability depends on its institutional capacity, as defined by the level of social capital, communal action, and access to resources (Bryan and Berhman, 2013). Institutions, therefore, determine the climate variability perceptions, impacts, and responses of individuals, households, or communities (Bryan and Berhman, 2013). Robinson and Berkes (2011) found that adaptive capacity among Gabra Pastoralists in Northern Kenya is strengthened by the institutional arrangements that promote participation and democratic decision-making.

IUCN *et al.* (2004) observe that since poor people mainly depend on ecological services for their livelihoods, the resilience of communities to climate variability is mainly built through activities that manage and restore ecosystems including agroecology, and the restoration of watersheds, rangelands, and forests. An assessment of resilience-building through sustainable forest management (Braatz, n.d.) found that trees and forests are key to climate variability resilience since they act as safety nets, water catchments, habitats for biodiversity, control land degradation, and diversify sources of income. According to Colls *et al.* (2009) and Pramova *et al.* (2012), ecosystem-based adaptation approaches conserve and restore ecosystem services thus building people's resilience to climate variability.

Improving human capital is also critical in augmenting the adaptive capacity of vulnerable households and communities to climate variability (Alemayehu and Lemma, 2014). Adeptu and Berthe (2007) in a study of the vulnerability of rural households in the Sahel to drought found that the vulnerability is determined by various factors including the household head's health status. Gash and Gray (2016) found that access to education has a positive influence on household resilience in Burkina Faso with each additional year of the household head's schooling being associated with a 5% chance of recovery from the disaster and a 0.3% increase in coping strategy index. Moreover, access to training has a positive effect on farmer's resilience since it influences their strategic decision making (Alemayehu and Lemma, 2014; Roco *et al.,* 2015). Access to training increases the ability and likelihood of a farmer to evaluate, adopt and implement climate variability resilience-building strategies (Fagariba and Song, 2018; Iheke and Agodike, 2016). According to Bryan and Berhman (2013), an individual's or household's adaptation capacity and approach are determined by access to information on climate variability and adaptation technology.

2.4 Informal microfinance institutions

Informal microfinance institutions are community-based financial organizations whose activities are not regulated and controlled by the monetary authority (Owusu-Sekyere *et al.,* 2011). Haworth *et al.* (2016) noted that informal microfinance institutions are found worldwide with the greatest prevalence being observed among low-income people in developing countries where the lending activities of the informal financial sector are three times bigger than those of the formal sector (Haworth *et al.,* 2016). Njeri *et al.* (2013) in an analysis of microfinance organizations in Kenya observed that informal microfinance institutions are mainly found among financially marginalized groups who hardly access the services of formal financial institutions in developed countries. Sayed (2011) observed that informal microfinance differs from other financial services based on three features including low loan amounts, low savings amounts, simple operations, and nonexistence of material assets as collateral.

Aryeetey and Gockel (1991) noted that informal microfinance institutions are not a recent phenomenon since some of the practices being undertaken in the informal sector today date back to ancient societies. Anyango *et al.* (2007) gathered that the rise of informal microfinance institutions was driven by the failure of formal financial institutions in providing the poor with financial services particularly in Africas' rural areas which drove the interest in finding alternative models of financial service delivery. Informal microfinance institutions are a common response strategy by the rural poor to counter financial marginalization by turning inwards to mobilize their resources, however small, to meet their credit needs (Tilakaratna, 1996). Mashigo and Schoeman (2012) observed that formal financial services have historically been inaccessible to low-income groups due to the high collateral required and the high risk associated with low-income borrowers.

Gugerty (2007) noted that self-commitment to save as being the key purpose because most participants join informal microfinance institutions in Kenya. Informal microfinance institutions offer a collective self-control mechanism against time-inconsistent options and the inexistence of other self-commitment technologies hence helping time-inconsistent individuals to save (Gugerty, 2007). Mwangi and Kimani (2015) in an analysis of factors influencing participation of informal finance groups in Thika Subcounty in Kenya deduced that collective saving enables people to more easily save the lump sum required to purchase capital assets faster compared to if they were saving alone. Besides, Anderson and Baland (2002) observed that household conflicts over finances due to differing spending preferences between spouses drive people to join informal finance groups as they seek financial independence.

Informal microfinance institutions include client-based institutions such as shylock schemes and member-based institutions which include rotational savings and credit associations and accumulated savings and credit associations (Kaburi *et al.,* 2013). Rotational savings and credit associations are formed when people form a group and agree to cyclically make contributions to develop a mutual fund (Varadharajan, 2004). Bouman (1995) in a comparative study of informal microfinance institutions in low-income countries found that as a rule, members in rotational savings and credit associations contribute a similar amount per cycle with each member drawing out as much as they contributed. The lump-sum contributed in a cycle is lent to one member of the group giving him or her access to a larger amount of capital than would otherwise be possible if they were alone (Kedir *et al.,* 2011).

On the other hand, member's contributions in accumulating savings and credit associations are invested by making loans to members at a relatively high interest rate and earnings paid to members as dividends after an agreed period during the auction audit (Collins *et al.,* 2010). The members' contributions plus interest and fines on loans, therefore, build up the fund increasing its lending capacity while also boosting the value of the member's shares in the fund (Bouman, 1995). In some accumulating savings and credit associations, members may make contributions larger than the agreed amount to have more shares and gain more from the investment (Bouman, 1995). Accumulating savings and credit associations are marked by a broader set of goals other than just individual goals (Bouman, 1995). They are broader organizations with multiple functions and are often characterized by a heterogeneous membership that cuts across economic, class, and ethnic differences (Bouman, 1995).

Ritchie (2007) noted that based on their sources of initial funds, community-based financial models can either be described as credit-led or savings-led community-based financial organizations. Credit-led community-based financial organizations are those that receive outside funding during their initiation stage while savings-led community-based financial organizations are those that initiate their activities using member's savings but could seek external funding if necessary, when they are already experienced in their business activity (Ritchie, 2007).

Funding credit-led community-based financial organizations aim to establish revolving funds to support the development of rural livelihoods with the expectation that initial recipients of funds will repay to enable others to benefit from the same (Ritchie, 2007). It has however been observed that such funds eventually decapitalize benefiting fewer people than expected since they also encourage a culture of default (Ritchie, 2007). Adoyo (2013) found that credit-led community-based financial organizations include government and donor-supported microcredit models and entail standard predefined intervention packages whereby the financier's become players in the program, laying down the required rules and structures. They mainly provide financial services to the poor by channeling funds through several steps that involve other entities including local banks and micro-credit institutions (Adoyo, 2013). This leads to accumulation in the interest rate burden before the funds finally reach the target marginalized borrowers and thus becoming debt traps (Adoyo, 2013). The real players in these interest-driven microcredit models, therefore, end up being the intermediaries who claim to be the link between the lenders and the vulnerable borrowers (Adoyo, 2013).

Member-based savings-led informal microfinance institutions have thus emerged to replace such credit-led revolving loan funds (Ritchie, 2007). These community-based financial models comprise organizations formed by local people to cater to their financial needs and provide greater opportunities for members to fully participate in their development and management resulting in democratic organizations that are more sustainable, efficient, and adapted to the prevailing local conditions (Adoyo, 2013). This organizational structure enables poorly educated people who are inexperienced in financial management other than in their households to govern and manage themselves (Ritchie, 2010). In this model members first develop their foundation with a focus on building savings as the main source of lending capital rather than relying primarily on external sources (Adoyo, 2013).

Informal microfinance institutions are more resilient to financial crises and can forge partnerships and invest in economic activities that contribute to their progress (Adoyo, 2013). The fact that informal microfinance institutions are not run based on external regulations means they are more efficient than the formal sector in the backdrop of policy distortions and repression (Njeri *et al.,* 2013). Allen (2002) observed that informal microfinance institutions are more affordable, flexible, and easily accessible since they exist in the communities where the members live. Further, Gwasi and Ngambi (2014) found that the attractiveness of informal microfinance institutions lies in their proximity to clients, simplicity of operations, and adaptive capacity.

Gomez and Santor (2001) found that informal microfinance borrowers use social capital to overcome problems related to information asymmetry, adverse selection, moral hazard, status verification, and contract enforcement in credit markets. Furthermore, Mwangi and Ouma (2012) observed that informal microfinance institutions seek no legal enforcement since their contracts rely on a sense of moral duty than absolute rights. These are binding concepts that institute effective borrowing channels and means of governance based on reputation and relationships i.e., social capital (Mwangi and Ouma, 2012).

Chiteji (2002) in a study of enforcement in informal microfinance institutions found that social collateral solves the potential problem of default and defrays the costs that an informal microfinance institution might incur in enforcing the terms of the contract. This involves tapping preexisting relationships between members and the tendency for repeated interactions as a means of obtaining information that allows groups to screen candidates for membership or to impose penalties on defaulters (Chiteji, 2002). Therefore, according to Mushuku and Mayisa (2014) in a study of the role of informal microfinance institutions in poverty reduction in Gutu District in Zimbabwe, members of informal microfinance institutions depend on social capital to assess creditworthiness, assess financial risk, promote savings, network, gather information and build peer pressure that ensures persistent commitment. Mwangi and Ouma (2012) observed that social cohesion enables collectiveness in decision-making leading to reciprocity and unity that reduces opportunistic behavior. Additionally, Silwal (2003) in a study of loan repayment performance in Nepali Village banks gathered that informal microfinance institutions maintain high repayment performance through peer selection, peer monitoring, self-motivated incentives, regular repayment schedules, and social collateral.

However, informal microfinance institutions often tend to stop functioning because of default and fraud that erodes their asset base (Anyango *et al.*, 2007). The groups could also fail due to a lack of literacy and numeracy skills which leads to failure in bookkeeping and policy compliance (Anyango *et al.*, 2007). Failure can also be brought about by unequal power relations within the group leading to failure in governance (Anyango *et al.*, 2007). A study of village savings and loan associations in Zanzibar (Brannen, 2010) found that the process of self-selection that marks informal microfinance institutions creates the risk of excluding the poorest members of society.

2.5 Microfinance performance

Thrikawala *et al.* (2013) in a study of the social performance of microfinance institutions noted that microfinance institutions just like other firms need to measure their performance to evaluate their growth. However, unlike other firms, the performance of microfinance institutions encompasses both financial and social aspects (Thrikawala *et al.*, 201). A review of microfinance institutions by Brau and Woller (2004) found that two schools of thought exist as appertains to measuring the performance of microfinance institutions including the welfarist and the institutionalists. The institutionalists' model of microfinance focuses on the financial function and argues that a microfinance institution should be able to attain sustainability by financing its operations from its revenue and that financial sustainability is pertinent to institutional sustainability (Mustafa and Saat, 2012). The welfarist's model of microfinance on the other hand focuses on the social function and posits that a microfinance institution can attain sustainability without financial self-sufficiency (Mustafa and Saat, 2012).

Mustafa and Saat (2012) noted that impact assessment in microfinance institutions is based on the intermediary and the intended beneficiary schools of thought. The intermediary school of thought focuses purely on changes in the microfinance institution and its operations including institutional outreach and institutional sustainability with the assumption that their enhancement implies the interventions of the microfinance institution had a beneficial impact (Mustafa and Saat, 2012). The intended beneficiary school of thought, on the other hand, builds on the ideas of conventional evaluation by seeking to get into the impact chain as far as feasible to assess the impact on beneficiaries that is individuals and households (Mustafa and Saat, 2012). Therefore, although many studies have been done on the measurement of microfinance performance and the underlying factors, the literature lacks consensus which allows great room for research on how to measure microfinance social and financial performance (Hermes and Hudon, 2018).

According to Hashemi (2007) performance of microfinance institutions is based on five core aspects including outreach breadth, outreach depth, loan repayment performance, financial sustainability, and efficiency. Financial sustainability is the capacity of a microfinance institution to meet its costs independent of external subsidies from the donor or government agencies (Adongo and Stork, 2005). Microfinance institutions in Kenya should be self-sustaining to be able to attain their outreach potential and goal of providing poor people with quick access to financial services (Wambugu and Ngugi, 2012). Adongo and Stork (2005) noted that since reaching large numbers of poor people who lack access to financial services is the key goal of microfinance institutions, outreach is a vital factor in microfinance. Further, Osotimehin *et al.* (2011) found that outreach in microfinance institutions in South-Western Nigeria had a significant positive relationship with average loan size and loan repayment rate.

Kipesha (2013) in a study of microfinance performance in Tanzania defines efficiency as an indicator of how well the microfinance institution allocates and controls its resources while loan repayment performance measures the effectiveness in collecting loan repayments from borrowers. Moreover, Tendler (1989) in a study of poverty alleviation notes that the number of loans issued, and savings made, and loan repayment performance are good indicators of performance because they can be easily measured. Furthermore, D'Espallier *et al.* (2011) measured the performance of microfinance institutions based on four parameters including size of the loan amount, repayment time, and purpose of borrowing the loan. According to Owour *et al.* (2020), the lending and savings services of a microfinance institution have a positive influence on financial performance.

Zeller *et al.* (2003) in a study on measurement of social performance in microfinance institutions noted that because integrating social and financial performance is essential for existence in a competitive market, microfinance institutions have developed both social and financial metrics to evaluate their performance. Also, Agarwal and Sinha (2010) found that since microfinance institutions are also regarded as instrumental to social change in India, their performance often employs non-financial parameters. Gwasi and Ngambi (2014) defined social performance as the effective operationalization of a microfinance institution’s social mission within accepted social values. Hashemi (2007) in a study of the social performance of microfinance institutions noted that these social values include enhancing outreach, improving client’s socioeconomic conditions, and reinforcing social responsibility to clients and the community.

Measuring social performance entails investigating an organization’s structure and its conduct in the market and the community (Gwasi and Ngambi, 2014). The complex nature of the concept of social performance necessitates the use of a multidimensional approach in its measurement (Hermes and Hudon, 2018). Yaron (1994) measured social performance in microfinance institutions using an outreach composite index which considered several dimensions including average loan amounts and the number of clients reached.

The performance of an organization is a function of different internal and external factors that influence its operations (Kipesha, 2013). A study of microfinance performance in Malaysia by (Mokhtar, 2011) found that the performance of a microfinance institution is influenced by three factors including the characteristics of borrowers, the business, and lending and saving activities. According to Gwasi and Ngambi (2014), institution-specific indicators, that is internal factors, are major determinants of a microfinance institutions’ performance. The most important determinants of performance in microfinance institutions include the microfinance institution characteristics including size and age, sources of funding, quality of governance, and external contextual factors including the political, institutional, and macroeconomic conditions (Hermes and Hudon, 2018). Arrassen (2017) noted that the financial performance of microfinance institutions in sub-Saharan Africa is majorly influenced by financial costs and portfolio quality whereas social performance is influenced by the lending methodology and institutional structure in microfinance institutions.

According to Aveh (2011), understanding the factors that influence the performance of microfinance institutions is important because it provides greater knowledge of factors that should be leveraged to form successful institutions. Knowledge of determinants of the performance in microfinance institutions can inform policies for increasing the microfinance institution’s capacity in reaching their social and financial goals and ensuring they espouse financial sustainability in poverty alleviation (Hermes and Hudon, 2018). Ahlin and Maio (2011) observed that the performance of microfinance institutions is determined by a country’s specific context. Also, Hermes and Hudon (2018) observed that the effect of microfinance institution's characteristics on their performance is influenced by their specific local context.

2.6 Role of microfinance institutions in climate variability resilience

Microfinance institutions need assessment from an adaptation perspective in rural areas especially given the high number of climate-vulnerable participants (Scheyvens, 2015). Komba and Muchopondwa (2018) found that microfinance services including microcredit, micro insurance, or micro-savings provide poor people with a means for accumulation, diversification, and management of assets which makes them vital in addressing their vulnerability to climate risks. Galab *et al.* (2006) in a study of livelihoods in rural Andhra Pradesh in India deduced that microfinance institutions facilitate participants to cope and adapt to climate risks by enhancing their asset base through direct and indirect income effects, and non-pecuniary effects such as greater social networks and empowerment.

A study on climate resilience and financial services by Haworth *et al.* (2016) observed that microfinance institutions are an effective means for building climate resilience since their networks enable access to highly vulnerable people especially women. Moreover, Hammil *et al.* (2008) in a study of the linkage between microfinance and climate change adaptation noted microfinance is a strategy of poverty reduction that is related to resilience building since poverty is a state and contributing factor of vulnerability. Mushuku and Mayisa (2014) observed that microfinance services help alleviate poverty through income generation, job creation, facilitating access to education and healthcare, and allowing people to choose suitable livelihood options. Gash and Gray (2016) observed that financial services in Burkina Faso help poor households in anticipating, adapting, and recovering from climatic shocks in a way that protects their livelihoods and supports their growth.

Microfinance helps fill the adaptation deficit which results due to a household lacking adequate capital (Scheyvens, 2015). Egyir *et al.* (2015) in Ghana noted that microfinance institutions help households to smooth their consumption gaps regardless of income fluctuations due to climate shocks. Hohenkammer (2005) noted that microfinance institutions help communities to cope with climate risks by providing participants with instruments to either retain the risk, share the risk, or transfer the risk. Microfinance institutions thus provide a social security function that protects their participants against climate risks (Mushuku and Mayisa, 2014). They provide participants with liquid cash to secure their livelihoods enabling quick reconstruction and financial recovery after extreme climate events (World Bank, 2012).

Ncube *et al.*, (2016) observed that microfinance institutions in South Africa enable members to save thus providing them with an invaluable reserve that cushions and insures them against climate risks. Further, Lopez (2009) found that microfinance institutions prevent the poor from engaging in self-insurance through the sale of productive assets whenever disasters strike. They enable poor people to enhance and diversify their capital assets and sources of income thus increasing their capacity to self-insure against future risks and smooth their consumption patterns in the backdrop of income fluctuations during shocks and stresses (Bhattamishra and Barret, 2010; Catholic Relief Services, 2012; Hohenkammer, 2005).

Agrawala and Carraro (2010) found that the services of microfinance institutions help the poor in building climate resilience by enabling them to initiate and enhance existing production and entrepreneurship activities. Microfinance institutions in Bangladesh create opportunities for self-employment enhancing the capacity to cope and recover from climate shocks (Islam, 2011). Recha *et al.* (2012) gathered that farmers in semi-arid Eastern Kenya employ microfinance institutions as a resilience-building mechanism to enhance their ability to stock livestock and purchase inputs of crop and livestock production. According to (Ojwang *et al.*, 2010), microfinance programs can provide farmers with credit to buy fertilizer and seeds in times of need. Besides, Scheyvens *et al.* (2012) gathered that microfinance institutions help households to diversify their livelihoods to avoid dependency on one source of income thus increasing resilience to climate variability. Further, Khandker and Samad (2014) found that participation in microfinance had a direct relationship with income diversity in Bangladesh.

A study of the effects of microfinance institutions on poverty reduction in Kenya (Okibo and Makanga, 2014) concluded that microfinance institutions help to build human capital by providing access to training opportunities. Microfinance institutions provide access to training in various areas including health and nutrition (Komba and Muchopondwa, 2018) and advice on agricultural practices (Haworth *et al.*, 2016) and income-generating activities and disaster preparedness (Scheyvens *et al.*, 2012). Moreover, Tjikan (2015) in a study of village Tontines in Mali observed that microfinance institutions provide training on financial management. The networks offered by microfinance provide a means for information sharing, information dissemination, and access to communication devices for example cell phones (Patel and Nanavaty, n.d.; Dowla, 2018; Haworth *et al.*, 2016). A study of the impacts of microcredit in Peru by Dunn and Arbuckle (2001) observed that higher incomes due to microcredit increases a households' spending on access to technology and learning opportunities. Brannen (2010) found that microfinance institutions in Zanzibar improve the capacity of people to access health services. Moreover, Osmani (2014) observed that microfinance credit increases food security over time while Khandker (2005) noted that increase in a households' income due to microcredit results in increased spending on food consumption leading to more healthy diets in Bangladesh.

Levine *et al.* (2011) found that microfinance institutions in Mozambique, Uganda, and Ethiopia provide and enhance social capital through their social networks which help communities to cope and adapt to climate shocks and stresses and hence maintain their wellbeing. Social capital facilitates risk pooling and risks sharing practices of individuals, households, and communities through mutual assistance mechanisms and collective action (Osbahr *et al.,* 2008). Helin *et al.* (2007) found that the collective action of farmer's organizations in Meso-America facilitates member's access to markets by increasing their bargaining power, scale economies, and enhances access to new skills and technologies through shared learning which have positive implications on the resilience of socioecological systems. Likewise, Germain *et al.* (2012) deduced that community groups in the East African Highlands facilitate the collective action and coordination mechanisms needed for climate risk adaptation and effective natural resource management. In addition, Nakagawa and Shaw (2004) observed that social capital is imperative in post-disaster recovery.

GGLN (2014) in a study of community resilience and vulnerability in South Africa observed that microfinance institutions enhance households and community resilience by empowering members to effectively participate in decision-making processes and improving their transformative capacity. Kaburi *et al.* (2013) found that microfinance institutions in Kenya empower members by increasing their dignity, self-esteem, and self-dependence, and participation in community activities. Access to microfinance can enhance the ability of women in dealing with challenges associated with gender inequality by enhancing their confidence (Ritchie, 2007). Microfinance institutions provide networks and entry points that enable climate variability response actions to target the most vulnerable people including the poor, women, and other marginalized groups (Agrawala and Carraro, 2010; Haworth *et al.,* 2016). This increases local community participation, consideration of local priorities, more sustainable projects, increased legitimacy, accountability, better targeting of interventions, and lower costs in implementation (Bhattamishra and Barret, 2010; Mansuri and Rao, 2013). Microfinance makes women financially independent enhancing their participation in community activities, contribution to household expenditure needs, and thus household decision making, self-worth, confidence, and their overall socioeconomic status (Mokhtar, 2011; Janda and Turbat, 2013). In this way, microfinance substantially contributes to gender equality and promotes better livelihoods and working conditions for women (Noreen, 2011).

Moser and Gonzalez (2015) in a case study of Agroamigo in Brazil observed that microfinance institutions contribute to adaptation and mitigation strategies by financing tree planting activities and creating awareness on sustainable agriculture. Rippey (2012) in a study of microfinance and climate change gathered that microfinance institutions play a role in forest protection by supporting ecologically friendly income-generating activities that don't depend on forest timber products. They enable members to mobilize and access financial capital to invest in climate-smart technologies such as drip irrigation projects (Rippey, 2012). Dowla (2018) in a study of climate change and microfinance in Bangladesh observed that microfinance institutions enable access to clean, renewable, and efficient energy technologies including efficient cooking stoves thus helping participants to reduce their carbon emissions. In doing this the microfinance institutions could directly fund household's purchase of energy-saving devices, provide financial capital to small scale enterprises that supply the devices, fund community-based mitigation initiatives (Rippey, 2012), or leverage on the economics of scale to make these technologies more affordable (International Finance Corporation, 2007). Microfinance institutions can also participate in carbon trading schemes through activities such as buying offsets and reselling them at a profit or directly investing in carbon offset projects (House of Commons, 2007).

Moreover, in the backdrop of a changing climate, microfinance institutions need to start climate-proofing their activities through various approaches such as product reconfiguration to best deal with impacts (Dowla, 2018). This could include changing lending terms and conditions including through the adoption of a flexible loan repayment schedule as opposed to the current often rigidly fixed installments approach that makes it extremely difficult for borrowers to repay in case of shocks (Dowla, 2018). Shoji (2010) in a study of the effect of contingent loan repayment in microfinance on the poor during disasters in Bangladesh found that rescheduling loans serve as a safety net to prevent borrowers from sliding further into poverty in case of shocks. McKee (2008) in a study on the connection between microfinance and climate change noted that green microfinance may reinforce the long-term resilience of investments by setting terms and conditions that promote sustainable practices. This could involve setting lending conditions that ensure that the investments undertaken by borrowers are climate-proof as observed in the case of the Grameen Bank which requires houses built by borrowers to be flood-proof, incorporate concrete pillars, and have trees planted around them to avoid damage by strong winds (Dowla, 2018).

2.7 Theoretical framework

2.7.1 Social capital theory

Social capital theory is based on the ability of actors to secure benefits from social relationships and membership in social networks, that is social capital (Rankin, 2002; Claridge, 2004). Social capital theory originated from the 18^{th} and 19^{th} century economics and sociology (Claridge, 2004) but was popularized by in the 1990s through the writings of Bourdieu (1986), Coleman (1988) and Putnam (1993), and who had different but related views of social capital. Bourdieu (1986) defined social capital as the actual or potential resources that are linked to possession of a durable network of institutionalized relationships of mutual acquaintance and recognition. According to Coleman (1988) social capital is a collective resource utilizable by actors who are goal oriented. He defines social capital by its function, focusing on the positive outcomes of groups, organizations, institutions, or societies (Coleman, 1988; McClenagham, 2000; Adam and Roncevic, 2003). Actors therefore maintain or engage in networks to gain a profit of which is reducible to economic profit (Tzanakis, 2013). Putnam (1993) refers to social capital as the features of social organizations such as networks, norms, and trust that facilitate actions and cooperation for mutual benefits. According to Putnam, voluntary organizations that enable horizontal linking of people produce trust, the norm that causes interpersonal bonding. Social capital is thus the amount of trust available in a social structure.

Social capital is critical for successful operation of informal microfinance institutions since it reduces transaction and monitoring costs by enabling better access to members information that helps decrease the risks of adverse selection and moral hazard that are often caused by information asymmetry (Fukuyama, 2001; Gomez and Santor 2001; Karlan, 2007; Karlan and

Murdoch, 2010). Social capital in informal microfinance institutions helps to assess individual's financial risk and viability (Mushuku and Mayisa, 2014) and thus provides social collateral (Chiteji 2002). Karlan et al, (2009) noted that the value generated by social relations in informal microfinance institutions generates value that is used as social collateral. Gugerty (2007) observed that social capital in informal microfinance institutions enable saving by providing a collective mechanism for individual self-control in the presence of time inconsistent preferences.

Social capital also augments the capacity for enforcement of contracts as members are pushed to repay through peer monitoring and peer pressure (Lopez-Rodriguez and Garcia, 2000; Kane, 2003). Furthermore, Mwangi and Ouma (2012) observed that informal microfinance institutions seek no legal enforcement since their contracts rely on a sense of moral duty than absolute rights. These are binding concepts that institute effective borrowing channels and means of governance based on reputation and relationships (Mwangi and Ouma, 2012).

Social capital in informal microfinance institutions enables inclusive governance including member's participation in formulation of group rules, deciding who joins the group, evaluation of borrowers, and the election of leaders (Lorpez-Rodriguez and Garcia, 2000). These processes of self-selection help reduce default and fraud problems and strengthen solidarity bonds which foster cooperative behavior (Lorpez-Rodriguez and Garcia, 2000; Chai et al, 2018). Social capital enables collectiveness in decision-making leading to reciprocity and unity that reduces opportunistic behavior (Mwangi and Ouma, 2012).

Social capital is a key component of resilience in rural households that insulates them through mutual support reciprocity and risk sharing mechanisms (Nikagawa and Shaw, 2004; Hoddinoff *et al*, 2009; Endris *et al*, 2017; Kiboro, 2017). It the basis of community groups that are a medium for access to resources which leads to resilience (Agrawal, 2010). Social capital contributes to sustainable livelihood outcomes by enhancing saving; livelihood diversification; participation in markets; access to information, access to essential services; learning of new skills and technologies, and other network mediated benefits (Gugerty, 2007; Bhandari and Yasunobu, 2009; Hellen *et al.*, 2009; Markeleva *et al*, 2009; Kiboro *et al*, 2017; Chai *et al*, 2018). Social capital increases local level participation in policy making, legislation, and development processes, and the demand and enabling environment for good governance (Fukuyama, 2001;

Bhandari and Yasunobu, 2009; Boyd *et al*, 2008; Galaz *et al*, 2010; Shwartz *et al*, 2011; Bene *et al*, 2012; Mansuri and Rao, 2013).

2.7.2 The sustainable livelihoods framework

The sustainable livelihoods framework is an analytical framework that was developed by DFID. Based on Chambers and Conway's (1992), the framework views a livelihood as encompassing abilities, assets, and actions that enable a living and a sustainable livelihood as that which can cope and pull through shocks and stresses and improve over time while sustainably managing the natural resource base. The sustainable livelihoods framework seeks to understand how people access capital assets and convert them through livelihood strategies to attain desirable livelihood outcomes including better income, food security, wellbeing, sustainability in the usage of natural resources, and reduced vulnerability (Moser *et al.*, 2001; Connolly-Boutin and Smit, 2016; DFID, 1999).

It visions people as functioning within a vulnerability context (DFID, 1999) that defines their outer living environment as shaped by different factors including shocks, trends, and seasonality (Nayak and Maharjan, 2013). Climate variability is one aspect of the vulnerability context since climate trends, shocks and seasonality frame the external environment in which people live and operate (DFID, 2004). The vulnerability context varies in space and time including between and within communities, social groups, sectors, regions, and nations as determined by socioeconomic and structural inequalities (United Nations, 2016; IPCC, 2001; Bohle *et al.*, 1994). These variables also influence people's perceptions of the vulnerability context, the understanding of which is pertinent in developing appropriate resilience-building strategies (IUCN *et al.*, 2004).

The vulnerability context influences people's livelihoods by affecting their access to capital assets (Moser *et al.*, 2001; Connolly-Boutin and Smit, 2016; DFID, 1999; Saxena *et al.*, 2016; Badjeck *et al.*, 2010; Nayak and Maharjan, 2013). The core outcome of the sustainable livelihood's framework is therefore to enhance resilience to shocks, trends, and seasonality by building household capital assets (DFID, 1999; Egyir *et al.*, 2015; Piya *et al.*, 2016; Badjeck *et al.*, 2010). Therefore, the sustainable livelihoods framework conceptualizes rural livelihoods as a process of transformation and substitution between human, social, financial, physical and natural capital (Jacobs *et al.*, 2015). It seeks to understand people's capital assets and how they convert them through livelihood strategies to achieve positive livelihood outcomes (Moser *et al.*, 2001).

Access to capital assets determines the viability and effectiveness of livelihood strategies and is influenced by ecological, socioeconomic, and institutional factors (Kabede and Adane, 2011; Majale, 2002). The sustainable livelihoods framework thus also seeks to understand the determinants of people's livelihoods and the relationships that exist between them (Uy *et al.*, 2011; IFAD, n.d.).

The process of access to assets and their conversion through livelihood strategies into livelihood outcomes, and the choice of livelihood strategies, is mediated by structures and processes, an important element of the sustainable livelihood's framework (Chambers and Conway, 1992; Daw *et al.*, 2009; Ellis, 2000). Structures include private and public organizations including households, the community, and member groups such as informal microfinance institutions (FAO, 2008) and form the basis for establishment and implementation of processes (DFID, 1999). Processes include social norms, culture, legislations, policies, agreements, rights of individuals, and power relations (DFID, 1999). Structures and processes by determining capital assets access and the way institutions and individuals operate and interact shape impacts and responses, and determine the level of resilience to shocks, trends, and seasonality in a socioecological system (DFID, 1999; Carney, 2003; Adger, 2000; Raymond and Robinson, 2013, Agrawal, 2009).

On the other hand, the effect of shocks, trends, and seasonality on access to capital assets and livelihood strategies could affect the activities of structures and their effectiveness in delivering desirable livelihood outcomes. According to (Gutierrez and Mommens, 2011; Fenton *et al.*, 2017; Drill *et al.*, 2016; UNEP, 2002; Finley and Schuchard, n.d; Piraeus Bank *et al.*, 2002) climate events and the underlying socioeconomic trends adversely affect entrepreneurship and production activities of groups, households, and individuals which impairs their capacity to repay borrowed loans and hence loan repayment performance and sustainability of microfinance institutions.

2.8. Conceptual framework

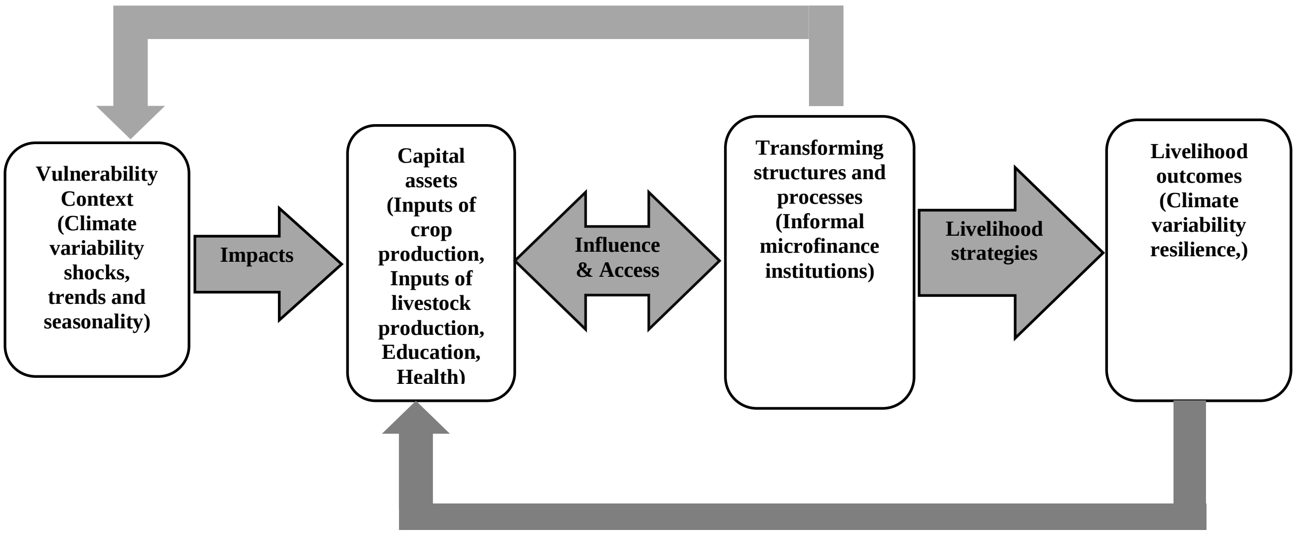


Figure 2.1: Conceptual framework. (Source: DFID, 1999)

According to the conceptual framework (Fig 2.1), climate variability defines the external environment in which people live and can hardly control. It entails climatic trends, shocks, and seasonality that affect rural people's livelihoods through the effect on access to capital assets. The vulnerability context can be changed through activities of transforming structures and processes that support rural people to access capital assets including physical, human, social, financial, and natural capital. Transforming structures and processes, therefore, include community-based institutions such as informal microfinance institutions and the policy and legal frameworks, and social norms that determine access to capital assets based on which they undertake livelihood strategies leading to the desired livelihood outcomes. The desired livelihood outcomes constitute goals that lead to rural livelihoods climate variability resilience.

2.9 Summary of research gaps

Although informal microfinance institutions have a great potential in building the resilience of rural livelihoods to climate variability. Limited studies have analyzed the contribution of informal microfinance institutions to rural livelihoods resilience to climate variability particularly based on access to capital assets. Most studies on factors influencing resilience to climate variability thus don't consider informal microfinance institutions as a contributing factor in their analysis. Besides, few studies have analyzed factors that determine the contribution of informal microfinance institutions to rural livelihoods resilience to climate variability. Such an analysis would help identify factors that could be leveraged to enhance the contribution of informal microfinance institutions to rural livelihoods climate variability resilience.

Also, recent studies aimed at analyzing long-term climate variability and trends in East Africa are limited compared to the larger Sahel region. Besides, climate studies often use course scale data as opposed to local-level data. This leads to a low understanding of climate variability. It also poses the risk of veiling local level climate variability impacts and vulnerability and misinforming response actions. This is mainly true for rural areas that time and again lack reliable local-level climate data. There is thus a lacuna in knowledge on local climatic variability and trends, especially at specific spatial and temporal contexts.

Moreover, limited studies have analyzed how climate variability affects participation and performance in informal microfinance institutions. Climate variability risks and opportunities, nor their integration in the decision-making processes of informal microfinance institutions are therefore not clearly understood. Studies analyzing how the vulnerability of informal microfinance institutions to climate variability is affected by their characteristics are scarce. This leads to a low understanding of how the structures of informal microfinance institutions could be leveraged to cushion them from the impacts of climate variability.

Additionally, few studies have undertaken a comprehensive analysis of the structures of informal microfinance institutions. This leads to an unclear understanding of their structures which hinders their development. Limited studies have also analyzed the performance in informal microfinance institutions especially based on a multivariate performance index. Studies analyzing the effect of structures of informal microfinance institutions and their performance are also sparse.

CHAPTER THREE: ANALYSIS OF RAINFALL AND TEMPERATURE TRENDS AND VARIABILITY IN SEMI-ARID THARAKA SOUTH SUBCOUNTY, KENYA

3.1 Abstract

Climate variability refers to spatiotemporal variations in the mean state of rainfall, temperature, and other climatic elements. Given the impacts of climate variability, analysis of the spatiotemporal dynamics of climatic elements is imperative. Therefore, the study analyzed rainfall and temperature trends and variability in Tharaka South Subcounty. The study used gridded rainfall and temperature data sourced from CHIRPS and CHIRTS. Variability analysis employed descriptive statistics, coefficient of variation, standardized anomaly, and precipitation concentration index. Trend analysis was done using Mann-Kendall (Z) statistical test and Sen's slope (Q) estimator. The study area is marked by low rainfall that has a decreasing trend. Local rainfall is generally marked by high and increasing variability, high and increasing concentration, and a high probability of extreme events. The study area experiences increasingly severe and frequent droughts with most of the years having below-average rainfall. Rainfall variability is thus associated with a decrease in rainfall, high rainfall concentration, extreme rainfall events, and more frequent and severe droughts. Besides, the study area has high-temperature levels that have an increasing trend. It is also marked by a fluctuating temperature regime. An increase in temperature is associated with a reduction in rainfall amount. The study will improve understanding of climatic trends and variability leading to a better understanding of their impacts and thus inform the development of effective response strategies.

Keywords: Rainfall, Temperature, Variability, Trends, Climate

3.2 Introduction

Climate variability refers to variations in the mean state of rainfall and temperature and other climatic variables, and the occurrence of extremes in space and time beyond those of individual weather events (IPCC 2007). Climate variability is caused by factors that are either internal or external to the climate system (FAO 2007). Climate variability is an integral part of climate change that leads to changes in short-term climate patterns (Smit et al. 2000).

Climate variability in Kenya is modulated by the factors that moderate climatic patterns in the East Africa region. Changes in sea surface temperature and large-scale climate driver's moderate climate variability in East Africa through changes in wind conditions and moisture fluxes (Spencer & Christy 1990). According to Ongoma et al. (2015) and Fer et al. (2017), the key driver of rainfall variability in Eastern Africa is the Elnino/Southern Oscillation (ENSO). Also, the Indian Ocean Dipole (IOD) significantly affects the region's atmospheric circulation and thus rainfall variability (Behera et al. 2005, Marchant et al. 2007). Besides, Ogalo et al. (2008) revealed that the extreme rainfall events and dry spells that occur over East Africa at inter-seasonal timescales are associated with the preferential phases of the Madden-Julian Oscillation (MJO).

According to Ojwang et al. (2010), climate variability in East Africa is also greatly influenced by the movement of the Inter-Tropical Convergence Zone (ITCZ). In addition, large water bodies and the diverse topography of East Africa results in a diverse range of climatic conditions. These include the coastal humid tropical climate and the arid climatic conditions of the inland low-lying and elevated plateau regions (Herrero et al. 2010). Localized climatic patterns are also brought about by the Indian Ocean, Lake Victoria, and Lake Tanganyika, and mountains such as Mount Kilimanjaro and Mount Kenya (KNMI 2006). The average temperature in East Africa fluctuates with the elevation (Herrero et al. 2010). Differences in the heating of the landmass are strongly influenced by topography (Fer et al. 2017).

Therefore, Kenya has a complex climate system that varies at regional and temporal scales (Parry et al. 2012). Ojwang et al. (2010) noted that rainfall is the prime climatic factor in Kenya although the temperature is also a significant factor particularly in the highlands, ASALs, and near large water bodies. Bryan et al. (2013) found that climate variability exhibits a general increasing trend in Kenya. According to the Government of Kenya (2012a), Kenya is projected to experience more frequent and long dry periods, interposed by rainfall events that are extreme and erratic. Climate variability is thus projected to manifest through increased frequency and intensity of drought. Recha et al. (2013) revealed that droughts in semi-arid Eastern Kenya have become more frequent and intense and occur almost on an annual basis.

Since climate variability and trends have enormous environmental and socioeconomic impacts. Examining the Spatial-temporal dynamics of climatic factors is imperative in understanding the impacts and vulnerability, and informing adaptation strategies (Ayugi et al. 2016, Asfaw et al. 2018, Mohammed et al. 2020). Temporal and spatial trends and variability in rainfall and temperature should be taken into consideration in development planning, agricultural planning, resources management, and in the analysis of climatic hazards (Asfaw et al. 2018). Besides, formulation and review of climate change policies should be guided by the current and local-level climate analysis (Umar & Bako 2019). Local-level climate analysis rather than course scale national-level analysis should also guide the development of context-specific adaptation strategies (Alemayehu et al. 2020).

However, although knowledge of climate trends and variability is vital for adaptation, mitigation, and development planning processes. Limited studies have analyzed the long-term trends and variability of climate variables in East Africa at local and regional scales (Xu et al. 2017). DFID (2009) noted that studies on rainfall variability in East Africa are scanty relative to other areas in the Sahel. Moreover, most climate studies make use of global, regional, and national level data rather than focus on specific local contexts hence the risk of veiling local level vulnerability (Deressa et al. 2011). This problem is mainly experienced in rural areas where climate data is often sparse (Xu et al. 2017), which leads to a low understanding of local-level climate variability.

There is thus a lacuna in knowledge on local climatic variability and trends, especially at specific spatial and temporal contexts. This calls for more detailed studies on the historical and current climatic trends and variability to inform adaptation and mitigation strategies, including development processes. The study, therefore, analyzed rainfall and temperature trends and variability in Tharaka South Subcounty.

3.3 Materials and methods

3.3.1 Study area

Tharaka South Subcounty (Figure 3.1) lies on the lower Mount Kenya East region in Tharaka Nithi County, Kenya. The surface area of the subcounty is 637 KM^2 (Government of Kenya 2019). The subcounty has a total population of 75,250 people who constitute 18,466 households. The population density in Tharaka South Subcounty is 118 people per KM^2 (Government of Kenya 2019).

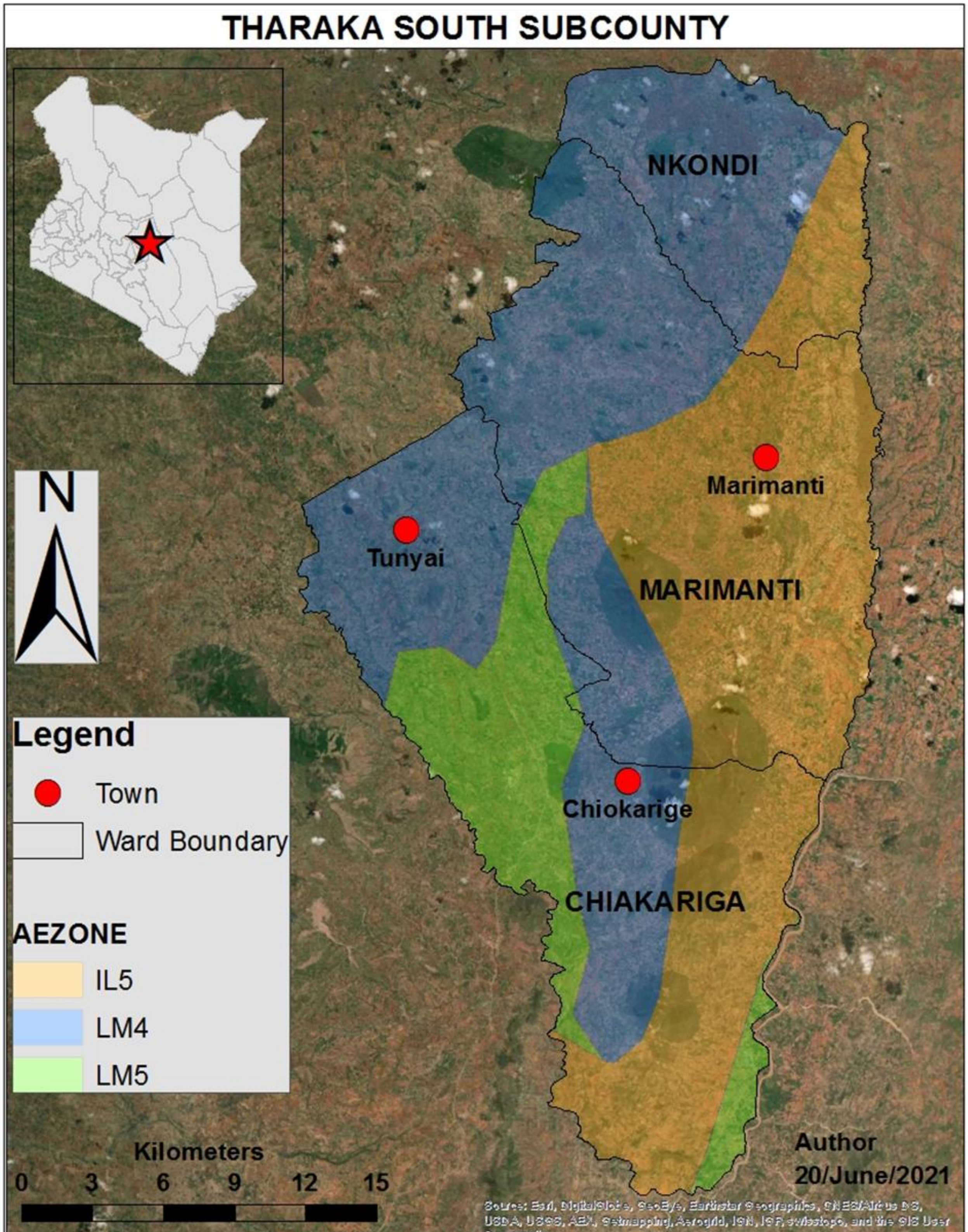


Figure 3.1: A map of Tharaka South Subcounty showing agroecological zones, wards, towns, and the landscape (Source: Author)

The major livelihood zones in the subcounty include the mixed farming zone, marginal mixed farming zone, and the rain-fed farming zone (Government of Kenya 2008). The people are largely agro-pastoralists with over 70% of their income being agricultural-based (Kirraine et al. 2012). Climate variability and hence rainfall unreliability is a major environmental challenge in the subcounty and has led to low and unsteady food production (Kirraine et al. 2012).

Tharaka South Subcounty is arid and semi-arid (Kirraine et al. 2012) and lies in the dry/savannah climatic zone based on the Köopen-Geiger climate classification system (Köopen 1936). It has three major agroecological zones that include the lower midland 4 (LM4), lower midland 5 (LM5), and intermediate lowland 5 (IL5) (Recha et al. 2013). The Northern Acacia-Commiphora bushland and thicket largely constitute the sub county's major vegetation type. The closeness of the area to Mount Kenya means that local climatic conditions are influenced by altitude, latitude, intertropical convergence zone, sea surface temperatures, and the *El Niño* /Southern oscillation amid other factors (Odingo et al. 2002).

3.3.2 Research design

The study used a descriptive approach to describe climate trends and variability. This involved the analysis of gridded rainfall and temperature data at monthly, seasonal, and annual scales.

3.3.3 Data collection

3.3.3.1. Rainfall and temperature data

Rainfall data was sourced from Climate Hazards InfraRed Precipitation with Station data (CHIRPS) for 38 years (1981 – 2018). CHIRPS is a quasi-global (spanning 50^{o} S to 50^{o} N and all longitudes) gridded rainfall data source that incorporates high resolution (0.05^{o} x 0.05^{o}, approximately 5KM x 5KM) satellite imagery with in-situ station data from field-based meteorological stations. This creates high spatial and temporal resolution gridded rainfall datasets that have high accuracy. CHIRPS rainfall data is available from 1981 and is designed for long-term climate variability and trend analysis and monitoring of drought and other environmental changes in regions that lack adequate long-term and temporally consistent observed climate data, for example, East Africa.

Temperature data was obtained from Climate Hazards InfraRed Temperature with Station data (CHIRTS) for 38 years (1983 – 2020). CHIRTS is a quasi-global (60^{o} S to 70^{o} N), high resolution (0.05^o x 0.05^o, approximately 5KM x 5KM) dataset of daily maximum and minimum temperatures. It's a global product that directly combines satellite and station-based estimates of temperature to produce routinely updated temperature data. CHIRTS data is available from 1983 and supports the monitoring of temperature extremes, especially in regions such as East Africa that often lack adequate long-term and temporally consistent observed climate data.

The temperature and rainfall data were downloaded from CHIRTS and CHIRPS websites in tiff raster format. The zonal statistics algorithm was then used to extract the rainfall and temperature values in an Arc GIS environment using the Tharaka south Subcounty polygon as the zone. The zonal statistics tool calculates all, a subset, or a single statistic that is valid for the specific input zone and returns the result as an excel table (ESRI 2016). The gridded temperature and rainfall data were derived from 35 box grids (0.05^o x 0.05^o) that covered the study area.

The gridded data were tested for certainty using Standard error of the mean rainfall and temperature data at the annual scale. The standard error is a method of measuring uncertainty and is often used to express uncertainty in the mean although it can also be used to estimate uncertainty in other measures of central tendency (Kirchner 1995). A high value of standard error indicates high uncertainty while a lower value indicates low uncertainty.

The study found the standard error of the mean annual rainfall to be 40.486. The standard error of the mean annual minimum temperature was found to be 0.068, while the standard error of the mean annual maximum temperature was 0.083. Moreover, the standard error of the mean of annual mean temperature was 0.068. These results indicated a good level of certainty in the model data.

The gridded climate data was validated by comparing the gridded rainfall data and the observed rain gauge rainfall data from 2013 to 2018 at monthly timescales. This is because observed rainfall data in Tharaka South Subcounty was only available starting from the year 2013 when the National Drought Management Authority (NDMA) started operating in the area. The observed rainfall data was sourced from the seven rain gauge stations in the study area.

The validation involved pairwise comparison of the gridded rainfall data and the observed rain gauge rainfall data using Pearsons Correlation analysis. Pearsons Correlation measures the linear relationship between estimates and observations, varying from -1 to 1 with a perfect positive correlation being 1 (Trejo et al. 2016). The study found a significant strong positive correlation between the gridded rainfall data and the observed rainfall data (r = 0.882**, n = 72, *P* = 0.000<0.01). This ascertained that the gridded data used in the study is valid.

3.3.4 Data analysis

Analysis of rainfall and temperature data was done using various statistical software including MS Excel and SPSS. Variability analysis was done using descriptive statistics, coefficient of variation (CV), precipitation concentration index (PCI), and standardized anomaly. Mann-Kendall (Z) statistical test and Sens Slope (Q) estimator were used to analyze the trends in rainfall and temperature. Kendall's tau-b correlation analysis was used to calculate the relationship between variables.

3.3.4.1 Variability analysis

3.3.4.1.1 Descriptive analysis.

Variability analysis of rainfall and temperature was done using descriptive statistics including mean, median, range, standard deviation, kurtosis, and skewness.

3.3.4.1.2 Coefficient of variation (CV)

Rainfall and temperature variability was analyzed using the coefficient of variation. The coefficient of variation was calculated as in Asfaw *et al.* (2018) i.e.

$$CV = \frac{SD}{\bar{x}} \quad \textbf{(3.1)}$$

Where:

CV = Coefficient of variation

SD = Standard Deviation

$\bar{x}$ = Mean

A higher coefficient of variation indicates larger variability while a lower coefficient of variation indicates smaller variability. Coefficient of variation values are classified as <20% less variable, 20-30% moderately variable, and >30% highly variable (Hare 1983).

3.3.4.1.3 Precipitation Concentration Index (PCI)

The Precipitation Concentration Index (PCI) was used to analyze the heterogeneity of rainfall patterns. The Precipitation Concentration Index (PCI) has largely been used at an annual scale in the past and is a great indicator of the temporal distribution of precipitation (De Luis et al. 2011).

The PCI at annual scale was calculated based on Oliver (1980) and De Luis et al. (2011) equation 1 i.e.

$$PCI_{annual} = \frac{\sum_{i=1}^{12} P_i^2}{(\sum_{i=1}^{12} p_i)^2} \times 100 \quad \textbf{(3.2)}$$

Where: p_i is rainfall amount for the i^{th} month

A lower PCI indicates low rainfall concentration while a high PCI indicates high rainfall concentration. According to Oliver (1980), PCI value < 10 denotes uniform precipitation distribution, 11-15 moderate precipitation distribution, 16-20 irregular distribution, and values above 20 denote strong irregularity of precipitation distribution.

3.3.4.1.4 Standardized anomaly

Standardized rainfall anomaly was used to analyze the annual and seasonal frequency and severity of drought, analyze fluctuations in rainfall (Agnew & Chappel 1999). Standardized rainfall anomaly also enables the determination of the dry (negative) and wet (positive) years on record (Mohammed et al. 2020). The standardized anomaly was calculated as in (Agnew & Chappel 1999) i.e.

$$Z = \frac{(xi - \overline{x})}{s} \quad \textbf{(3.3)}$$

Where:

Z = Standardized rainfall anomaly index

x_i = Annual rainfall for the $_i$th year

$\overline{x}$ = Average annual rainfall

s = Standard deviation of annual rainfall

A low standardized anomaly indicates more severe drought while a high standardized anomaly indicates less severe drought. According to Agnew & Chapel (1999) the drought severity classes are extreme drought (Zi < - 1.65), severe drought (Zi - 1.28 - > - 1.65), moderate drought (- 0.84 - > -1.28) and no drought (> - 0.84). However, Bruins and Berliner (1998) defined drought as a dry period characterized by precipitation that is significantly less than the average amount. The percentage of months with below normal rainfall indicated the frequency of drought.

In addition, the standardized anomaly was used to analyze fluctuations in temperature at the annual scale and to determine the warm (positive) and cool (negative) years on record. Loua et al. (2019) used the standardized anomaly to analyze anomalies in temperature.

3.3.4.2 Trend analysis

3.3.4.2.1 Mann-Kendall (Z) statistical test

Trend analysis of rainfall and temperature was done using Mann-Kendall statistical test. The Mann-Kendall statistical test is used in the analysis of monotonic trends in hydro-meteorological time series and the significance of the trend (Asfaw *et al.*, 2018, Pal et al. 2017). The test was computed using MEKESENS. MEKESENS is an MS excel template developed by the Finnish meteorological department for the detection and estimation of trends (Weldegerima et al. 2018). The Mann-Kendall S test statistic was calculated based on Mann (1945) and Kendall (1957) i.e.

$$S = \sum_{k=0}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad \textbf{(3.4)}$$

Where x_j and x_k are annual values in years *j* and *k* *(j>k)* respectively, and

$$sgn(x_j - x_k) = \begin{cases} 1 = \ \ if\, x_j - x_k > 0 \\ 0 = if\ \ x_j - x_k = 0 \\ -1 = if\, x_j - x_k < 0 \end{cases} \quad \textbf{(3.5)}$$

When the number of observations is equal to or more than 10 (n≥10) as is the case for this study, the S test statistic is approximately normally distributed with the mean, and E(S) becomes 0 (Kendall 1957). Therefore, if n is at least 10 the normal approximation (Z statistic) test is used (Salmi et al. 2002).

In doing this, the variance of S is first computed using the following equation which considers that ties may be present:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n-5) - \sum_{p=1}^{q} t_p\,(t_p - 1)(2t_p + 5)\right] \tag{3.6}$$

Where q is the number of tied groups and t_p is the number of data values in the p^{th} group

The values of S and $VAR(S)$ are then used to compute the Z test statistic i.e.

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if\ S < 0 \end{cases} \tag{3.7}$$

A positive value of Z indicates an upward trend while a negative value of Z indicates a downward trend.

3.3.4.2.2 Sen's slope (Q) estimator test

Sen's slope estimator test was used to estimate the magnitude of the trend (change per unit time) within the time series. The test was also computed using MEKESENS, alongside the Mann-Kendall statistical test.

The Sens slope estimator is a non-parametric test that estimates the magnitude of the trend in a time series. This is by computing both the slope (linear rate of change), such as the amount of change per year and the intercept (Sen 1968). The Sens slope estimator statistic was computed as in Sen (1968).

Firstly, the slopes of the data value pairs are calculated to get the slope estimate Q

$$Q_i = \frac{x_j - x_k}{j - k} \tag{3.8}$$

Where x_j and x_k are considered as data values in the time j and k $(j>k)$ respectively. The median of N values of Q_i is the Sens slope estimator of the slope. If N is odd, the median is computed as:

$$Q = Q_{[(N+1)/2]} \quad (3.9)$$

Moreover, if N is even, the median is calculated as:

$$Q = \frac{1}{2}\left(Q_{[\frac{N}{2}]} + Q_{[(N+2)/2]}\right) \quad (3.10)$$

A positive Sens slope estimator value indicates an increasing trend while a negative trend indicates a decreasing trend in the time series.

3.3.4.3 Correlation analysis

3.3.4.3.1 Kendall's tau-correlation analysis

Kendall's tau-b correlation analysis was used to test the relationship between variables. Kendall rank correlation coefficient is a measure of rank correlation that measures the similarity of the orderings of the data when ranked by each of the quantities in paired observations (Kendall, 1938). The formula for Kendall's Tau-b coefficient is:

$$\tau_B = \frac{n_c - n_d}{\sqrt{(n_0 - n_1)(n_0 - n_2)}} \quad (3.11)$$

Where:

$n_o = n(n-1)/2$

$n_1 = \sum_i t_i(t_i-1)/2$

$n_2 = \sum_j u_i(u_i-1)/2$

n_c = Number of concordant pairs

n_d = Number of discordant pairs

t_i = Number of tied values in i^{th} group of ties for the first quantity

u_j = Number of tied values in j^{th} group of ties for the second quantity

3.4. Results and discussion

3.4.1 Analysis of monthly rainfall

3.4.1.1 Analysis of monthly rainfall amount, trend, and variability

The lowest monthly rainfall was recorded in September of 2015 while the highest was recorded in November of 1997, an *El Niño* year. The monthly rainfall amounts for all the months are positively skewed. This means that the monthly rainfall amount in all the months received in most of the years was below the average monthly rainfall. Moreover, that the extreme rainfall events for all the months lie above the mean monthly rainfall amount. July, August, and October have a platykurtic distribution of monthly rainfall amount and thus a lower probability of extreme rainfall events. On the other hand, the rest of the months have a leptokurtic distribution of monthly rainfall amount and thus have a high probability of extreme rainfall events. The greatest kurtosis, and hence the probability of extremes is observed in January and June. This could be due to spillover effects from the preceding wet OND and MAM seasons respectively, either during extreme high rainfall events or late offsets.

The study area's monthly rainfall is mainly marked by a decreasing trend except for January, February, and November that have an increasing trend in monthly rainfall amounts. The positive trend in monthly rainfall in the normally dry months of January and February indicates the presence of variability in rainfall patterns. Only June, July, and September have a significant trend in monthly rainfall which is negative. The trends in monthly rainfall for the rest of the months were, however, non-significant. Monthly rainfall patterns in the study area are highly variable as shown by the high interannual monthly rainfall variability across all the months. The highest interannual monthly rainfall variability was observed in January (114.0%), and this could be due to the greater occurrence of extreme events. The analysis of the monthly rainfall amount, trend, and variability is shown in Table 3.1.

Table 3.1: Analysis of monthly rainfall amount, trend, and variability, 1981-2018

Analysis of monthly rainfall amount, trend, and variability, 1981-2018										
Month	Monthly rainfall amount (mm)							Trend analysis of monthly rainfall amount, 1981-2018		Interannual monthly rainfall variability (CV)
	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis	Contribution to annual rainfall amount (%)	Mann-Kendall (Z) Test	Sen's slope estimator (Q)	
January	6.52	167.25	27.71	31.593	3.212	11.676	2.70	0.28	0.044	114.0%
February	5.21	59.68	15.78	12.836	2.054	4.114	1.54	0.70	0.064	81.4%
March	12.18	262.74	84.18	61.694	1.208	1.339	8.20	-0.15	-0.201	73.3%
April	89.28	563.27	286.04	102.794	0.828	1.024	27.88	-0.70	-1.151	35.9%
May	23.04	271.08	99.28	54.797	1.139	1.567	9.68	-1.46	-1.109	55.2%
June	1.96	23.04	5.10	4.154	3.021	10.391	0.50	-2.45*	-0.064	81.5%
July	2.61	16.66	9.00	3.301	0.371	-0.376	0.88	-2.59**	-0.136	36.7%
August	3.09	13.35	7.18	2.607	0.618	-0.283	0.70	-1.02	-0.039	36.3%
September	0.82	8.29	2.85	1.583	1.949	4.387	0.28	-2.75**	-0.046	55.6%
October	5.62	275.52	113.71	70.304	0.552	-0.626	11.08	-0.68	-0.753	61.8%
November	36.63	673.81	269.24	115.670	1.267	2.974	26.24	0.53	0.626	43.0%
December	21.16	266.71	105.96	65.420	0.741	0.250	10.33	-0.43	-0.498	61.7%
** Trend is significant at $\alpha = 0.01$ level of significance * Trend is significant at $\alpha = 0.05$ level of significance										

3.4.1.2 Analysis of inter-month standardized rainfall anomaly

Analysis of inter-month standardized rainfall anomaly, that is based on average monthly rainfall amounts of each of the twelve months was done to identify dry and wet months, and thus dry and wet seasons in the study area (Figure 3.2). The wet months were identified to be March, April, and May and called the MAM rain season, which is the long rains season, with the peak rainfall for the season being in April. October, November, and December were also identified as wet months and called the OND rain season, which is the short rains season, with the peak rainfall for the season being in November. The area, therefore, has a bimodal rainfall pattern. This is confirmed by Ongoma (2019) who deduced that Kenya is largely characterized by a bimodal rainfall pattern with the two rain seasons being experienced in March to May (long rains), and October to December (short rains).

Moreover, the dry months were identified to be January and February and called the JF dry season with February being the drier month in the season. June, July, August, and September were also identified as dry months and called the JJAS dry season with September being the driest month in the season. This is in line with Ongoma (2019) who observed that Kenya largely experiences cool and dry conditions from June to August, whereas the entire country experiences hot and dry conditions in January and February. The analysis of inter-month standardized rainfall anomaly is shown in Table 3.2.

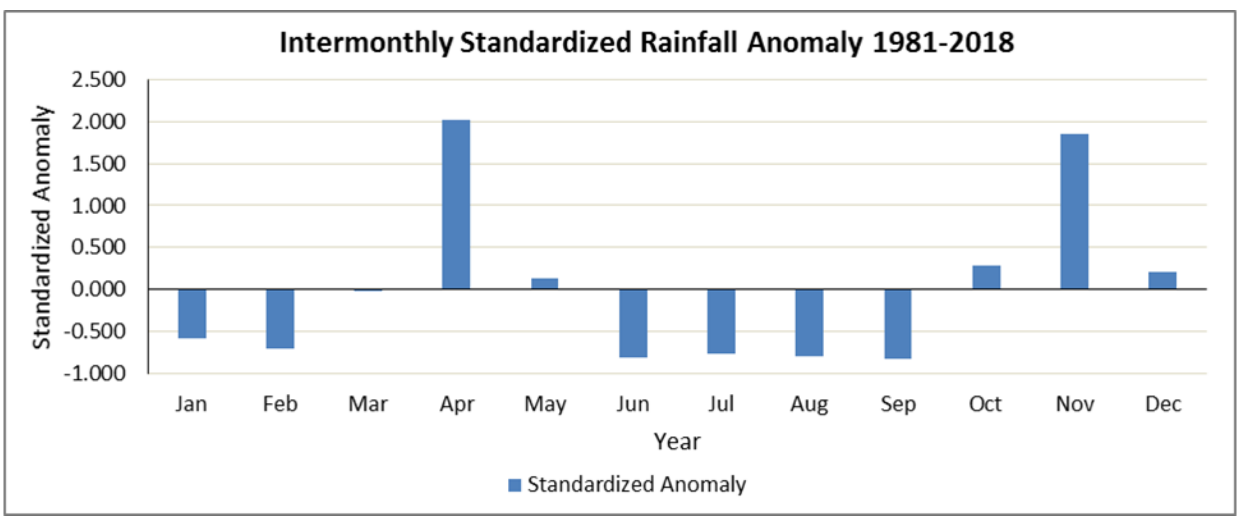


Figure 3.2: Intermonth standardized rainfall anomaly 1981-2018 (Source: Author)

Table 3.2: Analysis of inter-month standardized rainfall anomaly, 1981-2018

Analysis of inter-month standardized rainfall anomaly, 1981-2018												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inter-monthly standardized rainfall anomaly	-0.581	-0.701	-0.013	2.016	0.138	-0.808	-0.769	-0.787	-0.831	0.284	1.847	0.206

3.4.2 Analysis of seasonal rainfall

3.4.2.1 Analysis of the trend of seasonal rainfall amount

The lowest seasonal rainfall amount (11.80 mm) was recorded during JF of 1987, a drought year, while the highest seasonal rainfall amount (1188.72 mm) was recorded during OND of 1997, an *El Niño* year. All the seasons have positively skewed seasonal rainfall amounts. This means that all the seasons received rainfall that was below their average seasonal rainfall amount in most of the years. Moreover, that the extreme rainfall events of all the seasons are above the mean seasonal rainfall amount. JF, MAM, and OND have a leptokurtic distribution of seasonal rainfall and thus a high probability of occurrence of extreme rainfall events. However, JJAS has a platykurtic distribution of seasonal rainfall amount and thus a lower likelihood of extreme rainfall events. The greatest kurtosis and hence the probability of extremes are observed in the JF season which could be due to spillover effects of the preceding OND season during heavy rainfall years. This is particularly observed in the JF season of 1998 following the 1997 OND *El Niño* rainfall season.

The MAM season has a decreasing trend in seasonal rainfall amount that is not significant with the magnitude of the trend being -2.940 mm/year (Figure 3.3). The findings are in line with other studies that found a negative trend in MAM season rainfall in Kenya including (Xu et al. 2017, Opiyo et al. 2014, Ayugi et al. 2016, Gebrechorkos et al. 2019, Feleke & Abera 2020). It also agrees with Gebrechorkos et al. (2019) who observed a decreasing trend in MAM rainfall in Central parts of Kenya, around Kora and Marsabit. However, the magnitude of the negative trend in MAM rainfall differs from Gebrechorkos et al. (2019) who observed a slower magnitude of -1.389 mm/year. The magnitude of the trend in MAM seasonal rainfall also differs with Feleke &

Abera (2020) who found a faster magnitude of -4.705 in the short rainfall season's trend in rainfall.

Likewise, the OND season has a decreasing trend in seasonal rainfall that is not significant with the magnitude of the trend being -0.102 mm/year (Figure 3.3). The finding aligns with Xu et al. (2017) and Ayugi et al. (2016) who found a negative rainfall trend during the OND season in most parts of Eastern Africa. However, other studies found a positive trend in OND rainfall including (Opiyo et al. 2014, Gebrechorkos et al. 2019, Xu et al. 2017). Also, Gebrechorkos et al. (2019) found a faster magnitude (1.389 mm/year) in the positive trend of OND seasonal rainfall in western parts of Kenya and southern parts of Ethiopia.

The MAM season, therefore, has a stronger negative trend of seasonal rainfall amount than the OND season. This could be due to the negative trend in monthly rainfall observed in all the months in MAM including during its peak rainfall month of April whereas November the peak rainfall month in OND has a positive trend in monthly rainfall amount. Furthermore, the study found that the OND season contributes more rainfall to the total annual rainfall compared to the MAM season. The OND could thus be becoming a more significant contributor to annual rainfall and thus the reason why it contributes more annual rainfall as compared to the MAM season. This agrees with Recha et al. (2012) who observed that OND rains are becoming more reliable compared to MAM rainfall seasons in Kenya.

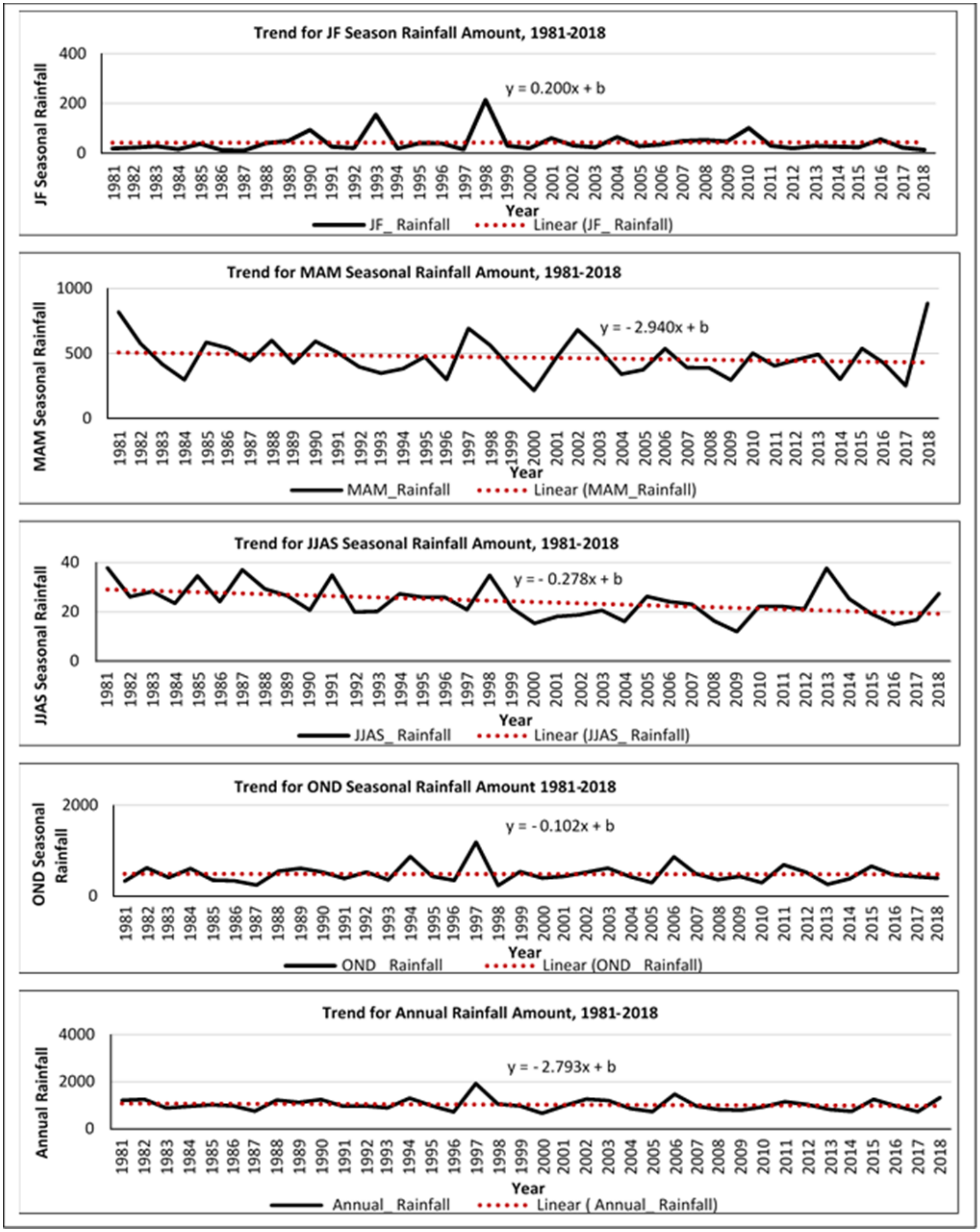


Figure 3.3: Trends in seasonal and annual rainfall amount (mm) 1981-2018 (Source: Author)

This observation however contrasts with Borhara et al. (2020) who concluded that Eastern Kenya is slightly wetter during the MAM season than the rest of the year.

Likewise, the OND season has a decreasing trend in seasonal rainfall that is not significant with the magnitude of the trend being -0.102 mm/year (Figure 3.3). The finding aligns with Xu et al. (2017) and Ayugi et al. (2016) who found a negative rainfall trend during the OND season in most parts of Eastern Africa. However, other studies found a positive trend in OND rainfall including (Opiyo et al. 2014, Gebrechorkos et al. 2019, Xu et al. 2017). Also, Gebrechorkos et al. (2019) found a faster magnitude (1.389 mm/year) in the positive trend of OND seasonal rainfall in western parts of Kenya and southern parts of Ethiopia.

The MAM season, therefore, has a stronger negative trend of seasonal rainfall amount than the OND season. This could be due to the negative trend in monthly rainfall observed in all the months in MAM including during its peak rainfall month of April whereas November the peak rainfall month in OND has a positive trend in monthly rainfall amount. Furthermore, the study found that the OND season contributes more rainfall to the total annual rainfall compared to the MAM season. The OND could thus be becoming a more significant contributor to annual rainfall and thus the reason why it contributes more annual rainfall as compared to the MAM season. This agrees with Recha et al. (2012) who observed that OND rains are becoming more reliable compared to MAM rainfall seasons in Kenya. This observation however contrasts with Borhara et al. (2020) who concluded that Eastern Kenya is slightly wetter during the MAM season than the rest of the year.

The JJAS season has a decreasing trend in seasonal rainfall amount that is significant with the magnitude of the trend being -0.278 mm/year. This finding deviates from Gebrechorkos et al. (2019) who found a significant positive trend in rainfall with a magnitude of 1.667 mm/year during the JJAS dry season in some areas of Western Kenya, Northeastern, and Southwestern Ethiopia, and North-Western Tanzania. The JF season has a positive trend in seasonal rainfall amount that is non-significant, and the magnitude of the trend was 0.200mm/year. The analysis of the trend of seasonal rainfall amount is shown in Table 3.3.

Table 3.3: Analysis of the trend of seasonal and annual rainfall amount, 1981-2018

Analysis of the trend of seasonal and annual rainfall amount, 1981-2018									
Period	Rainfall amount (mm)							Trend analysis of rainfall amount	
	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis	Contribution of seasonal rainfall to annual rainfall amount (%)	Mann-Kendall (Z) Test	Sen's slope estimator (Q)
JF	11.80	214.67	43.18	40.104	2.912	9.660	4.22	0.73	0.200
MAM	216.33	886.62	469.50	146.286	0.831	1.001	45.84	-1.36	-2.940
JJAS	11.93	37.81	24.12	6.656	0.549	- 0.234	2.36	-2.84**	-0.278
OND	232.44	1188.72	487.32	191.687	1.643	3.931	47.58	-0.05	-0.102
Annual	653.47	1918.93	1026.17	249.392	1.234	3.032		-0.93	-2.793
** Trend is significant at α = 0.01 level of significance									

3.4.2.2 Analysis of seasonal rainfall variability

High interannual seasonal and intraseasonal rainfall variability was found in the study area. The JF season has the highest interannual seasonal rainfall variability (92.9%) which could be due to the greater probability of extreme rainfall episodes during the season. MAM and OND also have high inter-annual variability with that of the OND being the higher among the two seasons. Nevertheless, the MAM season has higher intraseasonal variability than the OND season. These findings align with Gichangi et al. (2015) who found a high inter-annual variation in the short and the long rainfall seasons. Camberlin & Philippon (2012) also observed high rainfall variability but with greater interannual variability being observed in the short OND rainfall season than the long MAM rainfall season.

Moreover, the seasonal rainfall is becoming increasingly variable as shown by the positive trend in intraseasonal rainfall variability in all the seasons. JJAS was found to have the strongest trend in intraseasonal rainfall variability. OND has a stronger trend in intraseasonal variability than the MAM season. Therefore, although MAM has greater intraseasonal rainfall variability than OND, this could change in the future given the stronger positive trend in intraseasonal variability observed in the OND season. The analysis of seasonal rainfall variability is as shown in Table 3.4.

Table 3.4: Analysis of seasonal and annual rainfall variability, 1981-2018

Analysis of seasonal and annual rainfall variability, 1981-2018						
Period	Interannual variability (CV)	Intra-annual variability (CV)			Trend analysis of intra-annual rainfall variability (CV), 1981-2018	
		Minimum	Maximum	Median	Mann-Kendall (Z) Test	Sen's slope estimator (Q)
JF	92.9%	1.9%	107.8%	45.0%	0.31	0.001
MAM	31.2%	27.6%	118.0%	81.2%	0.73	0.003
JJAS	27.6%	26.5%	99.8%	57.8%	2.24*	0.006
OND	39.3%	18.5%	139.0%	61.9%	1.62	0.007
Annual	24.3%	100.9%	165.5%	127.05%	1.52	0.004
* Trend is significant is at α = 0.05 level of significance						

3.4.2.3 Analysis of standardized anomaly of seasonal rainfall

All the seasons are marked by low standardized rainfall anomalies which imply high severity of drought. The seasons are also characterized by a higher proportion of seasons having below-average seasonal rainfall amounts, that is dry seasons which means there is a high frequency of droughts (Figure 3.4).

MAM, JJAS, and OND show a decreasing trend in standardized seasonal rainfall anomaly which implies that they are getting drier over time. However, JF shows an increasing trend in standardized rainfall anomaly which means the season is getting wetter. The MAM wet season has a stronger negative trend of standardized seasonal rainfall anomaly ($Z = -1.36$, $P>0.1$) than the OND wet season ($Z = -0.05$, $P>0.1$). This shows that in the future the MAM long rain season could become far much drier and unreliable than the OND short rain season. The analysis of standardized seasonal rainfall anomaly is as shown in Table 3.5.

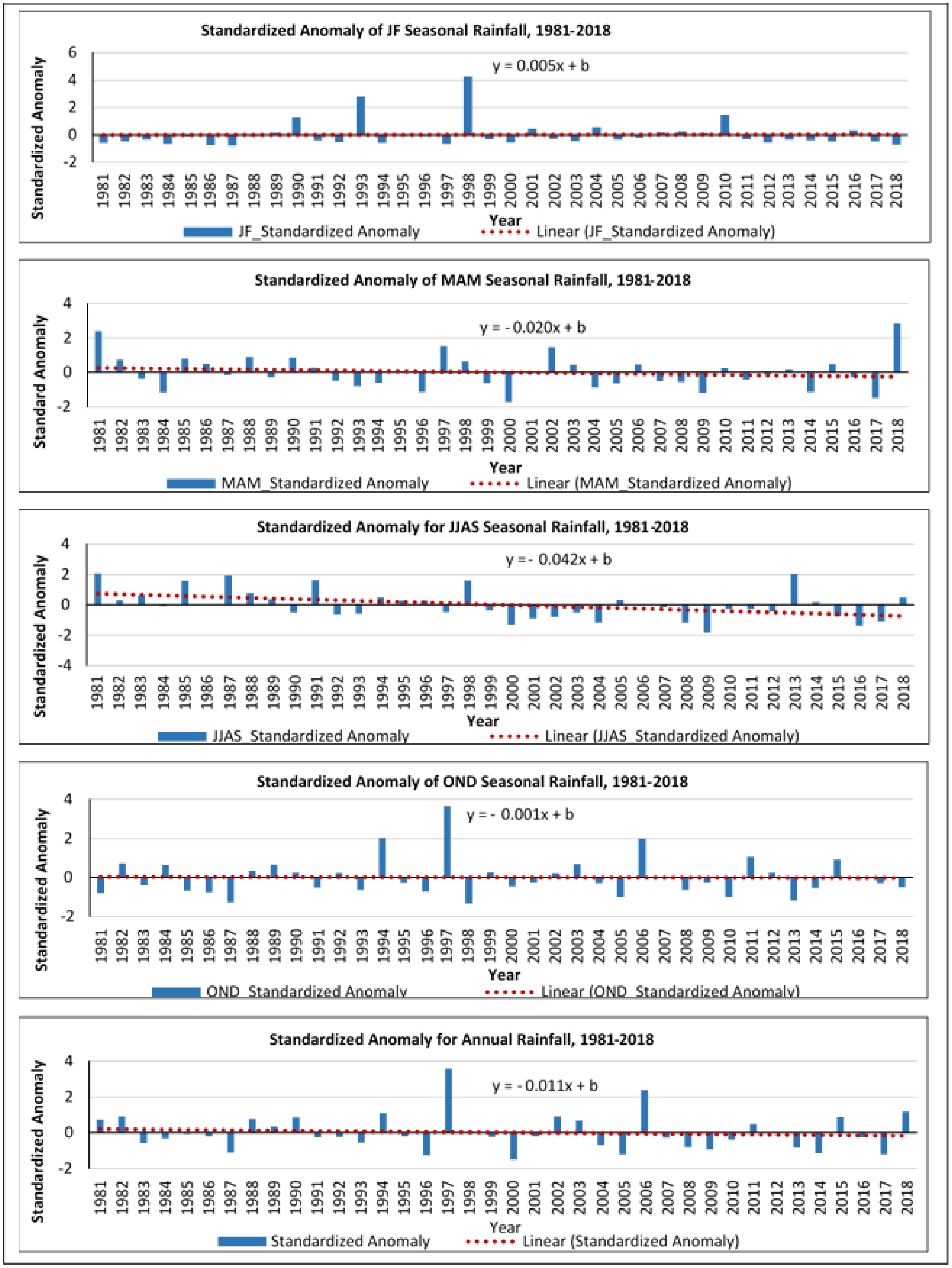


Figure 3.4: Standardized anomaly of seasonal and annual rainfall, 1981-2018 (Source: Author)

Table 3.5: Analysis of standardized anomaly of seasonal and annual rainfall, 1981-2018

Analysis of standardized anomaly of seasonal and annual rainfall, 1981-2018							
Period	Standardized rainfall anomaly			% Of periods with below mean rainfall	% Of periods with above mean rainfall	Trend analysis of standardized rainfall anomaly	
	Minimum	Maximum	Median			Mann-Kendall (Z) Test	Sen's slope estimator (Q)
JF	-0.782	4.277	-0.333	71.1	28.9	0.73	0.005
MAM	-1.731	2.851	-0.139	55.3	44.7	-1.36	-0.020
JJAS	-1.830	2.056	-0.127	55.3	44.7	-2.84**	-0.042
OND	-1.330	3.659	-0.268	57.9	42.1	-0.05	-0.001
Annual	-1.494	3.580	-0.210	63.2	36.8	-0.93	-0.011
** Trend is significant at $\alpha = 0.01$ level of significance							

Furthermore, analysis of standardized anomaly of seasonal rainfall helped to determine the dry and wet seasons over the study period. It also helped understand the fluctuations in seasonal rainfall and hence the cycles of dry and wet seasons (Figure 3.4). According to the analysis, the frequency of occurrence of dry years for the JF season has reduced over time. This is shown by the observation that in the first half of the study period (1981-1999), the JF was marked by a higher number of years (79%) having below-average seasonal rainfall compared to those in the second half of the study period (2000-2018) in which 63% of the year had below-average seasonal rainfall.

The frequency of occurrence of dry years has however increased in the MAM, JJAS, and OND seasons. In the case of the MAM season, the first half of the study period (1981-1999) was marked by a lower number of years (47%) having below-average seasonal rainfall compared to those in the second half of the study period (2000-2018) in which 63% of the years had below-average seasonal rainfall. For the JJAS season, the first half of the study period (1981-1999) was marked by a lower number of years (37%) having below-average seasonal rainfall compared to those in the second half of the study period (2000-2018) in which 79% of the years had below-average seasonal rainfall. Moreover, in the OND season, the first half of the study period (1981-1999) was marked by a lower number of years (53%) having below-average seasonal rainfall compared to those in the second half of the study period (2000-2018) in which 63% of the years had below-average seasonal rainfall.

3.4.3 Analysis of annual rainfall

3.4.3.1 Analysis of the trend of annual rainfall amount

The highest annual rainfall amount was observed in 1997 (1918.93 mm) an Elnino year and the lowest in 2000 (653.47mm) a severe drought year in Kenya. The annual rainfall amount was positively skewed. This means the rainfall amount for most years was below the average annual rainfall amount. Also, that the extreme rainfall events in the case of annual rainfall lie above the average annual rainfall amount. Annual rainfall has a leptokurtic distribution and is thus characterized by a high probability of extreme rainfall events.

Annual rainfall amount had a decreasing trend that was not significant (Figure 3.3). The magnitude of the decrease in annual rainfall was found to be -2.793 mm/year. The findings agree with other studies in the region that found a negative trend in annual rainfall including (Feleke & Abera 2020, Ghebrezgabher et al. 2016). The magnitude of the negative trend of annual rainfall however differs with Feleke and Abera (2020) who found a slower average trend of -2.048mm/year across the six areas studied in semi-arid north-eastern Ethiopia. Moreover, Ghebrezgabher et al. (2016) found the observed non-significant negative trend in annual precipitation, but which had a faster magnitude of −0.3913 mm/year.

The observed negative trend in annual rainfall disagrees with IPCC (2007) whose AR4 climate models show that East Africa will become wetter particularly during the short rains. Also, it is contrary to previous studies that found a positive trend in annual rainfall in the region including (Opiyo et al. 2014, Christensen et al. 2007, Maina & Raude 2017). The analysis of the trend of annual rainfall amount is depicted in Table 3.3 below.

3.4.3.2 Analysis of annual rainfall variability

The lowest intra-annual rainfall variability (100.9%) was observed in 1993 while the highest intra-annual rainfall variability (165.5%) was observed in 2016. Annual rainfall is marked by high interannual and intra-annual rainfall variability. This depicts that the area is marked by high variability in rainfall patterns. This agrees with previous studies that found high interannual and intra-annual variability in annual rainfall including (Opiyo et al. 2014, Asfaw et al. 2018). The annual rainfall is becoming increasingly variable over time as depicted by the positive trend in intra-annual rainfall variability. The analysis of annual rainfall variability is shown in Table 4 below.

3.4.3.3 Analysis of annual precipitation concentration index (PCI)

Annual rainfall in the study area is marked by a very high concentration. The lowest annual precipitation concentration index was observed in 1993 (16) while the highest was observed in 2016 (29). The rainfall in the area is becoming increasingly concentrated as shown by the positive trend in annual PCI. This finding concurs with IPCC (2014) who observed that there has been an increase in extreme weather events globally which is likely to increase further during the 21st century. Other studies in the region have also observed high rainfall concentration including Tura (2017) who also found high PCI values indicating the presence of highly concentrated rainfall for all seasons in Ethiopia's Central rift valley region. The analysis of the annual PCI is shown in Table 3.6.

Table 3.6: Analysis of the annual precipitation concentration index (PCI), 1981-2018

Analysis of the annual precipitation concentration index (PCI), 1981-2018									
Period	Annual PCI			The proportion of seasons per category of PCI				Trend analysis of annual PCI, 1981-2018	
	Minimum	Maximum	Mean	<10	11-15	16-20	>20	Mann-Kendall (Z) Test	Sen's slope estimator (Q)
1981 - 2018	16	29	21	0%	0%	47%	53%	1.48	0.076

3.4.3.4 Analysis of standardized anomaly of annual rainfall

Most of the years are characterized by below-average rainfall (63.2%). The lowest standardized annual rainfall anomaly (-1.494) was observed in 2000 while the highest was observed in 1997 (3.580). The standardized annual rainfall anomaly has a negative trend (-0.93, $P>0.1$) which means there is an increase in the frequency and severity of droughts. This agrees with previous studies which found a positive trend in droughts in Eastern Africa over the last 30-60 years including (Asfaw et al. 2018). The analysis of the standardized rainfall anomaly of annual rainfall is shown in Table 5 below.

Analysis of standardized annual rainfall anomaly helped to determine the dry and wet years in the study period and fluctuations in rainfall and hence cycles of dry and wet periods (Figure 3.4).

A large proportion of the study period was characterized by dry years (63.2%). This mainly involved dry periods of two to five years (mostly three years). The dry periods observed in the study period were (1983-1987, 1991- 1994, 1995-1996, 1999-2001, 2004-2005, 2007-2010, 2012-2014, 2016-2017). The dry period of 1991-1993 continued into 1994 since the MAM season of 1994 was marked by below-average rainfall amount (-0.598). Also, the dry period of 1999-2001 started in 1998 since the OND season of 1998 was marked by below-average rainfall (-1.340). Besides, the dry period of 2007-2010 continued into 2011 since the MAM season of 2011 was marked by below-average rainfall amount (-0.437).

These findings are in line with Mateche (2011) who found that drought in Kenya occurred in 1983/1984, 1995/1996, 1999/2000, 2004/2005, and 2009/2010. Also, Huho & Mugalavi (2010) noted that drought disasters were declared in Kenya in 1992/1993, 1996/1997, 1999/2000, 2005/2006, and 2008/2009. A chronology of droughts in Kenya since 1893 by UNDP (n.d.) identified 1983, 1984, 1987, 1992-1994, and 1999-2000 as drought years that affected the country including its Eastern Region. Uhe et al. (2018) observed that a severe drought occurred in Kenya in 2016/2017 and had severe impacts in 23 of Kenya's 47 counties.

The dry periods are interspersed with a wet period of one to two years (mostly one year). The dry periods therefore often occur after the heavy rain episodes recorded in the study area including 1982, 1990, 1994, 1997/1998, 2002, 2006, 2015, and 2018. These results align with Kilavi et al. (2018) who found that heavy rainfall and thus flood events with particularly high impacts in Kenya occurred in 1997/1998, 2006, 2012, and 2018. Macleod & Caminade (2019) also noted that an Elnino event occurred in Kenya in 2015 during the short rains although it was less intense compared to previous events.

The frequency of occurrence of dry years in the study area is increasing over time. This is confirmed by the observation that the first half of the study period (1981-1999) had fewer dry years, that is number of years having below-average annual rainfall (58%) than the second half period (2000-2018) in which 68% of the years are dry years, that is have below-average annual rainfall.

3.4.4 Analysis of the effect of rainfall variability on rainfall amount, concentration, and drought frequency and severity.

To determine the effect of rainfall variability on rainfall amount, concentration, and standardized anomaly in the study area. The relationship between intra-annual rainfall variability, and annual rainfall amount, annual precipitation concentration index, and annual standardized rainfall anomaly was calculated using Kendall's tau-b correlation analysis

To find out the effect of rainfall variability on rainfall amount in the study area, Kendall's tau-b correlation analysis was used to find the relationship between annual rainfall amount and intra-annual rainfall variability. A negative correlation was found (τb = - 0.14, P = 0.900>0.05). This indicates that rainfall variability is associated with a decrease in rainfall amounts. The negative trend in the MAM, JJAS and OND seasonal rainfall amount could therefore be explained by the corresponding positive trend in intraseasonal variability.

Secondly, to determine the effect of rainfall variability on rainfall concentration in the study area. Kendall's tau-b correlation coefficient was calculated between intra-annual rainfall variability and annual rainfall precipitation concentration index (PCI). A positive correlation was found (τb = 0.996**, P = 0.000<0.05). This indicates that rainfall variability is associated with higher rainfall concentration in the study area. The high PCI in 2016 could thus be due to the high intra-annual variability in the year while the low PCI in 1993 could be due to the lower intra-annual variability observed in the year.

Further, to determine the effect of rainfall variability on drought frequency and severity. Kendall's tau-b correlation coefficient was calculated between intra-annual rainfall variability and annual standardized rainfall anomaly. A negative correlation was found (τb = - 0.14, P = 0.900>0.05). This indicates that rainfall variability is associated with an increase in the frequency and severity of drought in the study area.

3.4.5 Analysis of annual minimum temperature

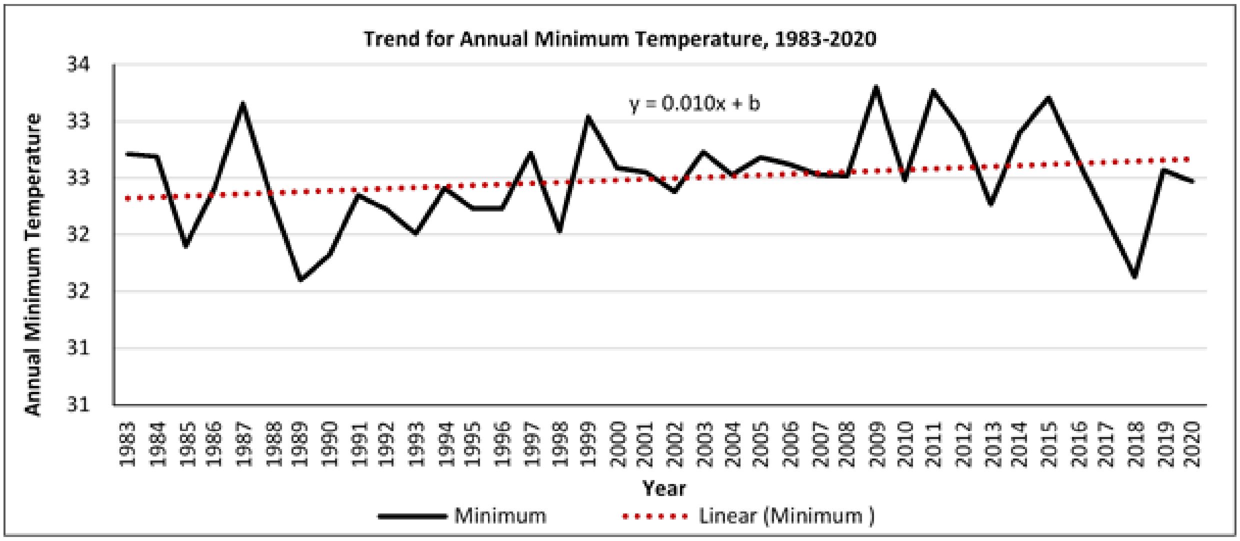
3.4.5.1 Analysis of the trend of annual minimum temperature amount

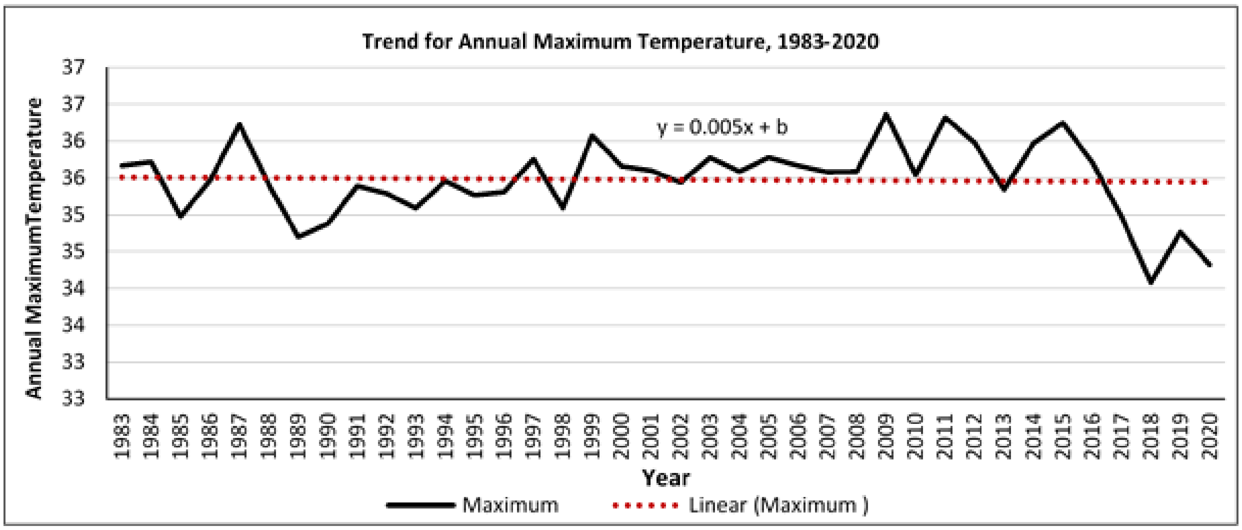
The highest annual minimum temperature was observed in 2009 (33.30 °C) and the lowest annual minimum temperature was in 1989 (31.60 °C). The annual minim temperature is fairly symmetrical but slightly negatively skewed. This means that extreme minimum temperature events in most of the years are below the average annual minimum temperature. However, the annual minimum temperature has a platykurtic distribution and thus has a lower probability of extreme minimum temperature events.

The annual minimum temperature amount had an increasing trend that is not significant (Figure 3.5). The magnitude of the increase in annual minimum temperature was 0.01°C /year. The results agree with other studies that have found a positive trend in minimum temperature in Kenya and the Eastern Africa region including (Asfaw et al. 2018, Gichangi et al. 2015, Gebrechorkos et al. 2019). According to the Government of Kenya (2010), Kenya has experienced a warming trend particularly in minimum temperature which shows a steeper trend than in maximum temperature. The study, however, differs from previous studies in terms of the magnitude of the trends in annual minimum temperature including Gebrechorkos et al. (2019) who found a faster magnitude of 0.038°C/year in Southern Ethiopia and large parts of Kenya and Tanzania. The analysis of the trend of the annual minimum temperature amount is shown in Table 3.7

Table 3.7: Analysis of the trends of annual minimum, maximum, and mean temperatures amount 1983-2020

Analysis of the trends of annual minimum, maximum, and mean temperatures amount, 1983-2020								
Variable	Annual temperatures amount (°C)						Trend analysis of annual temperatures amounts	
	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis	Mann-Kendall (Z) Test	Sen's slope estimator (Q)
Minimum temperature	31.60	33.30	32.49	0.416	-0.084	-0.010	1.45	0.010
Maximum temperature	34.08	36.37	35.48	0.514	-0.609	0.676	0.60	0.005
Mean temperature	32.93	34.63	33.86	0.421	0.069	-0.344	0.99	0.007


Trend for Annual Minimum Temperature, 1983-2020
Annual Minimum Temperature
y = 0.010x + b
Year
Minimum
Linear (Minimum)


Trend for Annual Maximum Temperature, 1983-2020
Annual MaximumTemperature
y = 0.005x + b
Year
Maximum
Linear (Maximum)

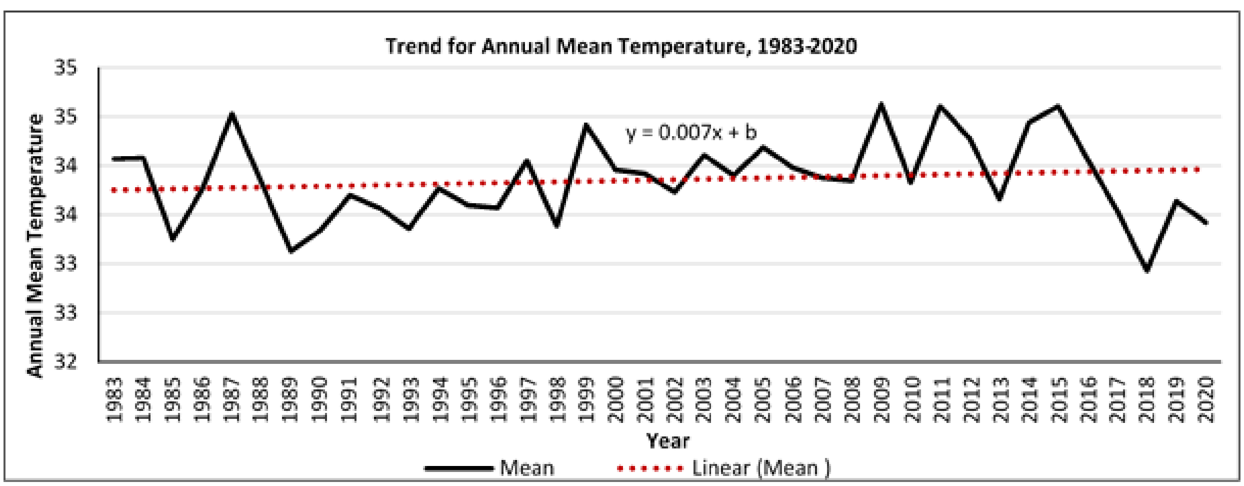

Trend for Annual Mean Temperature, 1983-2020
Annual Mean Temperature
y = 0.007x + b
Year
Mean
Linear (Mean)

Figure 3.5: Trends in annual minimum, maximum, and mean temperatures amount (°C), 1983-2020 (Source: Author)

3.4.5.2 Analysis of annual minimum temperature variability

The study area is marked by interannual and intra-annual variability in annual minimum temperature with the range between the highest and the lowest annual minimum temperature being 1.7°C. This finding is in line with Gichangi et al. (2015) who observed high year-to-year variation in annual minimum temperatures at Katumani meteorological station. A negative trend in intra-annual variability of annual minimum temperature was observed which implies it is becoming less variable over time. This could be due to the observed cooling trends of minimum temperature in the normally hot months, that is i.e. February (Z = - 0.36, $P<0.1$), and March (Z = - 0.18, $P<0.1$), and the warming trends of the coolest months i.e. June (Z = 1.23, $P<0.1$), July (Z = 2.21*, $P<0.05$), and August (Z = 2.89**, $P<0.01$). This could result in lower intra-annual variability between the months in a year as the extreme temperature months move towards the average temperature values. The analysis of annual minimum temperature variability is shown in Table 3.8.

Table 3.8: Analysis of annual minimum, maximum, and mean temperatures variability, 1983-2020

Analysis of annual minimum, maximum, and mean temperatures variability, 1983-2020						
Variable	Interannual variability (CV)	Intra-annual variability (CV)			Trend analysis of intra-annual temperature variability (CV), 1981-2018	
		Minimum	Maximum	Median	Mann-Kendall (Z) Test	Sen's slope estimator (Q)
Minimum temperature	1.3%	2.5%	6.4%	4.9%	-1.16	0.000
Maximum temperature	1.4%	2.6%	5.6%	4.5%	-0.98	0.000

3.4.6 Analysis of annual maximum temperature

3.4.6.1 Analysis of the trend of annual maximum temperature amount

The highest annual maximum temperature was observed in 2009 (36.37 °C) and the lowest annual maximum temperature was in 2018 (34.08 °C). The annual maximum temperature is negatively skewed and thus the extreme maximum temperature events lie below the average annual maximum temperature. The annual maximum temperature had a leptokurtic distribution which means there is a high probability of extreme maximum temperature events.

The annual maximum temperature amount had an increasing trend that is not significant (Figure 3.5). The magnitude of the increase in annual maximum temperature was 0.005°C /year, that is half the increase in minimum temperature. These findings align with other studies that found a positive trend in annual maximum temperature in Kenya and Eastern Africa including (Asfaw et al. 2018, Gebrechorkos et al. 2019, Gichangi et al. 2015). The observed magnitude of the positive trend in annual maximum temperature, the study differs from Gebrechorkos et al. (2019) who observed a faster magnitude of 0.094 °C/year in the increased of maximum temperature in the eastern parts of Ethiopia. The analysis of the trend of annual maximum temperature amount is shown in Table 3.7 below.

3.4.6.2 Analysis of annual maximum temperature variability

The study area is marked by interannual and intra-annual variability in annual maximum temperature with the range between the highest and the lowest annual maximum temperature being 2.3°C. This aligns with Gichangi et al. (2015) who gathered that there was a high year-to-year variation in annual maximum temperatures at Katumani weather station based on analysis of long-term data. A negative trend of intra-annual variability of annual maximum temperature was observed which implies it is becoming less variable over time. This could be due to the observed cooling trends of maximum temperature in the normally hot months, that is February ($Z = -0.59$, $P<0.1$), and March ($Z = -0.38$, $P<0.1$), and the warming trends of the coolest months i.e. June ($Z = 1.08$, $P<0.1$), July ($Z = 2.19^*$, $P<0.05$), and August ($Z = 2.45^*$, $P<0.05$). This could result in lower intra-annual variability between the months in a year as the extreme temperature months move towards the average temperature values. The analysis of annual maximum temperature variability is shown in Table 3.8 below.

3.4.7 Analysis of annual mean temperature

3.4.7.1 Analysis of the trend of annual mean temperature amount

The highest annual mean temperature was observed in 2009 (34.63 °C) and the lowest annual mean temperature was in 2018 (32.93 °C). The annual mean temperature has a fairly symmetrical distribution that is slightly positively skewed. This means the extreme mean temperature events lie above the average annual mean temperature. However, the annual mean temperature has a platykurtic distribution and thus has a lower probability of extreme minimum temperature events.

The annual mean temperature amount had an insignificant positive trend (Figure 3.5). The magnitude of the increase was 0.007°C/year. These findings agree with (Skogseid 2017) who established an increasing trend for Mean temperature in 8 of the 12 regional trends studied in Kenya. Asfaw et al. (2018) also revealed a positive trend in mean temperature using Mann Kendall trend analysis. Other studies that found a positive trend in temperature include (Gebrechorkos et al. 2019, Maina & Raude 2017, Christensen et al. 2007). The observed magnitude of the positive trend in annual mean temperature differs from previous studies including Ghebrezgabher et al. (2016) who found a faster increase in temperature (0.0084 °C /year) in the horn of Africa over the last 85 years. The Analysis of the trend of annual mean temperature amount is shown in Table 3.7 below.

3.4.7.2 Analysis of annual mean temperature variability

The study area is marked by interannual and intra-annual variability in annual mean temperature with the range between the highest and the lowest annual mean temperature being 1.7°C. This agrees with Gichangi et al. (2015) who found high year-to-year variability in mean temperature at Katumani station based on analysis of long-term temperature. It also agrees with Wagesho *et al.* (2013) who found high inter-annual temperature variability in ASAL areas in Eastern Africa. A negative trend of intra-annual variability of annual mean temperature was observed which implies it is becoming less variable over time. This could be due to the observed cooling trends of mean temperature in the normally hot months, that is February ($Z = -0.60$, $P<0.1$), and March ($Z = -0.18$, $P<0.1$), and the warming trends of the coolest months i.e. June ($Z = 1.01$, $P<0.1$), July ($Z = 2.36^*$, $P<0.05$), and August ($Z = 2.69^{**}$, $P<0.01$). This could result in lower intra-annual variability between the months in a year as the extreme temperature months move towards the average temperature values. The analysis of annual mean temperature variability is shown in Table 3.8 below.

3.4.8. Analysis of the relationship between temperature and rainfall amount, variability, concentration, and drought frequency and severity

Kendall's tau-b correlation analysis was used to analyze the effect of temperature on rainfall amount. In doing this, Kendall's tau-b correlation coefficient was calculated between annual mean temperature and annual rainfall amount. A negative correlation was found (τb = - 0.100, P = 0.391>0.05) indicating that increase in temperature contributes to decrease in rainfall amount. This agrees with Huang et al. (2009) who found a negative correlation between annual rainfall and temperature in the Yellow River basin in China. However, Nkuna & Odiyo (2016) found a positive correlation between annual rainfall and annual minimum and maximum temperature in Levubu Sub-catchment in South Africa.

Moreover, to determine the effect of temperature on rainfall variability. Kendall's tau-b correlation coefficient was calculated between annual mean temperature and intra-annual rainfall variability. A positive correlation was found (τb = 0.137, P = 0.241>0.05) indicating increase in temperature is associated with increase in rainfall variability. This aligns with Dai et al. (2004) who revealed that the multi-decadal variability in rainfall observed in West Africa was due to warming. According to IPCC (2014), warming in most parts of Sub-Saharan Africa is expected to lead to an increase in rainfall variability.

To determine the effect of temperature on rainfall concentration. Kendall's tau-b correlation coefficient was calculated between annual mean temperature and annual precipitation concentration index (PCI). A positive correlation was found (τb = 0.131, P = 0.278>0.05) indicating that an increase in temperature is associated with increased irregularity in rainfall distribution. This agrees with Cooley & Chang (2017) who revealed that warming due to climate change was associated with the uneven spatial and temporal distribution of precipitation. In addition, (Chang et al. 2016) noted that the intensity, frequency, and pattern of precipitation could change with increased warming thus enhancing the occurrence of extreme weather events including floods and droughts.

To determine the effect of temperature on drought frequency and severity. Kendall's tau-b correlation coefficient was calculated between annual mean temperature and annual standardized rainfall anomaly. A negative correlation was found (τb = - 0.100, P = 0.391>0.05) indicating that an increase in temperature is associated with an increase in drought frequency and severity. This finding is in line with IPCC (2014) who observed that an increase of 2°C in temperature will lead to an increase in drought thus posing risks to biodiversity and increasing economic losses. Also, an investigation of the impact of climate change on the severity, duration, and frequency of drought in a semi-arid agricultural basin in Khuzestan, Iran (Hosseinizadeh et al. 2015) found that the largest increases in the frequency of extreme droughts occurred in the western portion of the basin in response to the warmer climate scenario

The study also analyzed the relationship between temperature variability and rainfall variability. To determine the relationship, Kendall's tau-b correlation coefficient was calculated between variability in annual mean temperature and intra-annual rainfall variability. A positive correlation was found (τb = 0.326**, $P = 0.005<0.05$) indicating that temperature variability and rainfall variability have a direct relationship. The occurrence of extreme and severe drought events is more frequent in the regions with higher temperature variation compared to areas with lesser temperature variation (Amrit 2018).

3.5 Conclusion

The study area is generally characterized by low rainfall that has a decreasing trend. The rainfall pattern has high variability and is becoming more variable over time. Also, the rainfall has a high and increasing concentration and is marked by a high probability of extreme events. The study area experiences increasingly severe and frequent droughts with most of the years having below-average rainfall. Rainfall variability in the area is thus associated with a decrease in rainfall, more rainfall concentration, extreme rainfall events, and greater frequency and severity of droughts.

Besides, the study area is defined by increasing trends of minimum, maximum, and mean temperature. Minimum, maximum, and mean temperature are marked by variability which however has a decreasing trend. Moreover, an increase in temperature in the area is associated with a reduction in rainfall amounts, greater rainfall variability, more rainfall concentration, and greater frequency and severity of droughts. The findings of the study will improve understanding of local climatic trends and variability, and hence their impacts and vulnerability. This will in turn inform the development and implementation of effective policies, strategies, and programs for response to climate variability. Moreover, it will guide vulnerability analysis and planning of climate variability response actions in development, production, and entrepreneurship activities.

CHAPTER FOUR: ANALYSIS OF INFORMAL MICROFINANCE INSTITUTIONS STRUCTURES IN RELATION TO PERFORMANCE IN THARAKA SOUTH SUBCOUNTY, KENYA

4.1 Abstract

Informal microfinance is the delivery of financial services mainly to low-income people outside the regulation of the monetary authority. Despite their importance in development, no studies have undertaken a detailed analysis of structures and performance in informal microfinance institutions. Therefore, the study aimed to analyze structures of informal microfinance institutions in relation to their performance in Tharaka South Sub County. It used descriptive study design and multistage sampling design. Data analysis was done using thematic analysis, descriptive statistics, and Kendall’s tau-b correlation analysis. The study found that informal microfinance institutions are marked by high levels of performance including high loan repayment performance, outreach, and sustainability. Informal microfinance performance is a function of their structures which determine levels of governance and management, levels of commitment and capacity, and the suitability of the informal microfinance services. Women constitute 79% of the members in informal microfinance institutions. This reflects their great outreach, and contribution to poverty alleviation, financial inclusion, gender equity, and resilience building among vulnerable people.

Key words: Capital, Livelihoods, Informal, Microfinance, Performance, *social*

4.2 Introduction

Informal microfinance involves delivery of small loans and savings mainly to poor and low-income people who have little or no access to formal financial services (Hammil *et al.,* 2008; Thrikawala *et al.,* 2013). Informal microfinance institutions operate outside the regulation of the monetary authority (Owusu-Sekyere *et al.,* 2011). They are a strategy by low-income people to address their financial marginalization from formal financial services (Hammil *et al.,* 2008; Tilakaratna 1996). Informal microfinance institutions include rotational saving and credit associations and accumulated savings and credit associations (Kaburi *et al.,* 2013).

Informal microfinance institutions enable members to mobilize savings and access credit and are mainly marked by low default rates (Osei-Assibey 2011; Gugerty 2007; Swain and Flero 2007).

Besides, they enable members to accumulate capital assets, access essential services and undertake livelihood activities including production and entrepreneurship activities (Appiah *et al.,* 2009; Mushuku and Mayisa 2014; Moser and Gonzalez, 2015).

Despite the vital role of informal microfinance institutions in development, the informal finance sector in Africa has not been clearly defined of which undermines its development (Njeri *et al.,* 2013). Studies analyzing structures of informal microfinance institutions are scanty. Furthermore, no past studies have analyzed performance in informal microfinance institutions. Past studies on microfinance in Tharaka South Subcounty including (Kiplimo *et al.,* 2015; Machira *et al.,* 2014) only focused on the formal microfinance sector. A detailed context specific analysis of informal microfinance institutions is thus imperative to inform efforts aimed at improving their structures and enhancing their performance.

4.3 Theoretical framework

Informal microfinance institutions are founded on social capital which facilitates individuals to cooperate and coordinate their activities in pursuit of shared objectives for mutual benefit through collective action (Putnam 1995; Coleman 1988; Ostrom and Ahn 2009; Bourdieu 1986). Social capital in informal microfinance institutions helps to assess individual's financial risk and viability (Mushuku and Mayisa, 2014) and thus provides social collateral (Chiteji 2002). Mwangi and Ouma (2012) notes that enforcement of contracts in informal microfinance institutions is not based on legal systems but is embedded on social capital. Social capital enables access to private information thus reducing transaction, monitoring and enforcement costs (Mwangi and Ouma 2012) and helping overcome problems associated with asymmetric information, adverse selection, and moral hazard (Gomez and Santor 2001). Besides, Gugerty (2007) observes that informal microfinance institutions enable saving by providing a collective mechanism for individual self-control in the presence of time inconsistent preferences.

4.4 Materials and methods

4.4.1 Study area

Tharaka South Sub County is part of Tharaka Nithi County and lies to the East of Mount Kenya (Figure 4.1). It covers a surface area of 637 KM^2 (Government of Kenya 2019). Tharaka South Sub County has a total population of 75,250 people and a population density of 118 people per

KM^2 (Government of Kenya 2019). The sub county has 18,466 households with the average household size therefore being 4 people per household.

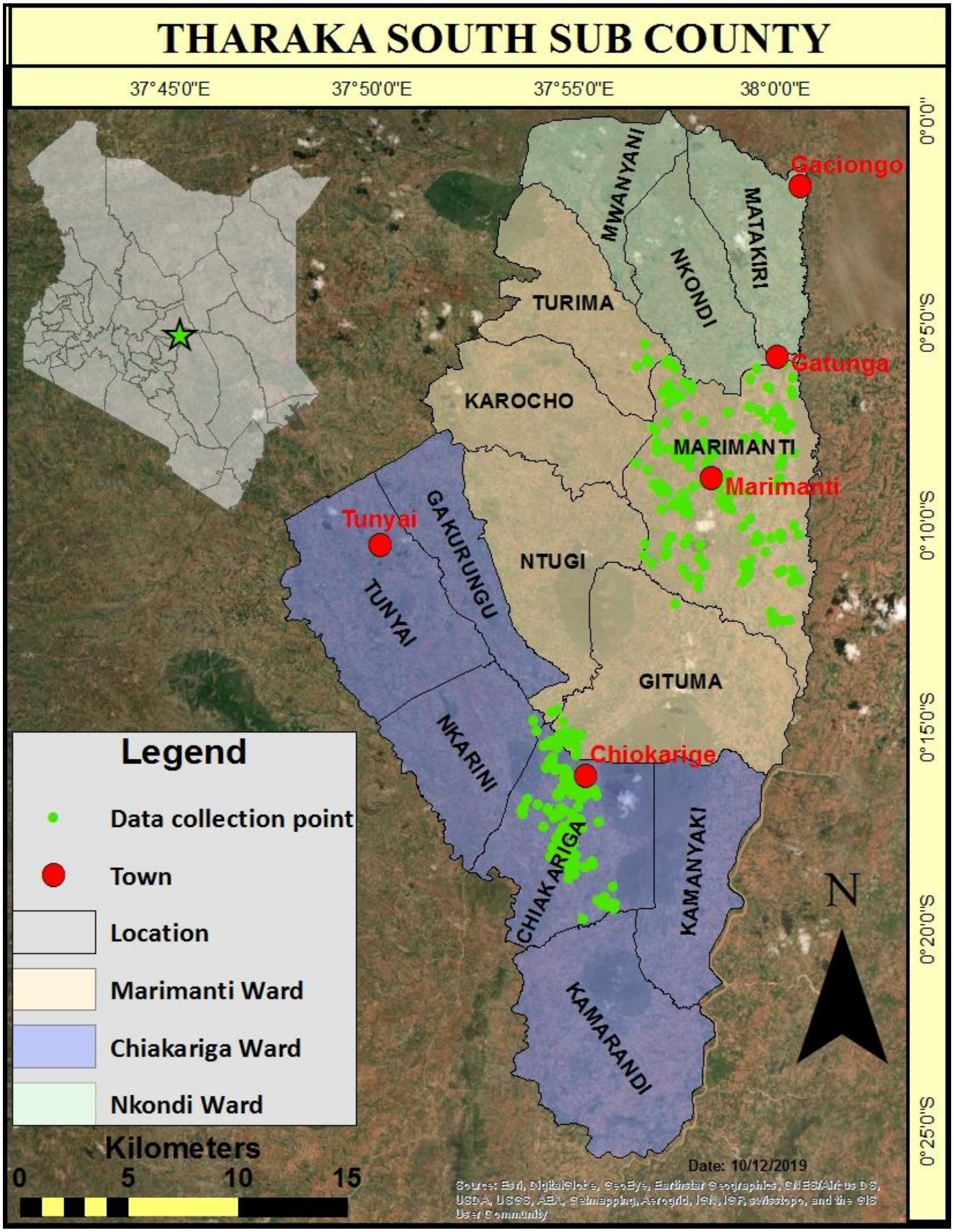


Figure 4.1: Location of the study area in Tharaka South Subcounty (Source: Author)

The subcounty has three main livelihood zones namely the mixed farming zone, marginal mixed farming zone and the rain fed farming zone (Government of Kenya 2008). People in Tharaka South Subcounty are therefore largely agropastoral with farming and animal husbandry accounting for over 70% of their income (Kirraine *et al.,* 2012). Informal microfinance institutions are the main source of financial services in the subcounty. These informal microfinance institutions are accumulated savings and credit associations which are member-based associations in which members engage in savings and lending activities. There are approximately 400 informal microfinance institutions engaged in savings and lending activities in Tharaka South Subcounty.

4.4.2 Data collection

The study used a descriptive study design. It employed multistage sampling design. First, two Locations, that is Marimanti and Chiakariga, were selected randomly for the study. An inventory of informal microfinance institutions was then created based on data sourced from the department of social development. The inventory of 177 informal microfinance institutions served as the sampling frame for the study. The number of informal microfinance institutions to be studied were allocated to the two locations proportionately. The groups to be studied were then chosen by picking every fifth group from the list. This led to a total of Thirty-six study groups, 18 from each study location.

Cochran's' (1963) Equation 1 was used to determine the study's sample sized. This led to a sample size of 385 respondents. The respondents were allocated proportionately to the selected study groups by dividing 365 by the number of study groups (36). This led to eleven respondents being allocated per group. The eleven respondents were then selected systematically from each group with the group's members list serving as the sampling frame. The sampling interval to be used in systematic sampling per group was arrived at by dividing the number of members in the list by 11.

Data collection was done using focused group discussions, key informant interviews, observation, and questionnaire surveys. This was done with the assistance of a mobile based georeferenced data management system called kMACHO. Methodological triangulation was used to cross verify, validate, and harmonize data from different data collection methods. Pilot testing of the data collection instruments was done to check for weaknesses in design and instrumentation. The data collection instruments were evaluated for validity through expert consultation. The instruments were tested for reliability using the Cronbach Alpha method which tests the degree of internal consistency between items (Cronbach, 1951; DeVellis, 2005). A Cronbach alpha of 0.774 was arrived at indicating good reliability.

4.4.3 Data analysis

Qualitative data analysis was done using thematic analysis. Moreover, quantitative data analysis was done using descriptive statistics, and Kendall's tau-b correlation analysis.

4.4.4 Computation of variables

A composite index to measure informal microfinance performance was developed using inductive and hierarchical approaches and called informal microfinance performance. This used three variables including savings (members contribution per month), loan access (total amount of loan borrowed by members) and loan repayment performance (number of delayments in loan repayment).

In developing the index, the negative oriented values were first adjusted for directionality using multiplicative inverse adjustment to ensure higher values always indicate higher loan repayment performance i.e.

$$x_i = 1/x_u \tag{4.1}$$

Where:

x_i = Adjusted value of x

x_u = Unadjusted value of x

The variables were then normalized to ensure comparability of indicators bearing different measurement units and scales. This was done using the Min-Max normalization to yield a standard index value with relative positions in the range of zero to one for each indicator i.e.

$$Zi = xi - min(x)/max(x) - min(x) \tag{4.2}$$

Where:

Z_i = Normalized value of x_i

min(x) = Minimum value of x

max(x) = Maximum value of x

These indicators were then weighted to avoid uncertainty of equal weights given their diversity. This entailed weighting the variables using the pairwise ranking matrix. This first involved allocating the variables ranks based on the number of times a variable was chosen as being more important than the other variables. The inverse of the rank allocated to a variable was then calculated to get its weight.

The member's informal microfinance performance composite index was then calculated using the formula:

$$CI = \sum (wi\ Zi)/n \qquad (4.3)$$

Where:

CI = Composite index

w_i = Weight of variable

z_i = Variable index value

n = Number of variables

The member's informal microfinance performance composite index was tested for accuracy and robustness using uncertainty and sensitivity analysis. Uncertainty analysis was done using the propagation of standard errors approach, that is based on uncertainties of index components. This involved adding their standard errors as a weighted sum in quadrature (squared, weighted, added and then square rooted) as in Kirchner (1995) i.e.

$$U = \sqrt{\sum (wiSi)^2} \qquad (4.4)$$

Where:

U = Uncertainty

w_i = Variable weight

S_i = Standard error of variable index value

Sensitivity analysis was done using multiple regression analysis to determine how components constituting the composite index influence it as in Hamby (1995). In doing this the coefficient of determination (R^2) gave an indication of the amount of variation in the composite index which can be explained by the model's components.

4.4.5 Coding of categorical variables

The categorical variables in the study were coded as illustrated in Table 4.1.

Table 4.1: Coding of variables

Coding of categorical variables		
#	Variable	Coding
1	Gender	1 = Male
		2 = Female
2	Age	1 = 18 -35
		2 = 36-60
		3 = >60
3	Marital status	1 = Married
		2 = Separated
		3 = Single
		4 = Widowed
		5 = Divorced
4	Level of education	1 = None
		2 = Nursery
		3 = Primary uncompleted
		4 = Primary completed
		5 = Secondary uncompleted
		6 = Secondary completed
		7 = Tertiary
5	If head of household	1 = Yes
		2 = No
6	How household is headed	1 = Male headed
		2 = Female headed
7	Group composition by gender	1 = Female and male members
		2 = Female members only
8	If member holds leadership position	1 = Yes
		2 = No
9	Gender of officials	1 = Male
		2 = Female
10	Gender of chairperson	1 = Male
		2 = Female

11	Chairperson leadership positions in other groups	1 = Yes
		2 = No
12	Allowances to officials	1 = Yes
		2 = No
13	If group gets external funding	1 = Yes
		2 = No
14	Follow up of borrowers	1 = Yes
		2 = No

4.5 Results

4.5.1 Membership characteristics

In terms of gender composition, 21% of the members are male while 79% are female. Only 13% of the female members have received post primary school education compared to 16% of the male members. Moreover only 27% of the female members are household heads while 95% of male members are household heads. Female members belong to more groups than male members as confirmed by the Kendall's tau b correlation analysis i.e. (τ_b = 0.161**, P<0.05). Besides, 59% of the female members belong to mixed membership groups and 41.3% belong to female member's only groups.

The members belong to different age categories with 28% aged between 18-35 years, 59% aged between 36-60 years and 13% being over 60 years old. Younger people are more educated since 35% of those aged over 60 years have not attained any formal education compared to only 1.9% for those aged 18-35 years and 6% for those aged 36-60 years. Only 19% of those aged 18-35 years head a household while 49% of those aged 36-60 years and 58% of those aged over 60 years old are household heads. Older members have larger households as affirmed by Kendall's tau b correlation analysis i.e. (τ_b = 0.150**, P<0.05). Younger members belong to more groups than older members i.e. (τ_b = -0.031, P>0.05). Older members have however belonged to informal microfinance institutions for a longer period i.e. (τ_b = 0.201**, P<0.05).

The members have attained different levels of education with 8% having no formal education while 41% have attained nursery school level education. Moreover, 35% have completed primary school, 3% attended primary school but didn't complete and 7% completed secondary school while 5% attended secondary school but did not complete. 1% of the respondents have attained tertiary level education. Similarly, women in male headed households are more educated with 14% having attained post primary education as compared to 11% of those in female headed households. The level of education has a negative correlation with household size (τ_b = -0.093**, P<0.05). Moreover, the level of education has positive correlation with number of informal microfinance institutions belonged to (τ_b = 0.133**, P<0.05).

Most of the members i.e., 81% are married. Moreover, 5% are separated, 7% are single, and 6.2% were windowed while 1% are divorced. The study observes that 69% of the married members are not household's heads with 96% of them belonging to male headed households. Married members have larger households as confirmed by Kendall's tau b correlation analysis i.e. (τ_b = - 0.129**, P<0.05). Non-married members belong to more groups i.e. (τ_b = 0.090, P>0.05). Besides, 65% of those who are married belong to mixed membership groups while 36% belong to female member's only groups.

The study observed that 41% of the members are household heads while 59% were not household heads. Those who are heads of households belong to more informal microfinance institutions (τ_b = 0.057, P>0.05). Further, 81% of the members households are male headed while 19% were female headed. Female headed households have less access to capital assets as measured based on the value of household's crop and livestock production (τ_b = - 0.003, P>0.05). Members from female headed households belong to more informal microfinance institutions (τ_b = 0.091, P>0.05). Members in male headed households have higher formal education with 14% having attained post primary education as compared to 11% of those in female headed households.

In terms of gender composition, 67% of the informal microfinance institutions constitute of mixed membership i.e., both male and female members while 33% constitute female members only. Female members only groups have more members (τ_b = 0.062, P>0.05) and are older (τ_b = 0.248**, P<0.05) than mixed membership groups.

The average member's household size is 6 members. Household has a positive correlation with access to capital assets as measured based on value of the household's crop and livestock production (τ_b = 0.038, P>0.05). The membership characteristics that define the structure of informal microfinance institutions are further illustrated in are further illustrated in Table 4.2.

Table 4.2: Membership characteristics

Informal microfinance institutions membership characteristics			
#	Variable	Statistic	Statistic value
1	Household size	Average	6
		Minimum	1
		Maximum	15
		Standard deviation	2.37
2	Member’s number of groups	Average	2
		Minimum	1
		Maximum	6
		Standard deviation	1.027
3	Member’s years of membership	Average	11
		Minimum	1
		Maximum	41
		Standard deviation	8.857
4	Age of group (years)	Average	12
		Minimum	1
		Maximum	37
		Standard deviation	10.25
5	Number of group members	Average	21
		Minimum	12
		Maximum	42
		Standard deviation	6.629
6	Number of female members	Average	17
		Minimum	5
		Maximum	34
		Standard deviation	7.595
7	Number of male members	Average	5
		Minimum	1
		Maximum	24
		Standard deviation	6.231

4.5.2 Leadership characteristics

The informal microfinance institutions are formed and governed participatorily. This is mainly done through regular group meetings. All the informal microfinance institutions have a strategy which stipulates the group's objectives and the activities to be undertaken. All the informal microfinance institutions have bylaws which are developed by the members. Informal microfinance institutions are however supported by government and non-government organizations in their activities. The groups are overseen and registered by the department of social development.

The informal microfinance institutions are marked by various leadership characteristics that define their structure. The study found 45% of the members interviewed hold leadership positions with 24% of the leader's being male while 76% were female. The informal microfinance institutions have an average of six officials. The average number of female officials is 5 while the average number of male officials is two.

The chairperson in 31% of the informal microfinance institutions is male while 69.4% have female chairpersons. Informal microfinance institutions that are led by female chairpersons have shorter terms of office as confirmed by Kendall's tau b correlation analysis (τ_b = -0.160**, $P<0.05$). Female led informal microfinance institutions also have a smaller number of officials than those that are led by a male chairperson (τ_b = - 0.020, $P>0.05$). Female led informal microfinance institutions have fewer male officials than those led by a male chairperson (τ_b = -0.650**, $P<0.05$). On the other hand, female led informal microfinance institutions have more female officials than those led by a male chairperson (τ_b = 0.619**, $P<0.05$).

Only 21% of the groups that are led by female chairpersons give allowances to officials as compared to 45% of those led by a male chairperson. Female chairpersons have held leadership positions in informal microfinance institutions for a longer period than male chairpersons (τ_b = -0.020, $P>0.05$). Besides, female chairpersons have less education with 12% having no formal education and 23% having attended post primary education as compared to male chairpersons who all have attained some formal education and 27% have attained post primary education. As appertains to the number of leadership positions held in informal microfinance institutions, female chairpersons hold less leadership positions compared to male chairpersons (τ_b = -0.169**, $P<0.05$).

The average period the chairpersons have held leadership positions in informal microfinance institutions is eleven years. The period the chairperson has held leadership positions in informal microfinance institutions is positively related with the length of the group's term of office (τ_b = 0.048, $P>0.05$). It is also positively related to the group's number of officials (τ_b = 0.012, $P>0.05$). Moreover, the period the chairperson has held leadership positions is positively related with the number of leadership positions they hold in informal microfinance institutions (τ_b = 0.163**, $P<0.05$).

Furthermore, 56% of the group chairpersons hold more leadership positions in other informal microfinance institutions. The number of leadership positions which the chairperson holds in informal microfinance institutions has a positive correlation with the term of office of officials (τ_b = 0.068, $P>0.05$). It however has a negative relationship with the number of officials in the informal microfinance institution (τ_b = - 0.100*, $P<0.05$). Besides the number of officials in an informal microfinance institution is negatively related to the length of the term of office (τ_b = - 0.001, $P>0.05$).

The chairpersons in 8% of the informal microfinance institutions have no formal education, 11.1% have attended primary school but not completed while 56% have attended primary school and completed. Chairpersons in 3% of the informal microfinance institutions have attended secondary school education and 14% have attended secondary school and completed. Chairpersons in 8% of the informal microfinance institutions have attended tertiary level of education. The level of education of the chairperson has a negative correlation with the number of group officials (τ_b = - 0.029, $P>0.05$). The level of education of the chairperson also has a negative correlation with the number female officials in a group (τ_b = - 0.085, $P>0.05$). On the other hand, the level of education of the chairperson also has a positive correlation with the number male officials in a group (τ_b = 0.124, $P>0.05$).

Moreover, the level of education of the chairperson has a positive correlation with the term of office for officials (τ_b = 0.006, $P>0.05$). It has a negative correlation with the number of years the chairperson has held leadership positions in informal microfinance institutions (τ_b = - 0.363**, $P<0.05$). In addition, the chairperson's level of educated is negatively correlated to the number of leaderships positions the chairperson holds in informal microfinance institutions (τ_b = - 0.005, $P>0.05$). Chairpersons who are more educated mainly belong to groups that don't give allowances to officials. This is because only 12% of chairpersons who have attained post primary education belong to groups that give allowances compared to 33% of chairpersons who have not attained post primary education.

Officials in 28% of the informal microfinance institutions are paid allowances while 72.2% do not give allowances to their officials. Further, 20% of officials from informal microfinance institutions that give allowances observe the allowances given are adequate while 80% observe the allowances are not adequate. Chairpersons in groups that give allowances to officials have held leadership positions in informal microfinance institutions for a longer period as confirmed by Kendall's tau-b statistical test i.e. (τ_b = - 0.283**, P<0.05). The chairpersons in groups that give allowances to officials also hold more leadership positions in informal microfinance institutions (τ_b = - 0.274**, P<0.05). Furthermore, informal microfinance institutions that give allowances to officials have a higher number of group officials (τ_b = 0.004, P>0.05) and longer terms of office for officials i.e. (τ_b = - 0.321**, P<0.05).

The leadership characteristics that define the structure of informal microfinance institutions are further illustrated in Table 4.3.

Table 4.3: Leadership characteristics

Leadership characteristics			
#	Variable	Statistic	Value
1	Number of officials	Average	6
		Minimum	3
		Maximum	9
		Standard deviation	1.713
2	Number of male officials	Average	2
		Minimum	1
		Maximum	7
		Standard deviation	2.106
3	Number of female officials	Average	5
		Minimum	2
		Maximum	9
		Standard deviation	1.957
4	Term of office (years)	Average	1.7
		Minimum	0.5
		Maximum	6
		Standard deviation	1.094
5	Number of years chairperson has held groups leadership	Average	11
		Minimum	0.5

		Maximum	39
		Standard deviation	11.194
6	Number of leadership positions held by chairperson	Average	1
		Minimum	1
		Maximum	4
		Standard deviation	1.12

4.5.3 Performance in informal microfinance institutions

4.5.3.1 Savings contribution

The average length of the full cycle in the informal microfinance institutions, that is the period between the beginning of the savings and lending cycle and the auction audit date is 14.3 months. The length of the full cycle has a positive correlation with length of the contribution cycle as confirmed by Kendall's tau-b statistical test i.e. (τ_b = 0.162**, P<0.05). It has a negative correlation with the minimum contribution per cycle (τ_b = - 0.122**, P<0.05). The full cycle also has a negative correlation with the amount of money saved per month (τ_b = - 0.187**, P<0.05). Moreover, the length of the full cycle has a negative correlation with the amount of loan borrowed (τ_b = - 0.079, P>0.05).

The average length of a contribution cycle, i.e., regular period after which members make savings, is 1 month. The length of the contribution cycle has a negative relationship with the minimum contribution per cycle (τ_b = - 0.090, P>0.05). It also has a negative relationship with the amount of money saved per month (τ_b = - 0.006, P>0.05). Moreover, the average minimum amount of savings per contribution cycle is KShs 573.12. The minimum amount of savings per contribution cycle has a positive correlation with the amount of money saved per month (τ_b = 0.241**, P<0.05).

The average amount of savings contributed per member per month was KShs 1,670. The amount of savings has a positive correlation with the maximum amount of money borrowable from the informal microfinance institution (τ_b = 0.049, P>0.05). The amount of savings also has a positive correlation with the amount of loan accessed (τ_b = 0.350**, P<0.05). Members in informal microfinance that that don't borrow from external funders contribute more savings as confirmed by Kendall's tau b correlation analysis (τ_b = 0.181**, P<0.05). Furthermore, informal microfinance institutions that have higher savings have better loan repayment performance. This is because the amount of saving has a negative correlation with the number of delayments in loan repayment (τ_b = - 0.039, P>0.05).

The savings contribution characteristics of the informal microfinance institutions are further illustrated in Table 4.4.

Table 4.4: Savings contribution characteristics

Contribution of saving's in informal microfinance institutions			
#	Variable	Statistic	Value
1	Full cycle (Months)	Average	14.34
		Minimum	12
		Maximum	36
		Standard deviation	6.196
2	Contribution cycle (Months)	Average	1
		Minimum	0.25
		Maximum	5
		Standard deviation	0.235
3	Minimum contribution per cycle (Kish's)	Average	573.12
		Minimum	50
		Maximum	2000
		Standard deviation	599.051
4	Savings per month (Kish's)	Average	1670
		Minimum	20
		Maximum	25000
		Standard deviation	2784.884

4.5.3.2 Loan lending

The average number of times members borrowed loans from informal microfinance institutions in year 2018 is 5 times. The number of times a member borrows loans has a negative correlation with the maximum amount borrowable per time as affirmed by Kendall tau b statistical test (τ_b = - 0.069, $P>0.05$). It is however positively correlated to the total amount of loan borrowed (τ_b = 0.353**, $P<0.05$). Members in informal microfinance institutions that don't borrow money from external sources borrow loans more frequently from the group (τ_b = 0.024, $P>0.05$). Informal microfinance institutions whose members borrow loans more frequently have higher loan repayment performance. This is confirmed by the negative correlation observed between the number of times members borrowed loans from the group and the number of delayments in loan repayment i.e. (τ_b = - 0.095*, $P<0.05$).

The average maximum amount of money that a member can borrow from the informal microfinance institutions per time is KShs 19,125. The maximum amount of loan borrowable has a positive correlation with the total amount of loans borrowed (τ_b = 0.208**, $P<0.05$). Informal microfinance institutions that don't borrow money from external sources have a lower maximum amount of loan borrowable from the group per time (τ_b = - 0.116**, $P<0.05$). Informal microfinance institutions that allow members to borrow more money per time have lower loan repayment performance. This is as affirmed by the positive correlation between the maximum amount of loan borrowable per time and number of delayments in loan repayment (τ_b = 0.062, $P>0.05$). Moreover, informal microfinance institutions that allow members to borrow higher amounts of loan per time are marked by higher levels of diversion of borrowed money to other uses other than the intended purpose i.e. (τ_b = - 0.068, $P>0.05$).

The average amount of loans borrowed from informal microfinance institutions per respondent in year 2018 was KShs 27,101. Informal microfinance institutions that don't borrow money from external sources are marked by higher total amounts of loan borrowed by members from the group (τ_b = 0.136**, $P<0.05$). Informal microfinance institutions whose members borrow higher amounts of loans in total have higher loan repayment performance. This is as affirmed by the negative correlation between total amount of loan borrowed and number of delayments in loan repayment (τ_b = - 0.058, $P>0.05$). Moreover, the higher total amount of loan borrowed by members the higher the levels of diversion of borrowed money to other uses other than the intended purpose i.e. (τ_b = - 0.232**, $P<0.05$).

Further, 28% of the informal microfinance institutions seek funding from external sources. This involves seeking funding from government lending programs and programs run by non-government organizations. Additionally, 17% of the informal microfinance institutions operate under umbrella organizations that support them.

The loan lending characteristics of the informal microfinance institutions are further illustrated in Table 4.5.

Table 4.5: Loan lending characteristics

Lending of loans in informal microfinance institutions			
#	Variable	Statistic	Value
1	Number of times loans accessed in 2018	Average	5
		Minimum	1

		Maximum	28
		Standard deviation	5.973
2	Maximum loan borrowable per time (Kish's)	Average	19125
		Minimum	1000
		Maximum	90000
		Standard deviation	24045.153
3	Amount of loans accessed in 2018 (Kish's)	Average	27101
		Minimum	300
		Maximum	360000
		Standard deviation	39232.213

4.5.3.3 Loan repayment

The average interest rate charged on loans by the informal microfinance institutions is 10%. The interest rate has a positive correlation with the total amount of loan borrowed by members as confirmed using Kendall's tau b correlation analysis ($\tau_b = 0.029$, $P>0.05$). Higher interest rates in informal microfinance institutions translate into better loan repayment performance. This is confirmed by the negative correlation between the interest rate charged and number of delayments ($\tau_b = - 0.015$, $P>0.05$).

A grace period prior to beginning of loan repayment is allowed by 58% of the informal microfinance institutions with the average grace period being 19 days. The length of the grace period has a positive correlation with the total amount of loan of loan borrowed ($\tau_b = 0.041$, $P>0.05$). A longer grace period decreases the loan repayment performance. This is confirmed by the positive correlation between the length of the grace period and number of delayments in loan repayment ($\tau_b = 0.113^{**}$, $P<0.05$).

The average maximum loan repayment period allowed to members by the informal microfinance institutions in the study area is 7 months. The loan repayment period allowed by the informal microfinance institution has a negative correlation with the total amount of loans borrowed by members ($\tau_b = - 0.072$, $P>0.05$). Moreover, allowing a longer loan repayment period leads to lower loan repayment performance. This is as confirmed by the positive correlation observed between the maximum loan repayment period allowed and the number of delayments ($\tau_b = 0.011$, $P>0.05$).

Follow up of borrowers is done by 44% of the informal microfinance institutions. Follow up is mainly done through visiting the borrowers and asking for purchase receipts. Informal microfinance institutions that follow up borrowers borrow a higher loan repayment performance. This is confirmed by the positive correlation between follow up of borrowers and the number of delayments in loan repayment (τ_b = -0.067, *P*>0.05).

The study found that 35% of the members had diverted borrowed money to other purposes other than the purpose which they had borrowed the loan in year 2018. Moreover, 1% of the members had defaulted in repaying borrowed loans. Additionally, 31% of the members had delayed in repaying loans borrowed from informal microfinance institutions.

The loan repayment characteristics of the informal microfinance institutions are further illustrated in Table 4.6.

Table 4.6: Loan repayment characteristics

Repayment of loans in informal microfinance institutions				
#	Variable	Statistic	Value	
1	Interest rate (%)	Average	10%	
		Minimum	1%	
		Maximum	20%	
		Standard deviation	3.417	
2	Grace period (days)	Average	19	
		Minimum	7	
		Maximum	60	
		Standard deviation	16.205	
3	Maximum loan repayment period (months)	Average	7	
		Minimum	0.5	
		Maximum	12	
		Standard deviation	5.253	
4	Number of delayments in loan repayment in 2018	1 = 0	265	68.8%
		2 = 1	79	20.5%
		3 = 2	28	7.3%
		4 = 3	10	2.6%
		5 = 4	2	0.5%
		6 = 5	1	0.3%

4.5.4 Calculation of member's performance in informal microfinance institutions using the informal microfinance performance index

The informal microfinance performance index was calculated based on savings, loan access, and loan repayment performance in the past year. This is as presented in (Table 4.7).

The average informal microfinance performance index arrived at was 0.976. The median is 1.021 and the mode is 1.021. The informal microfinance performance index ranges between 1.713 to 0.099 while the standard deviation is 0.189 and the skewness is - 0.951. The informal microfinance institutions are therefore mainly marked by high levels of informal microfinance performance.

The index was then tested for accuracy and robustness using uncertainty analysis and uncertainty of 0.028 arrived at indicating very high certainty. Also, the index was analyzed for sensitivity using multiple regression analysis and a coefficient of determination (R^2) of 1.00 arrived at indicating very high sensitivity.

Table 4.7: Calculation of informal microfinance performance index

<table>
<tr><td colspan="6">Adjustment of the direction of values for number of delayments in loan repayment</td></tr>
<tr><td colspan="3">Number of delayments in loan repayment</td><td colspan="3">Adjusted value</td></tr>
<tr><td colspan="3">5</td><td colspan="3">0</td></tr>
<tr><td colspan="3">4</td><td colspan="3">1</td></tr>
<tr><td colspan="3">3</td><td colspan="3">2</td></tr>
<tr><td colspan="3">2</td><td colspan="3">3</td></tr>
<tr><td colspan="3">1</td><td colspan="3">4</td></tr>
<tr><td colspan="3">0</td><td colspan="3">5</td></tr>
<tr><td colspan="6">Calculation of the household’s climate variability resilience index</td></tr>
<tr><td>Variable</td><td>Total</td><td>Average</td><td>Average variable index value</td><td>Variable weight</td><td>Average weighted variable index value</td></tr>
<tr><td>Amount of savings</td><td>642,879</td><td>1,670</td><td>0.675</td><td>2</td><td>1.35</td></tr>
<tr><td>Loan access</td><td>10,4339,00</td><td>27,101</td><td>0.075</td><td>1</td><td>0.075</td></tr>
<tr><td>Loan repayment performance</td><td>178</td><td>0.5</td><td>0.908</td><td>3</td><td>2.724</td></tr>
<tr><td colspan="5">Average composite index value</td><td>0.976</td></tr>
<tr><td colspan="6">Calculation of accuracy using uncertainty analysis</td></tr>
<tr><td>Variable</td><td>w_i</td><td>S_i</td><td>w_iS_i</td><td colspan="2">$(w_iS_i)^2$</td></tr>
<tr><td>Loan repayment performance</td><td>3</td><td>0.0083</td><td>0.0249</td><td colspan="2">0.00062001</td></tr>
<tr><td>Savings</td><td>2</td><td>0.0056174</td><td>0.0112348</td><td colspan="2">0.00012622073104</td></tr>
<tr><td>Loan access</td><td>1</td><td>0.0055541</td><td>0.0055541</td><td colspan="2">0.00003084802681</td></tr>
<tr><td colspan="4">$\sum(w_iS_i)^2$</td><td colspan="2">0.0007770787</td></tr>
<tr><td colspan="4">$\sqrt{\sum (w_iS_i)^2}$</td><td colspan="2">0.02787613136</td></tr>
<tr><td colspan="6">Calculation of sensitivity using multiple regression analysis</td></tr>
<tr><td colspan="6">Model Summary</td></tr>
<tr><td>Model</td><td>R</td><td>R Square</td><td>Adjusted R Square</td><td colspan="2">Std. Error of the Estimate</td></tr>
<tr><td>1</td><td>1.000</td><td>1.000</td><td>1.000</td><td colspan="2">0.002103415</td></tr>
</table>

4.5.5 Relationship between the structure and performance in informal microfinance institutions

Kendall's tau-b correlation analysis was used to determine the relationship between the structures of informal microfinance institutions and informal microfinance performance. This included analyzing the relationship between informal microfinance performance and, membership characteristics, leadership characteristics, and savings and lending characteristics. The observed relationships were as illustrated in Table 4.8.

Table 4.8: Relationship between the structure and performance in informal microfinance performance

Relationship between membership characteristics and informal microfinance performance			
#	Variable	Coefficient (τ_b)	Sig *(p)*
1	Gender	+ 0.045	0.284
2	Age	- 0.070	0.079
3	Marital status	- 0.074	0.068
4	Level of education	+ 0.144**	0.000
5	If head of household	+ 0.142**	0.001
6	How household is headed	- 0.091*	0.030
7	Household size	+ 0.031	0.391
8	Member's number of groups	+ 0.030	0.442
9	Member's years of membership	- 0.021	0.554
10	Age of group	- 0.005	0.882
11	Number of group members	- 0.065	0.071
12	Group composition by gender	- 0.008	0.854
Relationship between leadership characteristics and informal microfinance performance			
1	If member holds leadership position	- 0.027	0.519
2	Number of officials	+ 0.021	0.573
3	Term of office	- 0.019	0.630
4	Gender of chairperson	+ 0.039	0.347
5	Chairperson level of education	- 0.007	0.849
6	Number of years chairperson has held groups leadership	- 0.040	0.253
7	Number of leadership positions held by chairperson	+ 0.050	0.193
8	Allowances to officials	- 0.016	0.710
Relationship between savings and lending characteristics and informal microfinance performance			
1	Contribution cycle	+ 0.126**	0.002
2	Maximum loan borrowable	+ 0.044	0.129
3	Group access to external funding	+ 0.110**	0.008
4	Interest rate	+ 0.019	0.639
5	Grace period	- 0.051	0.204
6	Loan repayment Period	- 0.038	0.340
7	Follow up of borrowers	- 0.110**	0.008

4.6 Discussion

The study aimed to analyze informal microfinance institutions structures in relation to performance. It found that women are the main participants and perform better in informal microfinance institutions. Women having less income earning opportunities and income levels than men may participate more in informal microfinance institutions to access the more easily accessible and affordable financial services they offer. This is in line with Anderson and Baland (2002) deduced that participation in informal microfinance institutions is higher among women than men in Kenya. Also, Johnson (2005) in a study in Central Kenya noted that women use informal microfinance institutions more due to smaller income streams which are however more consistent as compared to those of men who receive bigger but less regular lump sum earnings. Ritchie (2007) in a study in India, Sri Lanka and Indonesia deduces that low-income earners in rural areas rely more on informal financial organizations due to poor access to formal financial services.

The greater vulnerability among women could also drive them to save more to cushion themselves against future shocks and stresses. This is affirmed by Gedela (2012) who observed that female headed households save more money than male headed households. Past studies including (Tenge and Heller, 2004; Okafor and Akokuwebe, 2015; Obisesan, 2014) observed that women are more vulnerable than men in society due to marginalization, lower access and control over resources, and unfavorable social cultural norms, and thus low adaptive capacity

Women also have better loan repayment performance which could be due to greater prudence in financial management and in undertaking investment. Women are more observant of group rules and more sensitive to peer pressure. Todd (1996) in a study of the Grameen Bank in Bangladesh observes that women have more prudent investment strategies which leads to better performance in informal microfinance institutions. Goertz and Gupta (1996) attribute the greater prudence among women members to their greater sensitivity to peer pressure. The fact that women have less economic opportunities compared to men means that they will observe set rules and repay loans better to safeguard opportunities for accessing informal microfinance services in future. This agrees with Chaudhary and Ishfaq (2003) and Roslan and Abdi Karim (2009) found that male borrowers formed the largest group of loan defaulters. Greater participation in informal microfinance institutions indicates that women have higher more social capital hence better mutual support systems, better access to social collateral and hence higher informal microfinance performance.

Moreover, the study found that informal microfinance institutions differ in terms of leadership characteristics which in turn influence performance. Most informal microfinance institutions are led by female chairpersons with female led groups performing better than men led groups. This aligns with Galema *et al.* (2011) who noted that female leaders are more effective since they spend more time on monitoring activities.

The study found that all informal microfinance institutions have bylaws that govern their activities. These bylaws are developed participatorily by members which reinforces ownership, adherence and thus effectiveness in enforcement. Savings and lending activities are thus based on set terms and conditions which influence informal microfinance performance. These terms and conditions define the saving and lending methodology and hence the nature of contracts in informal microfinance institutions. They also determine the favorableness of the financial services offered by informal microfinance institutions. Moreover, activities of informal microfinance institutions are guided by participatorily formulated strategies. Hunjra *et al.* (2014) in a study in Islamabad, Pakistan concluded that good planning has a significant positive relationship with performance of microfinance institutions.

The study observes that the informal microfinance institutions are marked by high levels of performance. This could be due to the high level of sustainability as indicated by their high dependence on member's savings as lending capital, and low reliance on funding from external sources. According Wambugu and Ngugi (2012) microfinance institutions need to be self-sustaining to achieve their outreach potential and provide adequate financial services to poor people. Besides, Al Azzam and Mimouna (2012) deduced that access to loans from commercial banks has a negative influence on the performance of microfinance institutions by reducing their repayment performance and thus increasing risks.

The informal microfinance institutions have high loan repayment performance as indicated by the low level of default and delinquency. Khandker *et al.* (1998) and (Kereta, 2007) noted that low default rate indicates higher financial sustainability since the microfinance institution will be able to finance future lending activity. Moreover, the informal microfinance institutions have high social performance given the relatively high membership which indicates high outreach and greater participation of women and vulnerable groups in the community. This agrees with Zeller and Meyer (2002) who observed that outreach to the poor is a key determinant of performance in microfinance institutions. Performance in informal microfinance institutions is influenced by their structure and saving and lending characteristics. In addition, Montgomery *et al.* (1997) observed that more members mean reduced costs and financial sustainability due to economies of scale.

The fact that most participants in informal microfinance institutions are women and other vulnerable groups means they are an important policy strategy that that should be considered in formulating of policies aimed at improving their livelihoods. These include policies geared towards gender equity, financial inclusion, poverty alleviation, rural development, social welfare and building resilience to climate change and variability. Microfinance helps address poverty and foster inclusive growth by providing microcredit which enables low-income people to initiate income generating activities, purchase capital assets and cope with economic shocks (Liang *et al.*, 2014).

4.7 Conclusion

Informal microfinance institutions are marked by high levels of informal microfinance performance. This is also depicted by the high repayment performance, outreach, and sustainability. They have well defined structures that determine their performance levels. The characteristics of the members by determining members commitment, resource endowment, and management capacity also affect the informal microfinance performance. The leadership characteristics of informal microfinance institutions influence performance by determining the effectiveness of their governance and management. The savings and lending terms and conditions of a microfinance institution determines the suitability of the informal microfinance institutions and thus performance. The study will inform strategies, policies, and programs for enhancing the structures and performance of informal microfinance institutions and hence their capacity to support livelihoods especially in rural areas.

CHAPTER FIVE: ANALYZING EFFECTS OF CLIMATE VARIABILITY IN THE NEXUS OF INFORMAL MICROFINANCE INSTITUTIONS: A CASE STUDY OF THARAKA SOUTH SUBCOUNTY, KENYA

5.1 Abstract

Climate variability is variation of climate elements from the long-term mean state on all spatiotemporal scales. Climate variability affects microfinance institutions directly and indirectly through physical and transition risks. However, no studies have analyzed the effects of climate variability in relation to informal microfinance institutions. The study, therefore, analyzed the effects of climate variability in relation to informal microfinance institutions. It used a descriptive study design and multi-stage sampling design. Data was analyzed using thematic analysis, descriptive analysis, and Kendall's tau-b correlation analysis. The study found a positive trend in climate variability (Z = 1.52, $P > 0.1$). Local people are highly vulnerable to climate variability as confirmed by 99% of the respondents who observed that climate variability affects their livelihoods. This vulnerability stems from the effect of climate variability on access to capital assets and livelihood strategies. Vulnerability to climate variability has a significant negative effect informal microfinance performance (τ_b = - 0.109**, $P<0.01$). This means informal microfinance institutions should put in place strategies to mitigate, cope, and adapt to climate variability. Nevertheless, climate variability increases participation in informal microfinance institutions. This is shown by the significant positive relationship between climate variability and the number of people who joined informal microfinance institutions (τ_b = 0.239**, $P<0.01$) from 1981 to 2018. This is because informal microfinance institutions help vulnerable households in building resilience to climate variability as observed by 81% of the respondents. The characteristics of informal microfinance institutions have positive or negative relationships with vulnerability to climate variability. These relationships are and could be further leveraged upon to address effects of climate variability on informal microfinance institutions. The study will inform strategies, policies and programs aimed at cushioning informal microfinance institutions against the impacts of climate variability.

Keywords: Capital asset, Climate variability, Informal microfinance institution, Informal microfinance performance, Livelihood strategy, Vulnerability.

5.2 Introduction

Climate variability is the variation of climate elements from the long-term mean state on all spatial and temporal scales (IPCC, 2007; United Nations, 1992). Climate variability in Kenya has been observed to exhibit a generally positive trend in Kenya (Bryan *et al.*, 2013; Mburu *et al.*, 2014) with its effects being associated with the deteriorating livelihoods in rural areas (Muitimba *et al.*, 2010). Just like other economic sectors, microfinance institutions are affected by climate variability (Rippey, 2012) with those in low-income countries being more vulnerable (Campiglio *et al.*, 2018). The impact of climate variability on microfinance institutions is aggravated by the high vulnerability of their clients who mainly earn low incomes, inhabit marginal areas, and largely depend on climate sensitive economic activities (Fenton *et al.*, 2017; Gutierrez and Mommens, 2011). In a study on the dynamics of microfinance and financial vulnerability in Tamil Nadu in India, (Guérin *et al.*, 2009) observed that most microfinance institutions member's households were vulnerable with more than half (57.6%) living below the poverty line per capita and a third (29.5%) living slightly above the poverty line.

The climatic risks facing financial institutions include physical risks and transition risks (Breeden, 2019). Climate events and the underlying socioeconomic trends have the potential to undermine asset values, employment opportunities, crop production, livestock production, business activities and investment returns of microfinance institutions and their clients hence impairing their loan repayment performance, portfolio quality and profitability to a point of insolvency (Fenton *et al.*, 2017; Gutierrez and Mommens, 2011; UNEP, 2002; Dowla, 2018; Piraeus Bank *et al.*, 2002; Drill *et al.*, 2016; Finley and Schuchard, n.d.). Climate variability therefore affects the economic performance of microfinance institutions clients leading to poor loan repayment performance (Dowla, 2018; Moser and Gonzalez, 2015) and hence hindering their social and financial performance (Ibtissem and Bouri, 2013). Moreover, poor loan repayment performance reduces the creditworthiness of microfinance institutions and their members compromising their ability to receive credit as well as stiffening of lending conditions by lenders in the future (Wamalwa, 2020). Further, the negative effects of climate risks on assets of clients of microfinance institutions reduces their credit worthiness and capacity to access loans (Wamalwa, 2020; Doan *et al.*, 2010).

Microfinance institutions are, however, an important tool for addressing vulnerability to impacts climate variability (Rippey, 2012; Recha *et al.*, 2012; Olusola, 2014; Gash and Gray, 2016). Microfinance institutions provide financial services through loans, savings and insurance services to the poor enabling them to undertake productive activities, accumulate assets, stabilize their consumption, manage disasters, and cushion themselves against risk (Dowla, 2018; Hammil *et al.*, 2008; Bueno, 2020; Fernando, 2016; Chirambo, 2020). Microfinance institutions enable households to diversify their income sources (Brannen, 2010), access inputs of crop and livestock production (Recha *et al.*, 2012), and access education and healthcare services (Mushuku and Mayisa, 2014). This is especially true among the poor who are more vulnerable to climate risks and are attracted by microfinance institutions as vehicles for facilitating adaptation due to the more favorable nature of their core structures (Agrawala and Carraro, 2010).

Given the important role of microfinance institutions, there is thus need to put in place measures aimed at cushioning them against the impacts of climate change and variability The financial sector thus addresses climate risks in various ways including integrating the risks into lending decision making processes, capacity building, focus on low risk investments and leveraging on mitigation and adaptation products and services (Piraeus Bank *et al.*, 2002; Finley and Schuchard, n.d; Boston Common, 2015). Microfinance institutions could also make their loan repayments more flexible during extreme climate events to ease the client's repayment burdens without increasing the risk of default (Bueno, 2020; Field and Pande, 2008; Dowla and Barua, 2006).

Nonetheless, very few studies have analyzed the impacts of climate variability on microfinance institutions (Fenton *et al.*, 2017; Moser and Gonzalez, 2015). The risks and opportunities posed by impacts of climate variability on microfinance institutions are not clearly understood and integration of the existing knowledge into their decision-making processes is minimal (Fenton *et al.*, 2017; UNEP, 2002; Finley and Schuchard, n.d; Breitenstein *et al.*, 2019). Besides, the response measures which microfinance institutions could employ in adapting to impacts of climate variability have not been analyzed properly (Bueno, 2020). Microfinance institutions are thus not able to clearly identify nor manage climate risks (Fenton *et al.*, 2017).

Furthermore, no studies have specifically analyzed the impacts of climate variability on informal microfinance institutions. Therefore, the risks and opportunities posed by climate variability on informal microfinance institutions are also not well understood. No studies have also analyzed the response measures that informal microfinance institutions could employ in responding to impacts of climate variability. Additionally, no past studies analyzed how the characteristics of informal microfinance institutions affect vulnerability to climate variability. Understanding the relationship between characteristics of informal microfinance institutions and vulnerability to climate variability is critical to enable leveraging on their structures and activities to cushion the groups and members against the impacts.

The research for study, therefore, analyzed the effects of climate variability in the nexus of informal microfinance institutions in Tharaka South Subcounty in Kenya. This involved analysis of the effects of climate variability on informal microfinance institutions. It also analyzed the relationship between the characteristics of informal microfinance institutions and vulnerability to climate variability and how the relationship could be leveraged on in addressing effects on the groups and members. The study informs actions for cushioning informal microfinance institutions and their members against the effects of climate variability.

5.3 Theoretical framework

The sustainable livelihoods framework provides an analytical framework that conceptualizes how people operate within a vulnerability context (GLOPP, 2008). The vulnerability context frames the external environment in which people exist and highlights their susceptibility to its effects and how they respond (Aniah et al, 2016). The vulnerability context is shaped by different factors including shocks, trends and seasonality which affect access to capital assets and livelihood strategies that convert the capital assets into desirable livelihood outcomes (Moser et al, 2001; Connolly-Boutin and Smit, 2016; DFID, 2000; Saxena et al, 2016; Badjeck, 2009; Nayak and Maharjan, 2013). Climate variability therefore constitutes part of the vulnerability context since it influences the external environment in which people live (DFID, 2004).

The process of accessing assets and converting them into livelihood outcomes through livelihood strategies is mediated by structures and processes (Chambers and Conway, 1992; Ellis, 2000). Structures include households, communities, and community member’s groups such as informal microfinance institutions (DFID, 2000; FAO, 2008). The effect of shocks, trends, and seasonality on access to capital assets and livelihood strategies thus affects the activities of structures and their effectiveness in delivering the desirable livelihood outcomes. According to (Finley and

Schuchard, n.d.; Piraeus Bank et al, 2002; UNEP, 2002; Gutierrez and Mommens, 2011; Drill et al, 2016; Fenton et al, 2017), climate events and the underlying socioeconomic trends negatively affect asset values, production activities, business activities, and investment returns of microfinance institutions hence impairing their loan repayment performance, sustainability, and profitability.

On other hand, structures, and processes by mediating access to assets, livelihood strategies and thus, livelihood outcomes have an influence on vulnerability to effects of climate variability. Therefore, transforming structures and processes have a direct positive or negative feedback on the vulnerability context by either enhancing or restricting access to capital assets and livelihood strategies (DfID, 1999). Agrawal and Perrin (2008) observed that local organizations greatly influence vulnerability to climate risks and how impacts are distributed across different social groups and populations.

5.4 Materials and methods

5.4.1 Study area

Tharaka South Subcounty is part of Tharaka Nithi County and covers a surface area of 637 KM^2 (Government of Kenya, 2019). The subcounty has a total population of 75,250 people living in 18,466 households. The population density is 118 people per KM^2 (Government of Kenya, 2019). The subcounty has three main livelihood zones namely the mixed farming zone, marginal mixed farming zone, and the rainfed farming zone (Government of Kenya, 2008). The people are largely agropastoralists with farming and animal husbandry accounting for over 70% of their income (Kirraine *et al.*, 2012).

Tharaka South Subcounty lies in a semiarid area characterized by a bimodal rainfall pattern and a temperature range of 24^o to 37^o Celsius, at times rising to 40^o Celsius (Government of Kenya, n.d; Government of Kenya, 2016; Kabui, 2012). The subcounty falls in the dry/savannah climatic zone in the Köopen-Geiger climate classification (Köopen, 1936). The main agroecological zone is intermediate lowland 5 with the main vegetation type being the Northern acacia-commiphora bushland and thicket. Proximity of the area to Mount Kenya means that the local climate is influenced by the *El Nino*/Southern oscillation, intertropical convergence zone, latitude and altitude, and sea surface temperatures among other factors (Odingo *et al.*, 2002). Climate patterns in the area are also influenced by the Indian Ocean Dipole which is responsible for driving climate variability in East Africa (Behera *et al.*, 2005; Marchant *et al.*, 2007). The study area is shown in Figure 5.1.

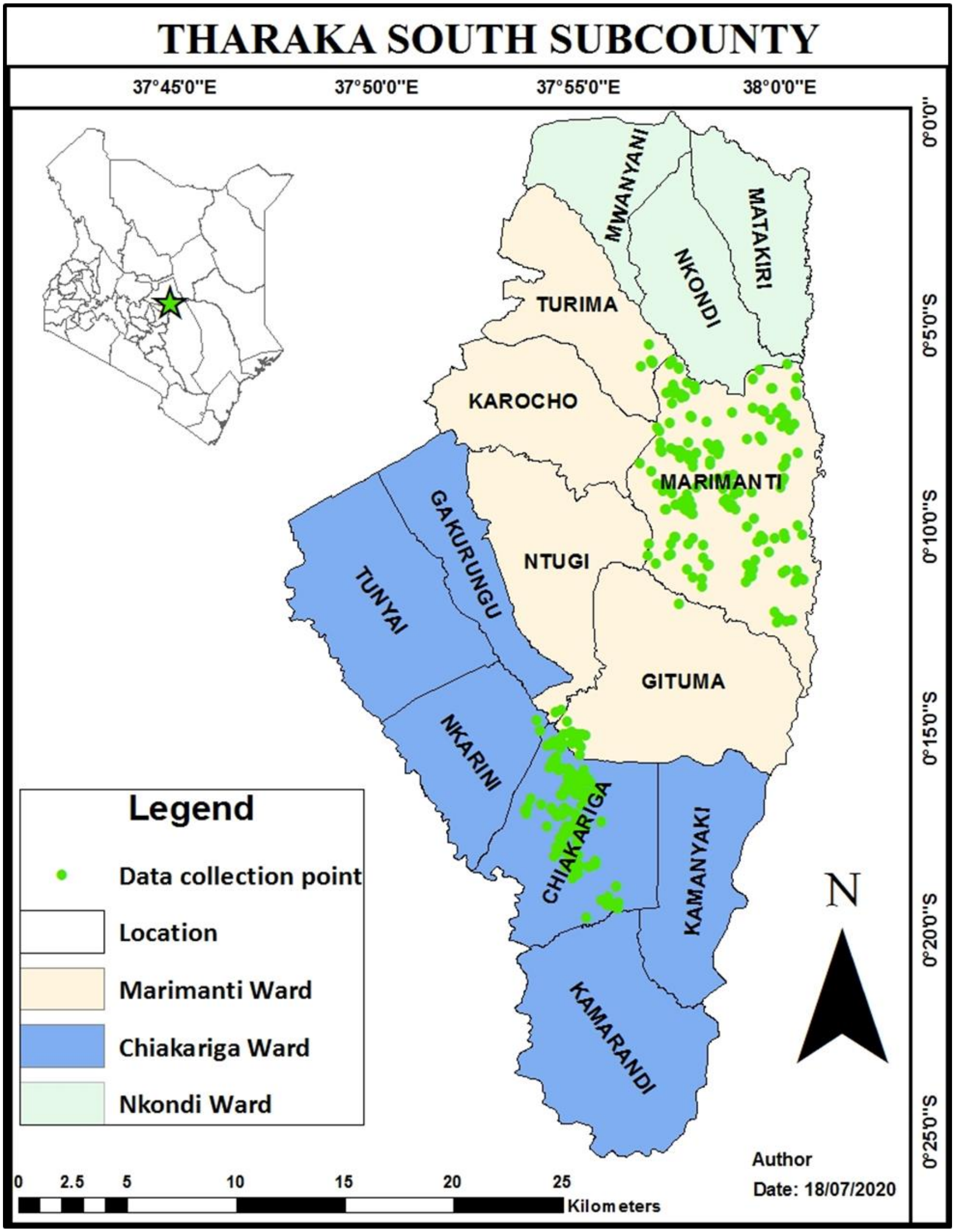


Figure 5.1: Location of the study area in Tharaka South Sub County (Source: Author)

5.4.2 Data collection

The study used a descriptive study design and employed the multistage sampling design. This first involved random selection of two locations, Marimanti and Chiakariga, in Tharaka South Sub County for the study. Then 177 informal microfinance institutions in the two locations were identified based on data at the department of social development and listed to form a sampling frame. The number of informal microfinance institutions to be studied were then distributed proportionately per study location. They were then selected systematically by picking every fifth group from the list. A total of 36 informal microfinance institutions, 18 from each location, were chosen for the study. The study's' sample size was determined using Cochran's Equation 1 (Robb, 1963) and a sample size of 385 respondents arrived at.

The total number of respondents (385) was then divided by the number of groups selected for the study, 36, to determine the number of respondents to interview per group and a figure of eleven gotten. The eleven respondents were then systematically chosen from each of the selected informal microfinance institutions using the group's member's lists as sampling frames. In choosing the respondents, the sampling interval was determined by dividing the total number of members by 11 for each informal microfinance institution selected for the study.

The study used both primary and secondary data. Primary data was collected through observation, questionnaire surveys, 2 focused group discussions, and 17 key informant interviews. Data collection was done with the assistance of a mobile-based georeferenced data collection system called kMACHO. This is an application system that allows a user to collect geographical location specific information. In doing this the data collection tools were first coded and uploaded into Android based mobile phones which were used to collect data. The data was then sent to an online data base and accessed through the kMACHO web portal.

Methodological triangulation was used to validate and harmonize data from different data collection methods. This helped increase the credibility and validity of the results. Pilot testing of the data collection instruments was done to check for weaknesses in design and instrumentation. The instruments were tested for reliability using the Cronbach Alpha method to test the degree of internal consistency between items. Cronbach's alpha is a measure used to assess the reliability, or internal consistency of a scale or test, expressed as a number between 0 and 1 with a higher score indicating greater reliability (Cronbach, 1951; DeVellis, 2005) and 0.7 indicating an acceptable reliability (Nunnaly, 1994). A Cronbach alpha of 0.784 was arrived at indicating good reliability. The instruments were evaluated for validity through expert consultation.

5.4.3 Calculation of variables

5.4.3.1 Calculation of climate variability

Climate variability was measured using the coefficient of variation. This was based on the annual rainfall of the last 38 years, i.e., from 1981 to 2018. Rainfall data was sourced from Climate Hazards InfraRed Precipitation with Station data (CHIRPS). CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and drought monitoring. The calculation of coefficient of variation used the formula.

$$CV = \frac{SD}{\overline{x}} \tag{5.1}$$

Where:

CV = Coefficient of variation

SD = Standard Deviation

$\overline{x}$ = Mean

Climate variability was also analyzed based on local people's perceptions.

5.4.3.2 Calculation of informal microfinance performance index

A composite index was calculated to measure informal microfinance performance and called informal microfinance performance index. The composite index was calculated using savings, loan access, and loan repayment performance (measured using the number of loans delayments in loan repayment) in the past one year as indicators.

In calculating the informal microfinance performance index, the negative oriented values were first adjusted for directionality using a multiplicative inverse adjustment to ensure higher values always indicate higher loan repayment performance, i.e.

$$x_i = 1/x_u \tag{5.2}$$

Where:

x_i = Adjusted value of x

x_u = Unadjusted value of x.

The variables were then normalized to ensure the comparability of indicators bearing different measurement units and scales. This was done using the Min-Max normalization to yield standard index values with relative positions in the range of zero to one for each indicator, i.e.

$$Zi = xi - min(x)/max(x) - min(x) \quad (5.3)$$

Where:

Z_i = Normalized value of x_i

min(x) = Minimum value of x

max(x) = Maximum value of x.

These indicators were then weighted to avoid the uncertainty of equal weights given their diversity. This entailed weighing the variables using the pairwise ranking matrix. This allocated weights according to the number of times a variable was chosen as being more important than the other variables. The inverse rank was then calculated to get the weight of a variable.

The member's informal microfinance performance composite index was then calculated using the formula:

$$CI = \sum (wi\ Zi)/n \quad (5.4)$$

Where:

CI = Composite index

w_i = Weight of variable

z_i = Variable index value

n = Number of variables.

The member's informal microfinance performance composite index was tested for accuracy and robustness using uncertainty and sensitivity analysis. Uncertainty analysis was done using the propagation of the standard errors approach i.e., based on uncertainties of index components. This involved adding their standard errors as a weighted sum in quadrature (squared, weighted, added and then square rooted) as in (Kirchner, 1995), i.e.

$$U = \sqrt{\sum (wiSi)^2} \tag{5.5}$$

Where:

U = Uncertainty

w_i = Variable weight

S_i = Standard error of variable's index value.

Sensitivity analysis was done using multiple regression analysis to determine how components constituting the composite index influence it as in (Hamby, 1995). In doing this the coefficient of determination (R^2) indicated the amount of variation in the composite index which can be explained by the model's components.

5.4.3.3 Calculation of perception-based climate variability vulnerability index

A composite index was calculated to measure the impact of climate variability and called perception-based climate variability vulnerability index. The composite index was calculated based on the perception of the effect of climate variability on household's access to education, health, crop production, and livestock production as indicators.

The perception-based climate variability vulnerability index was calculated using the procedure used in calculating the informal microfinance performance index.

5.4.3.4 Data analysis

Qualitative data was analyzed using thematic analysis whereas quantitative data was analyzed using descriptive statistics and Kendall's tau-b correlation analysis.

5.5 Results

5.5.1 Analysis of climate variability based on rainfall variability

The inter-annual rainfall variability for 1981—2018 is 0.25. This depicts a high inter-annual rainfall variability. The minimum intra-annual rainfall variability is observed in 1993 (100.9%) and the highest in 2016 (165.5%). The median intra-annual rainfall variability was 127.1%. The area has a positive non-significant trend for intra annual rainfall variability ($Z = 1.52$, $P>0.1$). The local climatic patterns are thus becoming more variable overtime.

This trend is confirmed by local people's perceptions of climate variability. Local people have perceived climate variability as witnessed by the fact that 87% of the respondents said local climatic patterns have changed to a high extent while 14% said climatic patterns have changed to a low extent. The changes observed include a decrease in rainfall amounts (56%) and erratic rainfall patterns (39%). Based on Kendall's tau-b statistical analysis, annual rainfall amounts depict a decreasing negative non-significant trend (τ_b = - 0.107, $\alpha>0.05$) meaning that rainfall amounts are decreasing over time with the rainfall pattern being nonlinear and unpredictable. A negative relationship was observed between intra-annual rainfall variability and total annual rainfall amount (τ_b = - 0.014, $\alpha>0.05$) meaning climate variability leads to a decrease in rainfall amounts.

Local people have also observed an increase in the severity, frequency, and length of droughts. Based on Kendall's tau-b statistical analysis, a non-significant negative trend (τ_b = - 0.107, $\alpha>0.05$) was observed for the percentage of normal precipitation along the years indicating increasing severity of droughts Further, a negative relationship between intra-annual rainfall variability and annual Percentage of normal precipitation which was not statistically significant (τ_b = -0.014, $\alpha>0.05$) was observed meaning climate variability causes an increase in drought severity. Local people have also perceived higher temperatures and erratic temperature regimes (5%), an increase in evapotranspiration rates and a decrease in streamflow. Furthermore, a negative relationship was observed between intra-annual rainfall variability and average annual NDVI (τb = - 0.95, $\alpha>0.05$) meaning climate variability leads to a decrease in the condition of the vegetation. This is confirmed by 72% of the respondents who observed that climate variability is caused by environmental degradation especially deforestation.

5.5.2 Calculation of perception-based climate variability vulnerability index

The household's perception-based climate variability vulnerability index was calculated based on the perception of the effect of climate variability. This perception of effect of climate variability on household's access to education, health, crop production, and livestock production as indicators. This is as presented in Table 5.1.

The mean household's perception-based climate variability vulnerability index arrived at was 2.256. The median was 2.500 while the mode was 2.500. The household's perception-based climate variability vulnerability index ranged between 0.000 and 2.500 while the standard deviation is 0.498 and the skewness is - 2.164. Local households are thus marked by high vulnerability to climate variability.

The index was then tested for accuracy and robustness using uncertainty analysis and uncertainty of 0.059 arrived at indicating very high certainty. Further, the index was analyzed for sensitivity using multiple regression analysis and a coefficient of determination (R^2) of 0.979 arrived at giving an indication of very high sensitivity.

Table 5.1: Calculation of perception-based climate variability vulnerability index

Calculation of perception-based climate variability vulnerability index					
Variable	Percentage of households affected	Median impact score	Average variable index value	Variable weight	Average weighted variable index value
Effect on health	88.3%	2	0.888	4	3.553
Effect on access to education	86.8%	2	0.868	3	2.604
Effect on crop production	96.9%	2	0.969	2	1.938
Effect on livestock production	93.0%	2	0.932	1	0.932
Average composite index value					2.256
Calculation of accuracy using uncertainty analysis					
Variable	w_i	S_i	w_iS_i		$(w_iS_i)^2$
Effect on health	4	0.01607389	0.06429556		0.0003145557639184
Effect on access to education	3	0.01729944	0.05189832		0.0026934356188224
Effect on crop production	2	0.00886786	0.01773572		0.0003145557639184
Effect on livestock production	1	0.01280582	0.01280582		0.0001639890258724
$\sum(w_iS_i)^2$					0.003486536172532
$\sqrt{\sum (w_iS_i)^2}$					0.05904689807
Calculation of sensitivity using multiple regression analysis					
Model Summary					
Model	Model	Model	Model		Model
1	1	1	1		1

5.5.3 Calculation of informal microfinance performance index

The informal microfinance performance index was calculated based on savings, loan access, and loan repayment performance in the past year. This is as presented in (Table 5.2).

The average informal microfinance performance index arrived at was 0.976. The median is 1.021 and the mode is 1.021. The informal microfinance performance index ranges between 1.713 to 0.099 while the standard deviation is 0.189 and the skewness is - 0.951. The informal microfinance institutions are therefore mainly marked by high levels of informal microfinance performance.

The index was then tested for accuracy and robustness using uncertainty analysis and uncertainty of 0.028 arrived at indicating very high certainty. Also, the index was analyzed for sensitivity using multiple regression analysis and a coefficient of determination (R^2) of 1.00 arrived at indicating very high sensitivity.

Table 5.2: Calculation of informal microfinance performance index

Adjustment of the direction of values for number of delayments in loan repayment	
Number of delayments in loan repayment	Adjusted value
5	0
4	1
3	2
2	3
1	4
0	5

Calculation of the household’s climate variability resilience index					
Variable	Total	Average	Average variable index value	Variable weight	Average weighted variable index value
Amount of savings	642,879	1,670	0.675	2	1.35
Loan access	10,4339,00	27,101	0.075	1	0.075
Loan repayment performance	178	0.5	0.908	3	2.724
Average composite index value					0.976

Calculation of accuracy using uncertainty analysis				
Variable	w_i	S_i	w_iS_i	$(w_iS_i)^2$
Loan repayment performance	3	0.0083	0.0249	0.00062001
Savings	2	0.0056174	0.0112348	0.00012622073104
Loan access	1	0.0055541	0.0055541	0.00003084802681
$\sum(w_iS_i)^2$				0.0007770787
$\sqrt{\sum (w_iS_i)^2}$				0.02787613136

Calculation of sensitivity using multiple regression analysis				
Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	1.000	1.000	0.002103415

5.5.4 Effect of climate variability on performance in informal microfinance institutions

To determine the effect of climate variability on informal microfinance performance. Kendall's tau-b correlation analysis was used to calculate the relationship between perceptions-based climate variability vulnerability index and informal microfinance performance index. A significant negative correlation (τ_b = - 0.109**, P<0.01) was found. This indicates that an increase in climate vulnerability leads to a decrease in performance in informal microfinance institutions.

Climate variability has a negative effect on member's loan repayment performance in informal microfinance institutions. This is illustrated by the negative correlation found between perception-based climate variability vulnerability index and loan repayment performance (τ_b = - 0.169**, P<0.01). Climate variability negatively affects loan access in informal microfinance institutions as depicted by the negative correlation between perception-based climate variability vulnerability index and loan access (τb = - 0.021, P>0.05).

Climate variability leads to a decrease in the sustainability of informal microfinance institutions. This is as shown by the positive relationship between perception-based climate variability vulnerability index and the ability of the informal microfinance institutions to fully meet their financial needs (τb = 0.012, P>0.05) when if informal microfinance institutions can fully meet their financial needs is coded as 1 = Yes, 2 = No. Moreover, 75% of the members said that lack of adequate funds to undertake activities is one of the challenges that informal microfinance institutions face. Additionally, 61.1% of the informal microfinance institutions said they have problems in fully meeting their financial requirements.

Informal microfinance institutions and their members mainly invest in climate-sensitive activities which aggravates vulnerability to effects of climate variability. This is as portrayed by the fact that 68% of the groups that engage in joint investment activities invest in climate-sensitive activities including crop and livestock production, agribusiness, and tree seedlings production. Further, 11.1% of the members said that the effect of harsh climate conditions on investments is one of the challenges faced by informal microfinance institutions in their activities. Problems facing informal microfinance institutions in their activities are associated with climate risks including fluctuations in the market and prices of products (3%), lack of raw materials for activities such as basketry (3%), and lack of adequate infrastructure (6%).

Effects of climate variability on activities undertaken by informal microfinance institutions and their member's leads to low returns on investments which causes loan delinquency and loan default. Lack of money to repay loans was identified as the cause of loan delinquency by 98% of those who delayed in repaying their loans while 80% of those who defaulted in repaying their loans attributed it to lack of money to repay the loan.

Response actions to impacts of climate variability such as migration also undermine loan repayment performance as shown by 3% of the delinquent members who attributed this to having traveled from the area when they were supposed to repay. In addition, response actions to impacts climate variability including health issues, food insecurity, and unfavorable conditions for crop productions cause members to divert the use of borrowed loans. Those who had diverted the use of loans to other purposes said they had used the money to address health issues (53%), to buy food (11%), to respond to emergencies (8%) and due to occurrence of unfavorable climatic conditions that couldn't allow the success of agricultural activities they had planned to invest the loans in (5%). Diversion of borrowed loans leads to a decrease in loan repayment performance as confirmed by Kendall's statistical test (τ_b = - 0.040, P>0.05).

5.5.5 Effect of climate variability on participation in informal microfinance institutions

Further, the effect of climate variability on participation in informal microfinance institutions was determined by using Kendall's tau-b correlation analysis to calculate the relationship between intra-annual climate variability and the number of informal microfinance institutions formed per year from 1981 to 2018. The results of the analysis indicated there is a positive correlation (τ_b = 0.137, P>0.05) between intra-annual climate variability and the number of informal microfinance institutions formed per year.

Additionally, Kendall's tau-b correlation analysis was used to determine the relationship between intra-annual climate variability and the number of people who joined informal microfinance per year from 1981 to 2018. A positive significant correlation (τ_b = 0.239*, P<0.05) was found between intra-annual climate variability and the number of people who joined informal microfinance institutions per year.

A positive relationship was found between perception-based climate variability vulnerability index and the number of informal microfinance institutions belonged to as confirmed by Kendall's statistical test (τ_b = 0.002, P>0.05). Participation in informal microfinance institutions helps in responding to climate variability as observed by 81% of the respondents. Climate variability is thus associated with greater participation in informal microfinance institutions.

5.5.6 Relationship between characteristics of informal microfinance institutions and member's vulnerability to climate variability.

The informal microfinance institutions were characterized based on their structures and activities (Table 5.3).

Table 5.3: Characteristics of the informal microfinance institutions

Characteristics of the informal microfinance institutions			
#	Variable	Classes	Value
1	Number of groups a member belongs to	Average	2
		Standard deviation	1.03
2	Member's years of group membership	Average	11
		Standard deviation	8.86
3	Age of group in years	Average	12
		Standard deviation	10.25
4	Number of members in the group	Average	21
		Standard deviation	6.63
5	Group composition by gender	1 = Female and male members	66.7%
		2 = Female members only	33.3%
6	Number of group officials	Average	6
		Standard deviation	1.71
7	Length of term of office in years	Average	1.7
		Standard deviation	1.09
8	If the group gives allowances to officials	1 = Yes	27.8%
		2 = No	72.2%
9	Number of group meetings per month	Average	2
		Standard deviation	1.46
10	Number of trainings attended by officials	Average	1
		Standard deviation	1.27
11	Number of trainings attended by members	Average	0.27
		Standard deviation	0.86
12	If group gets external support	1 = Yes	27.8%
		2 = No	72.2%
13	Belonging of group to an umbrella support organization	1 = Yes	16.7%
		2 = No	83.3%
14	Ability of the group to fully meet its financial needs	1 = Yes	39.5%
		2 = No	60.5%

15	Length of savings contribution cycle in months in month's	Average	1
		Standard deviation	0.24
16	Length of full cycle in months i.e., period between start of cycle to the auction audit date	Average	13.42
		Standard deviation	7.32
17	Minimum savings contribution per cycle (Kish's)	Average	573.12
		Standard deviation	599.05
18	Maximum loan amount lendable per time (Kish's)	Average	19125
		Standard deviation	24045.15
19	Loan interest rates (%)	Average	10
		Standard deviation	3.42
20	Length of the grace period in days	Average	19
		Standard deviation	16.21
21	Loan repayment period in months	Average	7
		Standard deviation	5.25
22	Follows up of loan borrowers	1 = Yes	44.4%
		2 = No	55.6%
23	Group engagement in other activities other than just savings and lending	1 = Yes	80.6%
		2 = No	19.4%
24	Group members engagement in joint investment	1 = Yes	22.2%
		2 = No	77.8%
25	Group use of mobile money services	1 = Yes	27.8%
		2 = No	72.2%

The relationship between the characteristics of informal microfinance institutions and vulnerability to climate variability was then analyzed. In doing this, Kendall's tau-b correlation analysis was used to determine the relationship between characteristics of informal microfinance institutions and perception-based climate variability vulnerability index (Table 5.4).

Table 5.4: Relationship between informal microfinance institutions characteristics and perception-based climate variability vulnerability index

Relationship between informal microfinance institutions characteristics and perception-based climate variability vulnerability index			
#	Variable	Coefficient (τ_b)	Sig *(p)*
1	Number of groups a member belongs to	+ 0.044	0.336
2	Member's years of group membership	- 0.027	0.502
3	Age of the group in years	- 0.050	0.225
4	Number of members in the group	+ 0.024	0.557
5	Group composition by gender	- 0.014	0.779
6	Number of group officials	+ 0.022	0.619
7	Length of term of office in years	+ 0.017	0.715
8	If the group gives allowances to officials	+ 0.060	0.219
9	Number of group meetings per month	+ 0.073	0.115
10	Number of trainings attended by officials	- 0.072	0.114
11	Number of trainings attended by members	- 0.066	0.166
12	If group gets external support	+ 0.013	0.794
13	Belonging of group to an umbrella support organization	+ 0.045	0.354
14	Ability of the group to fully meet its financial needs	+ 0.012	0.808
15	Length of savings contribution cycle	+ 0.001	0.979
16	Length of full cycle	- 0.048	0.311
17	Minimum savings contribution per cycle	- 0.062	0.141
18	Maximum loan amount lendable per time	- 0.033	0.423
19	Loan interest rate	+ 0.059	0.206
20	Length of loan grace period	- 0.004	0.931
21	Loan repayment period	+ 0.005	0.905
22	Follow up of loan borrowers	+ 0.119**	0.014
23	Group engagement in other activities other than just savings and lending	+ 0.060	0.218
24	Group members engagement in joint investment	+ 0.100*	0.040
25	Group use mobile money services	+ 0.063	0.198
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).			

5.6 Discussion

The study aimed to analyze the effects of climate variability in the nexus of informal microfinance institutions in Tharaka South Subcounty. The analysis shows that climatic variability in the study area has a nonlinear positive trend which means climatic patterns are becoming increasingly erratic and unpredictable. Climate variability manifests through a decrease in rainfall amounts; and more severe, frequent, and longer droughts. This concurs with Ogalleh *et al.* (2012) who in a case study of Laikipia, Kenya found that local farmers had perceived an increase in the variation of climatic conditions through decrease in rainfall amounts and increase in temperature levels. Besides, Recha *et al.* (2012) in a study on climate-related risks and opportunities for agricultural adaptation and mitigation in semi-arid Eastern Kenya who observed that the frequency and intensity of droughts have increased to almost being an annual phenomenon. According to the Government of Kenya (2012a), the climate projection for Kenya includes longer and more frequent dry spells interspersed with intense but unpredictable rainfall episodes.

The decrease in rainfall amounts coupled with an increase in the frequency of above-normal temperatures events have led to an increase in evapotranspiration rates and reduction in streamflow levels. The area is thus not only experiencing an increase in meteorological drought but also an increase in agricultural and hydrological drought. This is confirmed by (Parry *et al.*, 2012; Ncube *et al.*, 2016) who observe that climate variability leads to water insecurity and could further worsen its scarcity through higher evaporation and altered rainfall patterns. Additionally, an analysis of the impact of climate change on food production in the Nile Basin of Ethiopia by Yesuf *et al.* (2008) deduced that farmers in African countries have already perceived an increase in temperatures. Climate variability in the area leads to a decline in the condition of the vegetation. This finding agrees with Bryan *et al.* (2013) who in a study of thirteen arid and semi-arid divisions in Kenya found that 96% of the farmers attributed lack of pastures to climate variability. According to the World Bank (2004), climate change will have an impact on forests and trees of which are depended upon directly by more than one billion of the 1.2 billion extremely poor people making them even more vulnerable.

The analyses also show that climate variability has a negative effect on informal microfinance performance due to the negative effect of loan repayment performance and sustainability.

Besides, negative effect on informal microfinance performance is brought about by negative effects on assets, and production and entrepreneurship activities of groups and members which is aggravated by high dependence on climate-sensitive economic activities. It could also be due to adoption of response actions that negatively affect the assets, and production and entrepreneurship activities of groups and members.

This finding concurs with Gutierrez and Mommens (2011) who observed that climate variability impacts microfinance institutions directly through effects on their operations and indirectly through impacts on the client's loan repayment capacity. Further, Fenton *et al.* (2017) found that the vulnerability of microfinance institutions to climate risks mainly emanates from the exposure, sensitivity, and low adaptive capacity of their client's livelihoods. Moreover, Moser and Gonzalez (2015) gathered that climate change affects the loan portfolio of microfinance institutions indirectly by increasing disease incidences which affects the health and hence economic productivity of clients. According to Breeden (2019), climate risks affect financial institutions through physical risks which entail damage on their resources and infrastructure and transition risks which manifest in terms of reevaluation of assets, destabilization of markets, and stiffer financial conditions. Additionally, Piraeus Bank *et al.* (2002) notes that the need to address climate risks could increase the cost of doing business hence reducing competitiveness and loan repayment capacity.

In addition, the analysis found that climate variability has a negative effect on informal microfinance performance due to negative effects on loan access. Member's access to loans is affected by poor loan repayment performance which impairs their creditworthiness and increases their financial burdens thus affecting future access to credit. Negative effects of climate variability on member's capital assets endowment also affect their capacity to access loans. Climate variability has a negative effect on the sustainability of informal microfinance institutions which could have a negative effect on their capacity to lend loans to members. Negative effects of climate variability could thus reduce their capacity to provide financial capital thus affecting member's ability to undertake production and entrepreneurship activities and accumulate assets. A study by Wamalwa (2020) observed that loan default reduces a debtor's credit score and subjection to high interest rates during future borrowing thus their ability to access loans in the future. An evaluation of individual and group lending in Kenya by

Kodongo and Kendi (2013) found that loan default is the single biggest threat to microfinance profitability and sustainability.

Further, the calculations show that vulnerability to climate vulnerability is positively associated with participation in informal microfinance institutions. This could be because vulnerable people, who mainly constitute low-income earners participate more in informal microfinance institutions as a strategy to cushion themselves against future risks and due to marginalization by formal financial institutions. People thus join and form informal microfinance institutions in response to climate variability. Besides, Lasagni and Lollo (2011) observed that economically vulnerable people are more likely to participate in informal microfinance institutions since they tend to be more involved in insurance tools and saving solutions. A study of resilience in vulnerable households in Niger by Catholic Relief Services (2012) gathered that informal microfinance institutions cushion members against shocks and stresses through consumption smoothing and risk pooling during hardship periods.

The analysis found that the characteristics of informal microfinance institutions affect the groups and member's vulnerability to the effects of climate variability. Participation in more informal microfinance institutions is associated with higher vulnerability to impacts of climate vulnerability. Informal microfinance institutions that have more members have greater vulnerability to impacts of climate variability. Participation in informal microfinance institutions for more years is associated with greater vulnerability to climate variability. Similarly, older informal microfinance institutions are less vulnerable to impacts of climate variability. Women only informal microfinance institutions are also marked with higher vulnerability to climate variability.

Having more officials and a longer term of office in an informal microfinance institution leads to greater vulnerability to climate variability. On the other hand, giving allowances to officials is associated with less vulnerable to impacts of climate variability. Training of officials and training of members is also associated with lower vulnerability to impacts of climate vulnerability. However, informal microfinance institutions that hold more meetings have greater vulnerability to impacts of climate vulnerability.

Informal microfinance institutions that receive external support and belong to umbrella organizations have less vulnerability to impacts of climate vulnerability. Likewise, the ability of an informal microfinance institutions to fully meet its financial needs and thus sustainability is associated with less vulnerability. Informal microfinance institutions that have a longer savings contribution cycle and a shorter full cycle are marked by higher vulnerability to climate variability. A higher minimum contribution per cycle is however associated with lower vulnerability to climate variability.

Informal microfinance institutions that give larger loans per lending are less vulnerable to impacts of climate variability while higher loan interest rates are associated with higher vulnerability. A longer grace period leads to less vulnerability to impacts of climate variability whereas a longer loan repayment period is associated with higher vulnerability. Follow up of borrowers in an informal microfinance institution leads to lower vulnerability to impacts of climate variability.

Informal microfinance institutions that engage in diverse activities other than just savings and lending have less vulnerability to climate variability. Likewise, informal microfinance institutions whose members invest jointly as a group are associated with less vulnerability to climate variability. Also, informal microfinance institutions that use mobile money services in their financial activities have less vulnerability to impacts of climate variability.

The characteristics of informal microfinance institutions could be affecting their vulnerability to climate variability by creating conditions that either enhance or constrain their social and financial performance and thus capacity to address effects of climate variability. Unfavorable savings and lending conditions and governance structures in informal microfinance institutions could increase member's vulnerability to climate variability through influence on informal microfinance performance. The characteristics of informal microfinance institutions could also influence member's access to capital assets and thus outcomes of livelihood strategies.

These finding align with the previous observations that vulnerability is mediated by structures of which include community-based member's groups (Chambers and Conway, 1992; Ellis, 2000; FAO, 2008). Robinson and Berkes (2011) also noted that institutional arrangements that promote participation are likely to strengthen adaptive capacity among those involved. On the other hand, Scheyvens *et al.* (2012) revealed that microfinance schemes can be a risk to participants if their terms and conditions are very rigid especially in the backdrop of higher climate risks since this may impede the participant’s ability to repay loans forcing them to sell off productive assets to repay and into a downward spiral of poverty.

The climate variability response strategies mentioned by members during the focus group discussions and key informants during interviews align with these relationships. These include reducing their financial burden in the contribution of savings by reducing the minimum amount of savings contributed per cycle, suspending savings contributions until conditions improve, and increasing the length of the contribution cycle. Further, informal microfinance institutions use available savings to survive through harsh periods.

Also, that informal microfinance institutions increase the loan repayment period, allow members to make repayments in kind and some allow borrowers a grace period. They analyze loan requests based on set criteria, follow up on borrowers, and employ various enforcement measures to enhance loan repayment. Informal microfinance institutions also recover loans from member’s savings, defer loan repayment to the next installment, suspend loan repayments until conditions improve, and announce an early auction audit date to start a new cycle at an optimal time. Some use mobile money transfer services enabling members to make payments even when they migrate in response to impacts of climate variability.

Besides, that members support each other to repay loans during hardships or borrow loans from other groups to repay. To address lack of financial capital, informal microfinance institutions seek support from external agencies, conduct fundraising events, and engage in income-generating activities to diversify their income sources. They also facilitate access to training to enhance member’s management and adaptive capacity.

Informal microfinance institutions thus address vulnerability to climate variability by leveraging on their characteristics to integrate climate risks into their decision-making processes. This includes setting savings and lending terms and conditions that ease the financial burden of vulnerable members in savings and lending activities. This finding is supported by Breitenstein *et al.* (2019) who deduced that there is need for microfinance institutions to climate-proof their activities by adjusting their loan conditions, introducing flexibility in savings products, developing disaster management strategies, participating in climate policy-making processes, and leveraging on investment opportunities offered by response activities.

5.7 Conclusion

Climate variability in Tharaka South Subcounty has a positive trend and manifests through erratic climatic patterns and increasing severity and frequency of extreme weather events. Climate variability has direct or indirect negative effects on performance in informal microfinance institutions. This involves negative effects on access to capital assets and livelihood strategies which in turn negatively affects loan repayment performance, sustainability, and loan access in informal microfinance institutions. Climate variability, however, has a positive association with participation in informal microfinance institutions. This is because informal microfinance institutions are the major source of financial services among vulnerable households and help in building resilience to climate risks. Vulnerability to effects of climate variability is affected by the characteristics of informal microfinance institutions which create conditions that enhance or constrain their social and financial performance and member's access to capital assets and outcomes of livelihood strategies. The informal microfinance institutions thus leverage on their characteristics to address challenges associated with vulnerability to the effects of climate variability. The study will inform strategies, policies, and programs aimed at cushioning informal microfinance institutions against the impacts of climate variability.

CHAPTER SIX: INFORMAL MICROFINANCE INSTITUTIONS AND RURAL HOUSEHOLDS' CLIMATE VARIABILITY RESILIENCE; AN ANALYSIS OF THE CONTRIBUTION AND DETERMINANTS IN THARAKA SOUTH SUB COUNTY, KENYA

6.1 Abstract

The study analyzed the contribution of informal microfinance institutions to rural household's climate variability resilience and the underlying determinants based on the sustainable livelihood's framework. The study employed a descriptive and multistage sampling design. Data analysis was done using thematic analysis, descriptive statistics, and Kendall's tau-b correlation analysis. Informal microfinance institutions contribute to rural household's climate variability resilience by enabling access to capital assets. This is shown by their positive and significant contribution to access healthcare (τb = 0.372**, $P<0.01$), education (τb = 0.448**, $P<0.01$), inputs of crop production (τb = 0.447**, $P<0.01$), and inputs of livestock production (τb = 0.473**, $P<0.01$). Moreover, there was a positive and significant relationship between rural household's climate variability resilience and the contribution of informal microfinance institutions to the resilience (τb = 0.91**, $P<0.01$). Informal microfinance institutions should thus be considered as a source of climate finance and a key policy strategy in building rural household's climate variability resilience. Informal microfinance institution's contribution to rural household's climate variability resilience is determined by their characteristics such as member's sex (τb = +0.017, $P>0.05$) and loan interest rate (τb = +0.109*, $P<0.05$). These relationships could be leveraged to enhance their contribution to rural household's climate variability resilience.

Keywords: Climate variability, Capital assets, Informal microfinance institution, Livelihoods, Resilience.

6.2 Introduction

Climate variability is the deviation of climatic elements above or below the long-term average value (IPCC, 2007). Climate variability has significant impacts on rural livelihoods in Sub Saharan Africa (IPCC, 2007) and its effect on crop and livestock production is increasingly blamed for the deteriorating livelihoods in Kenya's rural areas (Muitimba *et al.*, 2010).

According to Ziervogel and Calder (2003), climate variability manifests as shocks and stresses that impact livelihoods through effects on access to capital assets.

Response to the effects of climate variability, therefore, involves enhancing access to capital assets and livelihood strategies (Badjeck, *et al.*, 2010). This could be achieved through microfinance institutions that enable low-income people to accumulate and manage capital assets by providing them with loans, savings, and other financial services (Agrawala and Carraro, 2010; Hammil *et al.*, 2008; Haworth *et al.*, 2016). Microfinance institutions enable people to generate incomes, create jobs, access education, and access healthcare, and make life choices that best suit their needs (Mushuku and Mayisa, 2014). In addition, microfinance enables households to diversify income sources and smooth temporal consumption patterns in response to shocks and stresses (Scheyvens, 2015; Egyir *et al.*, 2015).

Microfinance includes formal and informal microfinance institutions. Informal microfinance institutions include rotational savings and credit associations and accumulated savings and credit associations (Kaburi *et al.*, 2013). They are community-based organizations that provide loans, savings, and other financial services mainly to poor people who hardly access the formal finance sector services (Thrikawala *et al.*, 2013). Informal microfinance institutions are thus based at the local level and are prevalent in rural areas of low-income countries where they have been in existence since the pre-colonial period (Mairura and Okatch, 2015; Haworth *et al.*, 2016). According to (Boissiere *et al.*, 2013; Mertz *et al.*, 2009; Tschakert, 2007) impacts of climate variability are context-specific, and thus successful response actions should build on existing strategies that reflect the local socio-economic and environmental context. Microfinance institutions thus have a great but overlooked potential in climate variability resilience building in low-income households (Moser and Gonzalez, 2015).

There is a lacuna in detailed analysis on the contribution of informal microfinance institutions in building rural household’s resilience to climate variability. Limited studies have undertaken a detailed analysis on the contribution of informal microfinance institutions in building rural household’s resilience to climate variability. This is especially through their contribution to the household's access to capital assets. Most studies on factors influencing resilience to climate change and variability do not consider informal microfinance institutions as a factor in their analysis. Besides, past studies on microfinance, and climate change and variability in Tharaka including (Kiplimo *et al.,* 2015; Gioto *et al.,* 2016; Recha *et al.,* 2017a; Recha *et al.*, 2017b) did not analyze the contribution of informal microfinance institutions in building rural household's resilience to climate variability.

Besides, limited studies have analyzed the factors that determine the contribution of informal microfinance institutions in building rural household's resilience to climate variability. However, Gwasi and Ngambi (2014) found that institution-specific indicators are major determinants of microfinance institutions' performance. Furthermore, knowledge of determinants of the performance in microfinance institutions can inform policies aimed at improving their capacity in achieving social and financial goals in a financially sustainable manner (Hermes and Hudon, 2018). The study, therefore, analyzed the contribution of informal microfinance institutions to rural household's resilience to climate variability based on household's access to capital assets and the underlying determinants.

6.3 Theoretical framework

The study was based on the sustainable livelihood's framework. It is an analytical framework that seeks to understand people's access to capital assets and how they convert them through livelihood strategies to achieve desirable livelihood outcomes including more income, improved food security, improved wellbeing, sustainable use of the natural resource base, and reduced vulnerability (Connolly-Boutin and Smit, 2016; DFID, 1999).

The sustainable livelihoods framework views people as operating within a vulnerability context that's shaped by various factors including shocks, trends, and seasonality (DFID, 1999). The vulnerability context affects people's livelihoods through the effect on capital assets access and hence the outcomes of livelihood strategies (Connolly-Boutin and Smit, 2016; DFID, 1999; Badjeck *et al.,* 2010). The core outcome of the sustainable livelihood's framework is therefore to enhance resilience to shocks, trends, and seasonality by building a household's capital assets (DFID, 1999; Egyir *et al.*, 2015; Piya *et al.*, 2016; Badjeck *et al.*, 2010). Climate variability is one aspect of the vulnerability context since climatic trends, shocks, and seasonality define people's external living environment (DFID, 2004).

Transforming structures and processes mediate the process of accessing assets and transforming them into livelihood outcomes through livelihood strategies (Chambers and Conway, 1992; Ellis, 2000). Structures include private and public organizations such as households, members groups, and the community while processes are the policies, legislations, culture, institutions, and power relations that determine how structures operate and interact (FAO, 2008; DFID, 1999). Structures and processes by determining access to capital assets and how institutions and individuals operate and interact shape impacts and responses, and determine the level of resilience to shocks, trends, and seasonality in a socioecological system (DFID, 1999; Carney, 2003; Adger, 2000; Agrawal, 2009).

6.4 Materials and Methods

6.4.1 Data collection

The study was conducted in Tharaka South Subcounty in semi-arid Eastern Kenya (Figure 6.1). Tharaka South Subcounty was selected due to the high prevalence of informal microfinance institutions and climate variability. A descriptive study and multi-stage sampling designs were used in undertaking the study. This started by randomly selecting Marimanti and Chiakariga Locations for the study. This was followed by a systematic selection of 36 informal microfinance institutions i.e., 18 per location from a list of 177 informal microfinance institutions sourced from the department of social development. Based on Cochran's Equation 1 (Robb, 1963), a sample size of 385 respondents was attained. Systematic sampling was then used to select eleven respondents from the member lists of each of the chosen informal microfinance institutions.

The study used both primary and secondary data. Collection of primary data was done using various methods including semi-structured questionnaire surveys, key informant interviews, focused group discussions, and observation. A reconnaissance survey of the study area helped to identify aspects of local livelihoods that are most affected by climate variability and informed the development of the research tools. The data collection tools were subjected to a pilot test and tested for reliability using Cronbach's alpha (Cronbach, 1951; DeVellis, 2005). A coefficient of 0.784 was attained which indicates good reliability. Expert consultation was used to evaluate the validity of the data collection tools. Data collection was done using a mobile-based application system called kMACHO, which enables the collection of georeferenced data. Data from various data collection methods were validated and harmonized using methodological triangulation.

Rainfall data were obtained from Climate Hazards InfraRed Precipitation with Station data (CHIRPS). CHIRPS incorporates 0.05 degrees resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and drought monitoring.

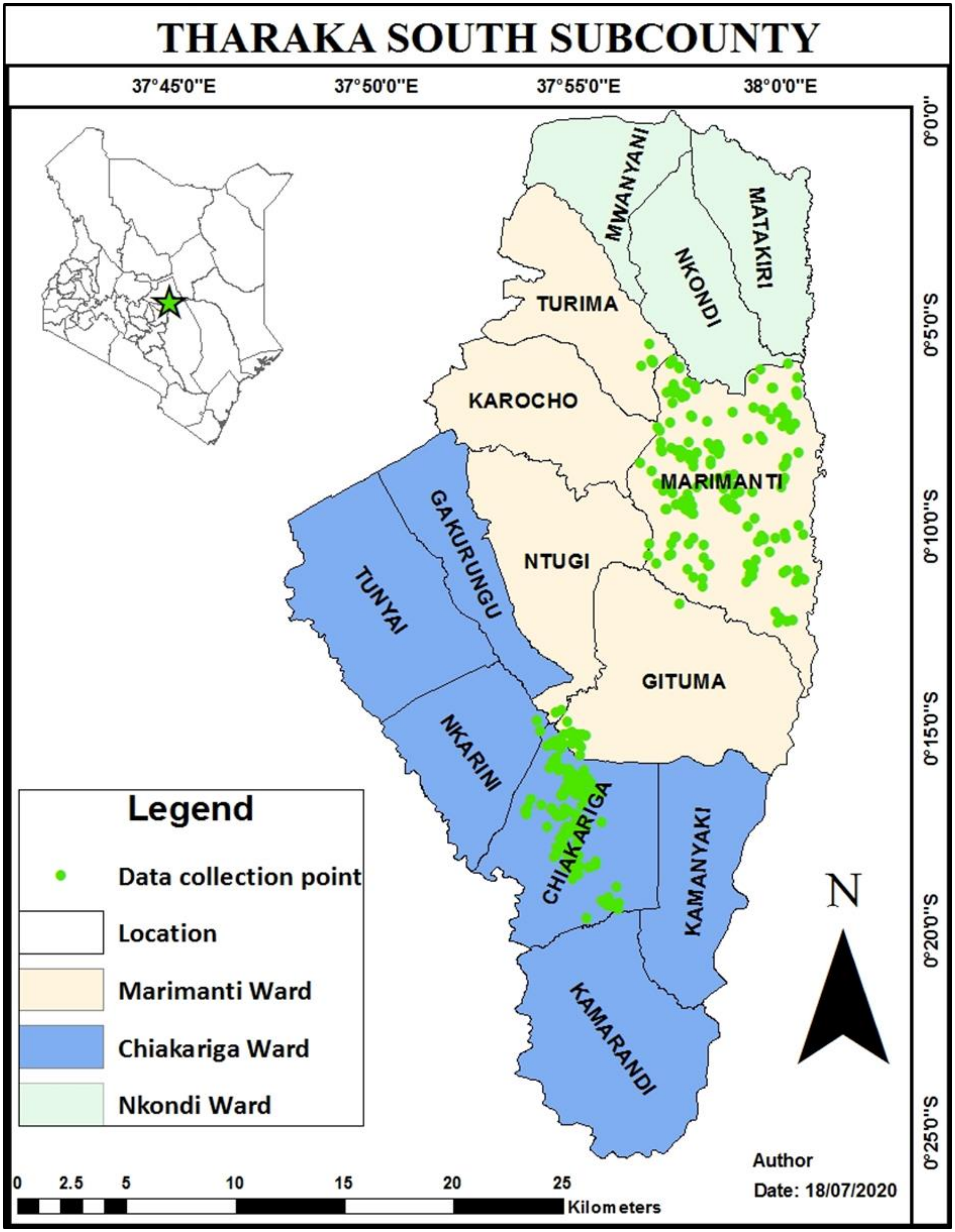


Figure 6.1: Location of the study area in Tharaka South Subcounty (Source: Author)

6.4.2 Data analysis

Data analysis was done using thematic analysis, descriptive analysis, and Kendall's tau-b (τb) correlation analysis. Climate variability was analyzed based on the variation of the annual rainfall of 38 years from 1981 to 2018 using the coefficient of variation. The Mann-Kendall (Z) test was used to calculate the trends in climate variability.

6.4.3 Computation of variables

A composite index was computed to measure a household's climate variability resilience and called the household climate variability resilience index. The composite index was computed based on household's access to capital assets including expenditure on access to education, healthcare, inputs of crop production, and inputs of livestock production in the past one year as indicators.

Also, a composite index was computed to measure the contribution of informal microfinance institutions to household's resilience to climate variability and called the contribution of informal microfinance to the household climate variability resilience index. The composite index was computed based on the proportion of the contribution of informal microfinance institutions to household's access to capital assets including expenditure on access to education, healthcare, inputs of crop production, and inputs of livestock production in the past one year as indicators. This was calculated by dividing the contribution of informal microfinance institutions on household expenditure on a capital asset divided by the total household expenditure on the capital asset.

In computing the composite indices, the variables were then normalized to ensure the comparability of indicators bearing different measurement units and scales. This was done using the Min-Max normalization to yield standard index values with relative positions in the range of zero to one for each indicator, i.e.

$$Zi = xi - min(x)/max(x) - min(x) \qquad (6.1)$$

Where:

Z_i = Normalized value of x_i

min(x) = Minimum value of x

max(x) = Maximum value of x.

These indicators were then weighted to avoid the uncertainty of equal weights given their diversity. This entailed weighing the variables using the pairwise ranking matrix. This allocated weights according to the number of times a variable was chosen as being more important than the other variables. The inverse rank was then calculated to get the weight of a variable.

The member's informal microfinance performance composite index was then calculated using the formula:

$$CI = \sum (wi\ Zi)/n \tag{6.2}$$

Where:

CI = Composite index

w_i = Weight of variable

z_i = Variable index value

n = Number of variables.

The member's informal microfinance performance composite index was tested for accuracy and robustness using uncertainty and sensitivity analysis. Uncertainty analysis was done using the propagation of the standard errors approach i.e., based on uncertainties of index components. This involved adding their standard errors as a weighted sum in quadrature (squared, weighted, added and then square rooted) as in (Kirchner, 1995), i.e.

$$U = \sqrt{\sum} (wiSi)^2 \tag{6.3}$$

Where:

U = Uncertainty

w_i = Variable weight

S_i = Standard error of variable's index value.

Sensitivity analysis was done using multiple regression analysis to determine how components constituting the composite index influence it as in (Hamby, 1995). In doing this the coefficient of determination (R^2) indicated the amount of variation in the composite index which can be explained by the model's components.

6.5 Results

6.5.1 Climate variability, trends, and effects

Analysis of inter-annual rainfall variability from 1981 to 2018 using coefficient of variation found a coefficient of 0.243 indicating climate variability. Analysis of the trend in intra-annual rainfall variability from year 1981 to 2018 using Mann-Kendall (Z) statistical test found a positive non-significant trend ($Z=1.52$, $P>0.1$) indicating climatic patterns are becoming increasingly variable. Trend analysis of annual rainfall amount found a negative trend that was not significant ($Z= - 0.93$, $P>0.1$) indicating rainfall amounts are decreasing and the patterns are erratic and unpredictable.

Local people have also perceived climate variability as observed by 87% of the respondents who said local climatic patterns have changed to a high extent. This includes perception of decrease in rainfall amounts (56%), erratic and unpredictable rainfall patterns (39%), and fluctuations in in local temperatures mainly marked by increased incidences of above normal temperature levels and erratic temperature regimes (5%). Participants in the focused group discussions and key informant interviews observed that there has been increased severity, duration, and frequency of droughts.

Besides, local people have perceived impacts of climate variability on their livelihoods as observed by 99% of the respondents. Majority of the respondents observed that climate variability affects local people's livelihoods through the effect on access to capital assets and livelihood strategies. This includes effects on health (88%), education (87%), crop production (97%) and livestock production (93%).

6.5.2 Household climate variability resilience index

Household's resilience to climate variability was measured using the household climate variability resilience index. The index was computed based on household expenditure on access to education, expenditure on healthcare, expenditure on access to inputs of crop production, and expenditure on inputs of livestock production in the past one year (Table 6.1).

Table 6.1: Computation of the household climate variability resilience index

Computation of the household climate variability resilience index				
Variable	Total expenditure for all the household's sampled for the study (Kish's.)	Average variable index value	Variable weight	Average weighted variable index value
Expenditure on healthcare	6,960,340	0.090	4	0.362
Expenditure on education	27,918,510	0.036	3	0.109
Expenditure on inputs of crop production	5,577,605	0.088	2	0.177
Expenditure on inputs of livestock production	4,523,270	0.042	1	0.042
Average composite index value				0.172

The household climate variability resilience index was then tested for accuracy and robustness using uncertainty analysis and an uncertainty of 0.029 arrived at giving an indication of very high certainty. Further, the index was analyzed for sensitivity using multiple regression analysis and a coefficient of determination (R2) of 0.999 arrived at giving an indication of very high sensitivity.

The household climate variability resilience index was found to range between 0.050 and 1.137 with a mean of 0.172 and standard deviation is 0.159.

6.5.3 Contribution of informal microfinance institutions to household's climate variability resilience.

Eighty one percent of the respondents said that informal microfinance institutions help in building resilience to climate variability. Moreover, 76% of the respondents said informal microfinance institutions help in building resilience to climate variability by providing members with financial capital through savings, loans, and dividends. The member's households use this financial capital to access capital assets including access to education, healthcare, inputs of crop production, and inputs of livestock production.

The study found 97% of the households spent on access to healthcare. Informal microfinance institutions contributed to access to healthcare in 51% of the households. This included expenditure on transport, drugs, medical fees, health insurance, prescribed food, and equipment. The household's total expenditure on access to healthcare across the studied households in the past one year was KShs 6,960,340 (1 USD = KShs. 100) with the average expenditure per household being KShs. 18,079. The informal microfinance institutions contributed KShs. 2,036,100 to the household's expenditure on access to healthcare with the average contribution per household being KShs. 5,302. Informal microfinance institutions therefore contributed 29% of the household's total expenditure on healthcare. Besides, Kendall's tau-b correlation analysis found a positive significant correlation ($\tau b = 0.372^{**}$, $P<0.01$) between the household's expenditure on healthcare and the contribution of informal microfinance institutions to the household's expenditure on healthcare. This indicates that informal microfinance institutions have a positive significant contribution to household's access to healthcare.

Further, 94% of the households spent on access to education. Informal microfinance institutions contributed to access to education in 79% of the households. This included expenditure on school fees, books, stationery and other learning materials, and school uniforms. The household's total expenditure on access to education across the studied households in the past one year was KShs. 27,918,510 with the average expenditure per household being KShs. 72,516. The informal microfinance institutions contributed KShs. 8,313,200 to the household's expenditure on access to education with the average contribution per household being KShs. 21,593. Informal microfinance institutions therefore contributed 30% of the household's total expenditure on education. Moreover, Kendall's tau-b correlation analysis found a positive significant relationship ($\tau b = 0.448^{**}$, $P<0.01$) between the household's expenditure on education and the contribution of informal microfinance institutions to the household's expenditure on education. This indicates that informal microfinance institutions have a positive significant contribution to household's access to education.

The study found 97% of the households spent on crop production. Informal microfinance institutions contributed to access to inputs of crop production in 63% of the households. The household’s total expenditure on inputs of crop production across the studied households in the past one year was KShs. 5,577,605, with the average expenditure per household being KShs. 14,487. The informal microfinance institutions contributed KShs. 1,602,680 to household’s expenditure on inputs of crop production with the average contribution per household being KShs. 4,163. Informal microfinance institutions therefore contributed 29% of the household's total expenditure on inputs of crop production. Kendall's tau-b correlation analysis found a positive significant correlation (τb = 0.447**, $P<0.01$) between the household's expenditure on inputs of crop production and the contribution of informal microfinance institutions to the household's expenditure on inputs of crop production. This indicates that informal microfinance institutions have a positive significant contribution to household's access to inputs of crop production. Informal microfinance institutions were also found to contribute significantly to household’s access to specific inputs of crop production (Table 6.2).

Table 6.2: Contribution of informal microfinance to household’s access to inputs of crop production

Contribution of informal microfinance to household’s access to inputs of crop production					
Expenditure	Total expenditure for all the household’s sampled for the study (Kish’s.)	Total contribution of informal microfinance institutions to expenditure of all the household’s sampled for the study (Kish’s.)	Proportion of informal microfinance institutions contribution (%)	Kendall’s tau correlation (τb) between household expenditure and contribution of informal microfinance institutions	
				Coefficient (τb)	Sig. *(p)*
Fertilizer	68,720	30,940	45.02	0.552**	0.000
Manure	49,600	14,350	28.93	0.709**	0.000
Seeds/planting materials	941,105	322,520	34.27	0.459**	0.000
Pesticides/herbicides	1,089,820	338,200	31.03	0.409**	0.000
Irrigation water	88,560	5,050	5.70	0.380**	0.000
Storage facilities	487,700	220,000	45.11	0.799**	0.000
Farmland	643,800	203,700	31.64	0.675**	0.000
Labor	1,517,000	340,300	22.43	0.486**	0.000
Tools	386,960	100,900	26.08	0.504**	0.000
Market/transport costs	304,340	26,900	8.84	0.270**	0.000
TOTAL	5,577,605	1,602,680	28.73	0.447**	0.000

Moreover, 89% of the households spent on inputs of livestock production. Informal microfinance institutions contributed to access to inputs of livestock production in 51% of the households. The household's total expenditure on inputs of livestock production across the studied households in the past one year was KShs 4,523,270, with the average expenditure per household being KShs 11,749. The informal microfinance institutions contributed KShs 1,117,750 to household's expenditure on access to inputs of livestock production with the average contribution per household being KShs 2,903. Informal microfinance institutions therefore contributed 25% of the household's total expenditure on inputs of livestock production. In addition, Kendall's tau-b correlation analysis found a positive significant correlation ($\tau b = 0.473^{**}$, $P<0.01$) between the household's expenditure on inputs of livestock production and the contribution of informal microfinance institutions to the household's expenditure on inputs of livestock production. Informal microfinance institutions were also found to contribute significantly to specific inputs of livestock production (Table 6.3).

Table 6.3: Contribution of informal microfinance to household's access to inputs of livestock production

Contribution of informal microfinance to household's access to inputs of livestock production					
Variable	Total expenditure for all the household's sampled for the study (Kish's.)	Total contribution of informal microfinance institutions to expenditure of all the household's sampled for the study (Kish's.)	Proportion of informal microfinance institutions contribution (%)	Kendall's tau correlation between household expenditure and contribution of informal microfinance institutions	
				Coefficient (τb)	Sig. *(p)*
Fodder	482,450	90,900	18.84	0.628**	0.000
Supplementary feeds	65,320	7,780	11.91	0.520**	0.000
Pastureland	1,012,550	282,600	27.91	0.571**	0.000
Medicine/pesticides	506,060	145,130	28.68	0.371**	0.000
Insemination services	3,950	300	7.59	0.606**	0.000
Water	761,610	281,840	37.01	0.698**	0.000
Shelter	282,610	67,800	23.99	0.512**	0.000
Tools	169,100	60,500	35.78	0.657**	0.000
Labor	1,070,690	164,800	15.39	0.665**	0.000
Market/transport costs	168,930	16,100	9.53	0.282**	0.000
TOTAL	4,523,270	1,117,750	24.71	0.473**	0.000

6.5.4 Contribution of informal microfinance to the household climate variability resilience index

The contribution of informal microfinance institutions to household's climate variability resilience was measured using the contribution of informal microfinance to the household climate variability resilience index. The index was computed based on the proportion of informal microfinance institution's contribution to household's expenditure on access to education, access to healthcare, access to inputs of crop production, and access to inputs of livestock production in the past one year (Table 6.4).

Table 6.4: Computation of contribution of informal microfinance to the household climate variability resilience index

Computation of contribution of informal microfinance to the household climate variability resilience index				
Variable	Proportion of informal microfinance institutions contribution	Average variable index value	Variable Weight	Average weighted variable index value
Contribution to expenditure on healthcare	29.30%	0.270	4	1.080
Contribution to expenditure on education	29.78%	0.356	3	1.069
Contribution to expenditure on inputs of crop production	29.37%	0.268	2	0.535
Contribution to expenditure on inputs of livestock production	24.19%	0.228	1	0.228
Average composite index value				0.670

The contribution of informal microfinance to the household climate variability resilience index was then tested for accuracy and robustness using uncertainty analysis and an uncertainty of 0.046 arrived at giving an indication of very high certainty. Further, the index was analyzed for sensitivity using multiple regression analysis and a coefficient of determination (R^2) of 0.857 arrived at giving an indication of very high sensitivity.

The contribution of informal microfinance to the household climate variability resilience index was found to range from 0.000 to 2.274 with a mean of 0.670 and standard deviation is 0.609.

6.5.5 Relationship between household's climate variability resilience and the contribution of informal microfinance institutions to household's resilience

To determine the relationship between household's climate variability resilience and the contribution of informal microfinance institutions to household's resilience. Kendall's tau-b correlation analysis was used to calculate the relationship between the household climate variability resilience index and the contribution of informal microfinance to the household climate variability resilience index. A positive correlation ($\tau b = 0.91^{**}$, $P<0.01$) was found indicating that informal microfinance institutions have a significant positive contribution to household's climate variability resilience.

6.5.6 Determinants of the contribution of informal microfinance institutions to rural household's climate variability resilience.

Determinants of the contribution of informal microfinance institutions to rural household's climate variability resilience were analyzed by finding the relationship between their characteristics and the contribution of informal microfinance institutions to household's climate variability resilience index using Kendall's tau-b correlation analysis (Table 6.5).

Table 6.5: Relationship between informal microfinance institutions and contribution to household's climate variability resilience

Relationship between informal microfinance institutions and contribution to household's climate variability resilience			
#	**Variable**	**Coefficient (τ_b)**	**Sig *(p)***
1	Member's sex	+0.017	0.691
2	How member's household is headed	-0.005	0.906
4	Age of the member	-0.029	0.477
5	Member's marital status	-0.020	0.617
6	Level of education	+0.022	0.578
7	Member's household size	-0.038	0.298
8	Member's household agricultural production (Value of crop and livestock production)	+0.171*	0.000
9	Member's perception of climate variability	-0.034	0.424
10	Member's vulnerability to climate variability	+0.096*	0.017
11	Number of years member has belonged to informal microfinance institutions	-0.070*	0.050
12	Number of groups member belongs to	-0.026	0.508
13	If member holds leadership position in the group	0.017	0.681
14	Amount of savings in groups i.e., contribution per month (KShs.)	0.015	0.673
15	Loan access i.e., number of times member received loans from the groups	0.055	0.129
16	Age of the group in years	-0.061	0.089
17	Number of members in the group	-0.052	0.152
18	Group composition by gender	+0.001	0.984
19	Ability of the group to fully meet its financial needs	-0.012	0.771
20	If the group belongs to an umbrella organization	-0.025	0.555
21	If group organizes trainings for its members	-0.061	0.593
22	Group's length of term of office in years	-0.174*	0.000
23	Number of group officials	+0.011	0.780
24	If the group gives allowances to officials	+0.100*	0.018
25	Number of years the group leader has been an official in informal microfinance institutions	+0.005	0.890
26	Level of education of the group leader	+0.021	0.595

27	Gender of the group leader	+0.104*	0.014
28	If group leader holds leadership position(s) in other groups	+0.089*	0.034
29	Group’s length of savings contribution cycle	-0.013	0.755
30	Group’s length of full cycle	-0.019	0.647
31	Group’s minimum savings contribution per cycle	+0.009	0.809
32	Group’s loan interest rate	+0.109*	0.007
33	Group’s length of loan grace period	+0.215*	0.000
34	Group’s maximum loan repayment period	+0.037	0.357
35	If group follows up on loan borrowers	-0.041	0.329
36	If the group seeks external funding	+0.024	0.572

6.6 Discussion

The study aimed to analyze the contribution of informal microfinance institutions on the resilience of rural households to climate variability. The study found that the local climatic conditions are becoming increasingly variable. Climate variability in the study area manifests through increasingly erratic and unpredictable rainfall patterns and decreasing rainfall amounts. The Government of Kenya (2012a) noted that Kenya's climate projection entails longer, and more frequent dry spells interposed with extreme and unpredictable rainfall events. Climate variability was found to be impacting rural households through the effect on access to capital assets and livelihood strategies. This includes effect on health, access to healthcare, access to education, crop production, and livestock production. This could negatively affect livelihood outcomes including income levels, food security, wellbeing, and sustainability of the natural resource base which in turn has a feedback effect on capital assets. Ziervogel and Calder (2003) observed that climate variability affects people's livelihoods through the effect on access to capital assets and livelihood strategies and hence their livelihood outcomes.

The study found that informal microfinance institutions thus have a significant contribution to rural household's climate variability resilience. Informal microfinance institutions contribute to rural household's climate variability resilience by providing members with financial capital. The financial capital provided by informal microfinance institutions enables members to access, enhance and diversify their capital assets based on which they undertake livelihood strategies leading to resilient livelihoods. Access to financial capital through informal microfinance institutions helps to smooth household consumption patterns and provides members with risk sharing and transfer mechanisms in response to shocks and stresses. This concurs with Agrawala and Carraro (2010) who found that microfinance institutions provide low-income people with lending, saving, and other financial services that enable them to accumulate and manage capital assets thus building resilience to climate risks. Catholic Relief Services (2012) concluded that informal microfinance institutions protect members from shocks and stresses by pooling risks and smoothing their consumption patterns over time in response to income fluctuations.

The financial capital provided by informal microfinance institutions enables households to invest in inputs of crop and livestock production which enhances productivity and incomes and hence livelihoods resilience. Besides, informal microfinance enables access to inputs that cushion against negative effects of climate variability including agrochemicals, feed supplements, irrigation water, and access to diverse seeds and planting materials. These findings are confirmed by Ncube *et al.* (2016) who found that adaptation to climate change and variability involves enhancing access to agricultural inputs such as fertilizers, use of drought-resistant crop varieties, pest and disease control, and increased irrigation. Komba and Muchopondwa (2018) observed that microfinance institutions are an important tool in decreasing the vulnerability of poor people to climate risks by facilitating their accumulation, diversification, management of assets needed to reduce susceptibility to shocks and stresses and to deal with the impacts in a better manner.

The study found that the financial capital provided by informal microfinance institutions enables members to access healthcare services which increase people's health and capacity to undertake livelihood activities and thus resilience. Besides, informal microfinance institutions enable members to subscribe to health insurance schemes that cushion them against climate-related health risks. By supporting agricultural production and providing the financial capital to purchase food, they help to improve food and nutritional security which improves the health status in member's households. This aligns with Pronyk (2007) who deduced that participation in microfinance programs improves health outcomes. Bloom *et al*. (2019) noted that access to healthcare increases labour productivity and income levels, and hence livelihoods resilience.

The study found that the financial capital provided by informal microfinance institutions enables members to meet educational expenses including school fees. Access to education increases people's knowledge and skills, and hence access to livelihood and employment opportunities. This is in line with Egyir *et al.* (2015) who deduced that education enhances adaptive capacity by increasing the capacity to learn, reducing ignorance, and broadening access to livelihood and employment opportunities. Furthermore, Toya and Skidmore (2007) found that education enables people to make broader choices in response to climate shocks and stresses.

The informal microfinance institution's characteristics positively and negatively affect their contribution to rural household's climate variability resilience. This is because they create conditions that augment or constrain the performance of informal microfinance institutions and thus capacity to contribute to rural household's climate variability resilience. The membership characteristics of informal microfinance institutions could affect their contribution to rural household's resilience to climate variability by affecting member's participation and informal microfinance performance. Moreover, the characteristics of members determine their dependence on informal microfinance through effects on household's access to resources, financial burden, and vulnerability. The savings and lending characteristics of informal microfinance institutions affect the level of savings, access to loans, loan repayment, and capacity to meet member's financial needs. This in turn affects informal microfinance institutions' contribution to rural household's resilience to climate variability. Furthermore, the leadership characteristics of informal microfinance institutions affect their governance and management and hence social and financial performance. This affects the capacity of informal microfinance institutions in providing services to members and hence contribution to the household's resilience to climate variability.

This is in line with Kipesha (2013) and Scheyvens (2015) who noted that the performance of an organization is a function of different internal and external factors that influence its operations. Also, Mokhtar (2011) found that the performance of a microfinance institution is influenced by the borrower's and business characteristics, and savings and lending characteristics. According to Hermes and Hudon (2018), the most important determinants of performance in microfinance institutions include the microfinance institutions characteristics including size, age, source of funding, and the governance structure.

Context-specific understanding of determinants of the contribution of informal microfinance institutions to rural household's resilience to climate variability could inform on factors that could be leveraged and how they could be manipulated to enhance the contribution. This agrees with Aveh (2011) who noted that knowledge of factors that determine the performance of microfinance institutions informs on the variables that should be leveraged to improve their capacity in meeting their social and financial goals. Furthermore, Hermes and Hudon (2018) noted that the direction of the relationship between characteristics of microfinance institutions and their performance depends on the local specific context.

6.7 Conclusion

Climate variability impacts rural households through the effect on access to capital assets and livelihood strategies and hence livelihood outcomes. However, local people are not submissive to impacts of climate variability but respond through various strategies including informal microfinance institutions. Informal microfinance institutions contribute significantly to building rural household's resilience to climate variability by enabling them to access capital assets based on which they undertake livelihood strategies leading to desirable livelihood outcomes and hence resilience. Informal microfinance institutions therefore should be considered as a key strategy in plans, policies, and programs for building rural household's resilience to climate variability. The informal microfinance institution's characteristics positively and negatively affect their contribution to rural household's climate variability resilience. These relationships could be leveraged to enhance the contribution of informal microfinance institutions to rural household's climate variability resilience.

CHAPTER SEVEN: OVERALL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1. Overall discussion

The study analyzed climate variability and trends based on temperature and rainfall data in Tharaka South Subcounty. Analysis of annual rainfall revealed that the area is marked by a low rainfall amount that is erratic and unpredictable. Rainfall amount is mainly marked by a non-significant negative trend meaning it is decreasing over time whereas the pattern is erratic and unpredictable. This agrees with the East African Region (Feleke & Abera, 2020; Langat *et al*. 2017; Shisanya *et al*. 2011; Ghebrezgabher *et al*. 2016) that found a negative annual rainfall trend. However, it disagrees with IPCC (2007) whose AR4 climate models show that East Africa will become wetter particularly during the short rains. Moreover, the finding is contrary to other studies that found a positive trend in annual rainfall in the region including (Opiyo *et al*., 2014; Christensen *et al*., 2007; Maina & Raude, 2017; Omondi *et al*., 2014).

Rainfall in the study area is marked by very high concentration and thus strongly irregular distribution. The rainfall is becoming increasingly concentrated and thus more irregular as shown by the positive trend in the annual precipitation concentration index. The rainfall is also characterized by a high probability of extreme rainfall events that mainly lie above the normal rainfall amount. This finding concurs with IPCC (2014) who observed that the frequency of extreme weather episodes has increased globally, and the rate of their occurrence will increase further in the 21st century. Other studies in the region have also observed high irregularity in rainfall distribution including Tura (2017) who also found high PCI values indicating the presence of an irregular distribution of rainfall for all seasons in Ethiopia's Central rift valley region.

The study found the study area is characterized by the occurrence of frequent and severe droughts as depicted by the negative standardized rainfall anomaly in most of the years. The JF season however has a positive trend in standardized rainfall anomaly meaning it is getting wetter despite being a dry season. The MAM season was observed to have a stronger negative trend in standardized rainfall anomaly vis-à-vis the OND meaning in the future the MAM season could become much drier and unreliable than the OND season. The severity and frequency of drought are increasing at seasonal and annual scales. This agrees with (Asfaw *et al*., 2018; Shongwe *et al*., 2011; William & Funk, 2011; Lyon & Dewitt, 2012) who found a positive trend in droughts occurrence in Eastern Africa over the last 30-60 years.

Local rainfall is thus highly variable, and the variability is increasing over time. The rainfall variability is associated with a decrease in rainfall, more irregular rainfall distribution, extreme rainfall events, and greater frequency and severity of droughts. This aligns with past studies that found high interannual and intra-annual variability in annual rainfall including (Opiyo *et al*., 2014; Asfaw *et al*., 2018; Camberlin & Philippon, 2012; Tesfaye, 2004; Seleshi & Zanke, 2004).

Besides, analysis of annual temperature revealed that the study area has a positive trend of minimum, maximum, and mean temperatures. This agrees with other studies that have found a positive trend in minimum, maximum, and mean temperatures in Kenya and the Eastern Africa region including (Asfaw *et al*., 2018; Gebrechorkos *et al*., 2019). The study area is generally marked by low variability in temperature that is becoming less variable over time. This contrasts with (Gichangi *et al*. 2015) who found high inter-annual variability in annual minimum, maximum, and mean temperatures at the Katumani weather station. Moreover, the study found that an increase in temperature is associated with a reduction in rainfall amounts. This agrees with Huang *et al*. (2009) who found a negative relationship between annual temperature and rainfall in the Yellow River basin in China. It is however contrary to Nkuna and Odiyo (2016) who found a positive correlation between annual rainfall and annual minimum and maximum temperature in Levubu Sub-catchment in South Africa.

Local people have also perceived climate variability and its impacts on local livelihoods. Climate variability affects livelihoods through the effect on access to capital assets including access to education, healthcare, inputs of crop production, and inputs of livestock production. This could have negative effects on livelihood outcomes including income levels, food security, wellbeing, and sustainability of the natural resource base, and thus livelihoods resilience. This is in harmony with Ziervogel and Calder (2003) who observed that climate variability affects people's livelihoods through the effect on access to capital assets and livelihood strategies and hence their livelihood outcomes. WHO (2003) notes that the health of Kenyans is influenced by extreme climatic events which increase incidences of vector-borne and water-borne diseases. Also, Randell and Gray (2016) noted that climate risks may reduce children's school participation and impede the achievement of development and poverty reduction goals in rural Ethiopia. A study by Omoyo *et al* (2015) in Lower Eastern Kenya revealed that maize yields vary in response to change in climate parameters meaning it negatively affects crop production. Moreover, according to Galvin *et al* (2015) and Lyimo and Kangalawe (2011), climate variability causes pasture and water scarcity leading to a reduction in livestock production, a decline in herd sizes, and enhancement of poverty among rural households.

Local people are however not passive recipients of impacts of climate variability but have developed and implement various response strategies. Such strategies include informal microfinance institutions that provide loans, savings, and other financial services mainly to low-income earners who hardly access formal financial services (Thrikawala *et al*., 2013). Therefore, informal microfinance institutions have a significant contribution to rural livelihood's resilience to climate variability. Informal microfinance institutions contribute to rural household's resilience to climate variability by providing financial capital to members that enable them to access capital assets based on which they undertake livelihood strategies leading to resilient livelihoods. Access to financial capital through informal microfinance institutions helps to smooth rural household's consumption patterns and provides them with risk sharing and transfer mechanisms when confronted with climate shocks and stresses. This concurs with Agrawala and Carraro (2010) who found that microfinance institutions provide low-income people with lending, saving, and other financial services that enable them to accumulate and manage capital assets thus building resilience to climate risks. Catholic Relief Services (2012) concluded that informal microfinance institutions protect members from shocks and stresses by pooling risks and smoothing their consumption patterns over time in response to income fluctuations. Nevertheless, Scheyvens *et al.* (2012) noted that microfinance could pose a risk to members if their terms and conditions are too inflexible particularly in the backdrop of climate change and variability that could negatively affect their loan repayment capacity pushing them to cheaply dispose of their productive assets to repay thus leading to asset erosion and poverty.

The financial capital provided by informal microfinance institutions enables households to invest in inputs of crop and livestock production which enhances productivity and incomes and hence livelihoods resilience. This is confirmed by Ncube *et al*. (2016) who found that climate change and variability adaptation entail enhanced access to agricultural inputs such as fertilizers, use of drought-resistant crop varieties, pest and disease control, and increased irrigation. Besides, informal microfinance institutions enable members to access healthcare services which increase people's health and capacity to undertake livelihood activities and thus resilience. By supporting agricultural production and providing the financial capital to purchase food, they help to improve food and nutritional security which improves the health status in member's households. This aligns with Pronyk (2007) who deduced that participation in microfinance programs improves health outcomes. Bloom *et al*. (2019) noted that access to healthcare increases labour productivity and income levels, and hence livelihoods resilience. Informal microfinance institutions enable access to education which increases resilience by enhancing people's knowledge and skills, and hence access to livelihood and employment opportunities. This agrees with Egyir *et al*. (2015) who deduced that education enhances adaptive capacity by increasing the capacity to learn, reducing ignorance, and broadening access to livelihood and employment opportunities. Furthermore, Toya and Skidmore (2007) found that education enables people to make broader choices in response to climate shocks and stresses.

However, climate variability affects informal microfinance institutions just like other sectors of the economy. Climate variability mainly affects informal microfinance performance especially through direct or indirect effects on the capacity to repay borrowed loans. This is caused by risks that directly affect their assets, entrepreneurship activities, and production activities, and those of members. It could also be due to risks that indirectly affect their assets and activities due to implementation of response actions and effect on member's loan repayment performance. Climate variability could affect the capacity of informal microfinance institutions in providing financial capital which affects member's ability to accumulate assets and undertake entrepreneurship and production activities. Vulnerability to climate variability thus negatively affects the performance of informal microfinance institutions. This finding concurs with

Gutierrez and Mommens (2011) who found that climate variability directly impacts microfinance institutions by affecting their assets and their operations and indirectly by affecting the loan repayment performance of clients. Financial institutions face various climatic risks including physical risks that are direct impacts of climate events on assets and operations and transition risks that are indirect impacts on assets due to changes made in response to climate change and variability including change in policy and technology, consumer sentiments. and adjustments to a low carbon economy (Drill *et al.*, 2016; Breitenstein *et al.*, 2019; Campiglio *et al.*, 2018; Dafermos *et al.*, 2018; Meel and Blijlevens, 2019; Breeden, 2019). Nonetheless, Adoyo (2013) noted that informal microfinance institutions are more sustainable, efficient, adapted to the prevailing local conditions, and thus more resilient to financial crises.

The study found that the vulnerability of informal microfinance institutions to the effects of climate variability is determined by their characteristics. This is by affecting the performance of informal microfinance institutions and thus the coping and adaptive capacity of the groups and members. Unfavorable savings and lending terms and conditions, poor governance, and unsuitable membership and organizational characteristics could negatively affect informal microfinance performance thus increasing vulnerability to climate variability. The effect of informal microfinance institution's characteristics on informal microfinance performance also affects access to capital assets and thus vulnerability to climate variability. The social and financial performance of microfinance institutions is associated with the economic performance of members (Dowla, 2018; Moser and Gonzalez, 2015; Ibtissem and Bouri, 2013).

The analysis of informal microfinance institution's structures found that they mainly comprise the more vulnerable groups in the community including women and people who have a low income. Vulnerability to climate variability thus increases participation in informal microfinance institutions since they help in building climate variability resilience. This aligns with Lasagni and Lollo (2011) who found that economic vulnerability is associated with greater participation in informal microfinance institutions due to their favorable and accessible insurance and saving solutions. Ritchie (2007) in a study in India, Sri Lanka, and Indonesia found that poor people largely depend on informal financial organizations given the inaccessibility of formal financial services. Women in Kenya participate more in informal microfinance institutions compared to men (Anderson and Baland, 2002). Moreover, according to Guerin *et al*. (2009), gender has a strong significant effect on participation in informal microfinance institutions with men, all else being constant, being less likely to participate.

Informal microfinance institutions thus promote gender equity and empower women by enabling their financial and economic independence, improving their socioeconomic status, and enhancing their role in decision-making processes. This agrees with Kabeer (2001) who observed that microfinance leads to women empowerment by improving their socioeconomic status, influence in decision-making, and freeing their entrepreneurship potential. Moreover, Kaburi *et al*. (2013) noted that microfinance institutions in Bangladesh enhanced the dignity, empowerment, self-dependence, and decision-making authority of participants. According to Noreen (2011), microfinance contributes to gender equity and promotes sustainable livelihoods and the working conditions of women.

The study found that informal microfinance institutions are mainly characterized by high levels of performance. They have high sustainability since they mainly depend on member's savings for lending capital, and most don't rely on external funding and have low default rates implying they will be able to finance future lending activities. The low default and delinquency rates show that they have high loan repayment performance. Moreover, the informal microfinance institutions have high outreach and hence social performance as shown by the relatively high number of members, and a higher proportion of female members and hence vulnerable people in the community.

The informal microfinance institutions are participatorily governed and managed based on bylaws and plans that are developed by members thus enhancing ownership, observance, and effectiveness in implementation. Their savings and lending terms and conditions and thus methodologies are thus mutually agreed which results in more effective enforcement of contracts. The terms and conditions also make the financial services of informal microfinance institutions more favorable. This agrees with Adoyo (2013) who noted that community-based financial models comprise organizations that provide greater opportunities for members to fully participate in their development and management resulting in democratic organizations that are more sustainable, efficient, and adapted to the prevailing local conditions.

The structures of informal microfinance institutions are defined by their membership, leadership, and savings and lending characteristics which negatively and positively affect informal microfinance performance. The study found women have higher informal microfinance performance. This could be due to limited access to livelihood opportunities which enhances their dependence and commitment to informal microfinance institutions, better observation of group laws, greater prudence in financial management, and thus higher loan repayment performance. This concurs with previous studies that deduced that women perform better in microfinance institutions since they save more (Gedela 2012), have better loan repayment performance (Chaudhary and Ishfaq, 2003; Roslan and Abdi Karim, 2009), and have more prudent investment strategies (Todd, 1996). The leadership characteristics of informal microfinance institutions could affect their performance by determining the quality and effectiveness of their governance and management processes. Moreover, savings and lending characteristics affect informal microfinance performance by determining the nature of the financial services offered by informal microfinance institutions.

The characteristics of informal microfinance institutions have positive and negative effects on their contribution to rural household's climate variability resilience. This is by enhancing or constraining informal microfinance performance and the contribution of informal microfinance institutions to building the climate variability resilience of rural households. The contribution of informal microfinance institutions to rural household's climate variability resilience could also be determined by their membership characteristics due to their effect on informal microfinance performance. Moreover, the characteristics of members determine their dependence on informal microfinance through effects on household's access to resources, financial burden, and vulnerability. The savings and lending characteristics of informal microfinance institutions affect their contribution to rural household's climate variability resilience by affecting the amount of savings, access to loans, loan repayment performance, and capacity to meet member's financial needs. Furthermore, the leadership characteristics of informal microfinance institutions affect their governance and management and hence their contribution to rural household's resilience to climate variability.

These findings are in line with Kipesha (2013) and Scheyvens (2015) who noted that the performance of an organization is a function of different internal and external factors that influence its operations. Also, Mokhtar (2011) found that the performance of a microfinance institution is influenced by the characteristics of the borrower's, business, and saving and lending terms and conditions. According to Hermes and Hudon (2018), the most important determinants of performance in microfinance institutions include the microfinance institution's characteristics for example size, age, and age; source of funding, and how they are governed.

Understanding the factors that determine the performance of informal microfinance institutions could inform on factors that could be leveraged and how they could be manipulated to enhance their role in building rural livelihoods resilience to climate variability. This agrees with Aveh (2011) who noted that understanding the factors that determine microfinance performance helps to identify the variables that should be leveraged to improve their capacity in meeting their social and financial goals. Furthermore, Hermes and Hudon (2018) noted that the direction of the relationship between characteristics of microfinance institutions and their performance depends on the local specific context.

7.2. Conclusions

i. Climatic patterns in the area are highly variable and characterized by decreasing trend in rainfall and an increasing trend in temperature amounts
ii. Informal microfinance institutions have well defined structures that determine their performance
iii. Climate variability negatively affects the performance of informal microfinance institutions
iv. Informal microfinance institutions contribute significantly to building rural household's resilience to climate variability by enabling them to access capital assets.

7.3. Recommendations

i. Development of strategies for response to climate variability should be based on proper understanding of the local climate variability and trends
ii. Development agencies should consider leveraging informal microfinance institutions in building rural climate variability resilience
iii. Policies and strategies for building rural livelihoods climate variability resilience through informal microfinance institutions should be based on a proper understanding of their structures in relation to performance.

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APPENDICES

Appendix 1: Summary of data analysis

SUMMARY OF DATA ANALYSIS			
Objective	**Data needed**	**Method of data collection**	**Method of data analysis**
1. To analyze the climate variability in Tharaka South Sub County	• Rainfall data • Temperature data	• Literature review • Gridded data from CHIRPS and CHIRTS	• Descriptive statistics • Coefficient of variation • Precipitation Concentration Index • Standardized anomaly • Mann-Kendall (Z) statistical test • Sens slope estimator (Q) test • Kendall's tau-b correlation analysis
2. To analyze structures of informal microfinance institutions in relation to performance	• Informal microfinance institutions data • Household's data	• Literature review • Key informant interviews • Focused group discussions • Questionnaire survey • Observation	• Thematic analysis • Descriptive statistics • Kendall's tau-b correlation analysis
3. To analyze climate variability effects and vulnerability in the nexus of informal microfinance institutions	• Informal microfinance institutions data • Household's data	• Literature review • Key informant interviews • Focused group discussions • Questionnaire survey • Observation	• Thematic analysis • Descriptive statistics • Kendall's tau-b correlation analysis

4. To analyze the role of informal microfinance institutions in resilience of rural livelihoods to climate variability	• Informal microfinance institutions data • Household's data	• Literature review • Key informant interviews • Focused group discussions • Questionnaire survey • Observation	• Thematic analysis • Descriptive statistics • Kendall's tau-b correlation analysis

Appendix 2: Household survey questionnaire

SECTION A: BASIC INFORMATION

BASIC INFORMATION				
Questionnaire ID No.		Date of Interview		
A1. County	A2. Sub County	A3. Location	A4. Sub Location	A5. Village
A6. Name of Informal Microfinance Group sampled from	A9. Interviewers Name	A10. Interviewers Number	A9. Respondent's Name	A10. Respondent's Number

SECTION B: RESPONDENTS INFORMATION

RESPONDENTS INFORMATION							
B1. Do you belong to an informal microfinance group?	B2. Sex of respondent	B3. Age of respondent	B4. Respondent's Marital Status	B5. Respondent's highest level of education	B6. When did the respondent settle in this area	B7. Are you the head of the household?	B8. Relationship to Household Head
1 = Yes *2= No*	*1=Male* *2=Female*	*1 = 18 – 35 years* *2 = 36 – 60 years* *3 = Over 60 years*	*1. Married* *2. Single* *3. Widowed* *4. Separated* *5. Divorced*	*1. None* *2. Nursery* *3.Primary uncompleted* *4.Primary completed* *5.Secondary uncompleted* *6.Secondary completed* *7. Tertiary (college diploma/certificate)* *8. University*	*State*	*1 = Yes* *2= No*	*1= Is Household Head* *2 = Spouse* *3 = Child* *4 = Parent* *5 = Grandchild* *6= Sister/Brother;* *7=Nephew/Niece* *8 = In Law* *9 = Employer* *10= Other relation (Specify)*
B9. How many people live within this household? _____________				Male _____		Female ________	
B10. How is the family headed/managed? *1. Male headed* *2. Female headed* *3. Child headed (below age 18/Orphan)*							

SECTION C: INFORMAL MICROFINANCE INSTITUTION

	INFORMAL MICROFINANCE INSTITUTIONS	
C1	Are you a member of a microfinance institution? *1 = Yes* *2 = No*	
C2	How many informal microfinance groups do you belong to (State)?	
C3	What is the name(s) of the informal microfinance group(s) you belong to? *1. ………………………………………………………………………………………* *2. ………………………………………………………………………………………* *3. ………………………………………………………………………………………*	
C4	When was the first time that you joined an informal microfinance group (State Year)?	
C5	Why did you decide to join the informal microfinance group(s) you belong to? *1. ………………………………………………………………………………………* *2. ………………………………………………………………………………………* *3. ………………………………………………………………………………………*	
C6	Do you hold any leadership position in an informal microfinance group? *1 = No* *2 = Yes*	
C7	If Yes, which leadership position(s) do you hold in the in the informal microfinance group? *1. ………………………………………………………………………………………* *2. ………………………………………………………………………………………* *3. ………………………………………………………………………………………*	
C8	How much money do you contribute to informal microfinance group(s) per month?	
C9	How many times did you borrow a loan from the informal microfinance group(s) in the last one year?	
C10	If you were not successful, state why ………………………………………………………………………………………	
C11	How much money did the informal microfinance group(s) lend to you in the last one year in total?	
C12	For what reason(s) had you borrowed a loan from the informal microfinance group(s)? *1. ……………………………………………………………………………………* *2. ……………………………………………………………………………………*	
C13	Are there times that you do not use money for borrow purposes? 1 = Yes 2 = No	
C14	If No, please explain why ………………………………………………………………………………………	

C15	How easy is it to get a loan from the informal microfinance group? *1 = Not easy* *2 = Easy* *3 = Very Easy*	
C16	How difficult is it for you to repay the loan you have borrowed from the informal microfinance group? *1 = Not difficult* *2 = Difficult* *3 = Very difficult*	
C17	Have you defaulted in repaying a loan borrowed from an informal microfinance group in the last one year? *1 = No* *2 = Yes*	
C18	If Yes, how many times have you defaulted in repaying a loan from a microfinance group in the last one year?	
C19	What contributed to your defaulting of the loan repayment? *1. ………………………………………………………………………………* *2. ………………………………………………………………………………*	
C20	Have you delayed in repaying a loan borrowed from an informal microfinance group in the last one year? *1 = No* *2 = Yes*	
C21	If Yes, how many times have you delayed in repaying a loan from a microfinance group in the last one year?	
C22	What contributed to your delayment in repaying the loan? *1. …………………………………………………………………………………* *2. ……………………………………………………………………………………*	
C23	Which benefits do you get from the informal microfinance group(s)? *1.…………………………………………………………………………………* *2. ……………………………………………………………………………………*	

SECTION D: CLIMATE VARIABILITY

CLIMATE CHANGE VARIABILITY		
D1	Have you experienced any changes in the local rainfall patterns? *1 = No* *2 = Yes*	
D2	If Yes, explain what changes …………………………………………………………………………………	

D3	What in your opinion, what has caused the changes in the local rainfall patterns? …………………………………………………………………………………
D4	What has been the impact of these changes in local rainfall patterns on your livelihood? …………………………………………………………………
D5	How do you address the impacts of change in local rainfall patterns on your livelihoods? ……………………………………………………………………………
D6	Does the informal microfinance group help in addressing the impacts of change in rainfall patterns on your livelihoods? *1 = No* *2 = Yes,*
D7	If Yes, how does the informal microfinance group help in addressing the impacts of change in local rainfall patterns on your livelihoods? …………………………………………………………………………………

SECTION E: EDUCATION

EDUCATION				
E1	Provide the following information on school attendance and level of education attained in the household			
	Personal Identification Number (PID)	Has the household member attained school going age? *1 = No* *2 = Yes*	If attained school going age, is the household member still attending school? *1 = No* *2 = Yes*	If attained school going age what is the highest level of education that the household member attained? *1 = None* *2 = Nursery* *3= Primary uncompleted* *4 = Primary completed* *5=Secondary uncompleted* *6 = Secondary completed* *7=college (diploma/certificate)* *8 = University (Degree)*
	1 (Head)			
	2			
	3			
	4			
	5			

	6			
	7			
	8			
	9			
	10			

E2	Does climate variability have an impact on the household's access to education? *1 = Yes* *2 = No*	
E3	If Yes, please explain how? …………………………………………………………………………	
	How much money did the household spend on education in the last one year (State)?	
E4	In which areas was this cash spent, e.g. books, school uniforms, school fees etc?	
E5	Does the informal microfinance group contribute to the households cost of education? 1 = Yes 2 = No	
E6	If Yes, what proportion of the household's total educational costs did the informal microfinance group contribute in the last one year (State)? *1 = 1 % – 25 %* *2 = 26% - 50%* *3 = 51% - 75%* *4 = 76% - 100%*	

SECTION F: HEALTH

HEALTH		
F1	Does climate variability have an impact on the household's health status? 1 = Yes 2 = No	
F2	If Yes, please explain how? …………………………………………………………………	
F3	How much money did the household spend on health in the last one year (State)?	
F4	How this cash was spent, e.g. transportation to the hospital, drugs from chemist, medical attention at hospital etc?	

F5	Does the informal microfinance group contribute to the households cost of education? 1 = Yes 2 = No	
F6	If Yes, what proportion of the household's total health care costs did the informal microfinance group contribute in the last one year (State)? *1 = 1 % – 25 %* *2 = 26% - 50%* *3 = 51% - 75%* *4 = 76% - 100%*	

SECTION G: CROP PRODUCTION

CROP PRODUCTION					
G1.	What are the quantities and values of crops that the household harvested in the last one year?				
	Crop	Total production of the crop in the last one year	Measurement Unit	Price per unit (KShs.)	Value of crops produced (KShs.)
	Maize				
	Beans				
	Millet				
	Sorghum				
	Finger millet				
	Cow peas				
	Pigeon peas				
	Green grams				
	Dolichos				
	Fruits				
	Vegetables				
G2.	Provide the following information on household's access to inputs/cost of crop production in the last one year?				
	Input/Factor	What amount of money did the household spend on the input/factor in the last one year?	Did the informal microfinance group contribute towards payment or purchase of the input/factor? *1 = No* *2 = Yes*	If Yes, how much	
	Fertilizer				
	Manure				
	Planting Seeds/materials				
	Pesticides/ Herbicides				

	Irrigation water			
	Storage facilities/granaries			
	Access to farming land			
	Hired Labour			
	Crop production tools e.g. Panga's and Rippers			
	Marketing			
G3	Does climate variability have an impact on the household's crop production? *1 = No* *2 = Yes*			
G4	If Yes, please explain how? ……………………………………………………………………………………………………			
G5	How much money did the household spend on crop production in the last one year in total (State)?			
G6	How much money of the household's total crop production costs did the informal microfinance group contribute in the last one year (State)?			

SECTION H: LIVESTOCK PRODUCTION

LIVESTOCK PRODUCTION				
H1	What are the quantities and values of livestock do you have?			
	Livestock	Current number of units/animals owned by the household	Price per animal (KShs)	Total value of animals in the last one year
	Cattle			
	Goats			
	Sheep			
	Chicken			
	Donkeys			
	Pigs			
	Bee hives			
H2	Provide the following information on access to factors of livestock production in the last one year?			
	Input/Factor	What amount of money did the household spend on the input/factor in the last one year?	Did the informal microfinance group contribute towards payment or purchase of the input/factor? *1 = No*	If Yes, how much?

			2 = Yes	
	Fodder			
	Supplementary feeds			
	Leasing of grazing land			
	Pesticides and medicine purchase			
	Insemination/ breeding services			
	Access to water for livestock			
	Livestock shelter			
	Livestock production tools e.g. sprayers			
	Hired labour			
	Training/Extension services			
	Livestock marketing			
H3	Does climate variability have an impact on the household's livestock production? *1 = No* *2 = Yes*			
H4	If Yes, please explain how? …………………………………………………………………………………………			
H5	How much money did the household spend on livestock production in the last one year in total (State)?			
H6	How much money of the household's total livestock production costs did the informal microfinance group contribute in the last one year (State)?			

Appendix 3: Informal microfinance institution survey questionnaire

SECTION A: RESPONDENT INFORMATION

A/1 Sex of respondent? Male [ ] Female [ ]

A/2 Name of respondent? ....

A/3 Respondent phone number? …………………..

A/4 Name of informal microfinance group? ………………………

A/5 When did you join the group? ....

A/6 What position do you hold in the group? ....

SECTION B: INFORMAL MICROFINANCE GROUP

B/1 In which year was this informal microfinance group formed? ....

B/2 How many members does the group have? ....

B/3 How many of these members are women? ....

B/4 How many of these members are men? ....

B/5 How many officials does the group have? ....

B/6 What are the requirements for joining the group as a new member? ....

B/7 Does the group have a constitution/bylaw to govern it? No [ ] Yes [ ]

B/8 After what period are the groups' meetings held (in Days/Weeks/Months)? ....

B/9 Does the informal microfinance group organize trainings for its members? No [ ] Yes [ ]

B/10 What other activities does the group engage in other than savings and credit? ....

B/11 Which challenges does the group face in the conduct of its activities? ....

B/12 How does the group address these challenges? ....

SECTION C: GROUP LEADERSHIP

C/1 How many of these officials are women? ....

C/2 How many of these officials are men? ....

C/3 Have the groups officials undergone any training(s)? No [ ] Yes [ ]

C/4 If Yes, how many trainings have the officials undergone? ....

C/5 Are the group officials given allowances for their services? No [ ] Yes [ ]

C/6 Are these allowances adequate given what the officials do for the group? No [ ] Yes [ ]

C/7 After what period does the group hold elections of its leaders? ....

C/8 What is the level of education of the groups chairperson? ....

C/9 Which year did the chairperson first hold a leadership position in a microfinance group(s), including other groups? ....

C/10 Does the group chairperson currently hold leadership position(s) in other groups? No [] Yes

C/11 If Yes, in how many other groups does the chairperson hold a leadership position? ....

SECTION D: GROUP FINANCIAL ACTIVITIES

D/1 What criteria does the group use to decide if a member should be given a loan? ....

D/2 What is the maximum amount of money that a member can borrow from the group? ....

D/3 How much interest is charged on money borrowed from the group? ....

D/4 Is there a grace period between receiving a loan and starting to make payments? No [] Yes

D/5 What is the maximum period within which a loan can be paid to the group? .....

D/6 Does the group do follow up on those who borrow loans? No [ ] Yes [ ]

D/7 What is the length of the groups regular contribution cycle? ....

D/8 How much money is each member supposed to contribute per cycle? ....

D/9 How long is one full cycle in the group (i.e. the period between the day a cycle starts and the end day when group members share dividends to start a new cycle)? ....

D/10 Are there cases of members delaying in making contributions? No [ ] Yes [ ]

D/11 How does the group deal with those who delay in making contributions? ....

D/12 Are there cases of members delaying in making loan repayments? No [ ] Yes [ ]

D/13 How does the group deal with those who delay in making loan repayments? ....

D/14 Does the group and members use mobile money services in the groups financial transactions? No [ ] Yes [ ]

D/15 If Yes, in what way does the group and members use mobile money services in the groups financial transactions? ....

D/16 What are the benefits of using mobile money services in the groups financial transactions?

D/17 What are the challenges in using mobile money services in the groups financial transactions?

D/18 Have the groups members undertaken any investments as a group? No [ ] Yes [ ]

D/19 If yes, what investments have the members undertaken as a group? ....

D/20 Is the group able to fully finance and support its activities? No [ ] Yes [ ]

D/21 Does the group seek external funding to finance and support its activities? No [ ] Yes [ ]

D/22 If Yes, where does the group seek this external funding? ....

D/23 Does the group operate under any umbrella organization e.g. JOYWO etc? No [ ] Yes [ ]

D/24 If Yes, under which umbrella organization(s) does the group operate? ....

D/25 In what way does the umbrella organization(s) support the group? ....

D26 Other comments? ....

Appendix 4: Key informants interview guide

1. What benefits do members derive from the informal microfinance groups?
2. What constrains performance of members in the informal microfinance groups (Including in terms of contributions, loan borrowed and loan repayments)?
3. What enhances and/or can be done to improve performance of members in the informal microfinance groups (Including in terms of contributions, loan borrowed and loan repayments)?
4. What other challenges do the informal microfinance groups face in conducting their activities?
5. What is done and/or what can be done to address the challenges informal microfinance face in conducting their activities?
6. How have the local climatic patterns changed over time?
7. What causes climate variability?
8. What is the impact of climate variability on people's livelihoods (Including on: Access to education, Health, Crop production, Livestock production)?
9. What is done and/or what can be done address the impacts of change in local climate patterns on their livelihoods (Including impacts on capital assets and production activities e.g. Access to education, Health, Crop production, Livestock production)?
10. How do informal microfinance groups help in addressing impacts climate variability on people's livelihoods? (Including impacts on capital assets and production activities e.g. Access to education, Health, Crop production, Livestock production)?
11. What constrains local people in addressing the impacts of climate variability?
12. What enhances and/or can be done to improve local people's capacity in addressing the impacts of climate variability?

Appendix 5: Focused group discussion guide

1. What benefits do members derive from the informal microfinance groups?
2. What constrains performance of members in the informal microfinance groups (Including in terms of contributions, loan borrowed and loan repayments)?
3. What enhances and/or can be done to improve performance of members in the informal microfinance groups (Including in terms of contributions, loan borrowed and loan repayments)?
4. What other challenges do the informal microfinance groups face in conducting their activities?
5. What is done and/or what can be done to address the challenges informal microfinance face in conducting their activities?
6. How have the local climatic patterns changed over time?
7. What causes climate variability?
8. What is the impact of climate variability on people's livelihoods (Including on: Access to education, Health, Crop production, Livestock production)?
9. What is done and/or what can be done address the impacts of change in local climate patterns on their livelihoods (Including impacts on capital assets and production activities e.g. Access to education, Health, Crop production, Livestock production)?
10. How do informal microfinance groups help in addressing impacts climate variability on people's livelihoods? (Including impacts on capital assets and production activities e.g. Access to education, Health, Crop production, Livestock production)?
11. What constrains local people in addressing the impacts of climate variability?
12. What enhances and/or can be done to improve local people's capacity in addressing the impacts of climate variability?