UNIVERSITY OF NAIROBI

INCREASING FOOD PRODUCTION RESILIENCE THROUGH ECO-BASED FARMING PRACTICES UNDER CHANGING CLIMATE IN THARAKA-NITHI COUNTY, KENYA

BY

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A Thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy (PhD) in Climate Change and Adaptation of the University of Nairobi

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PLAGIARISM STATEMENT

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DEDICATION

This thesis is dedicated to my husband Vincent Alwaka and my son Barak Mwencha for the endless encouragement

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I am grateful to God for the guidance that enabled me to successfully complete the doctorate program on time.

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ABSTRACT

In Kenya, the highest proportion of people gets their income and food from rain fed agriculture. Tharaka Nithi County is not an exception with particularly low annual rainfall. The research was done in Tharaka Nithi County and specifically in Tharaka South Sub County and Tharaka North Sub County. The two Sub Counties have a population of 158,023 people. This is about 65% of population in Tharaka Nithi County. The area of the targeted Sub Counties is 1,569 square kilometres (Km^2) and is subjected to an increasing number of people in need of food aid due to minimal on farm production. The study's main objective was to assess the resilience of food production through eco based methods of farming which would be suitable to the changing climate. The specific objectives were to examine historical climatic data and the effect it had on food security on the households, analysing and assessing the status of food security and what determined it, assess conservation agriculture practices to buffer the effects of climatic change and build resilience.

Low rainfall and above normal temperatures have considerably affected food security through reduction in food production in Tharaka Nithi County. Climate change is real and households must have adaptation remedies that can be used to achieve household food security. Some remedies have been suggested including reduction in amount of food consumed and adaptation of modern farming method such as the use of eco-based farming methods. This study was initiated because food security status in Tharaka Nithi County has not been examined besides any indicated study on the impact of climate change on livelihood based on a trans-disciplinary approach.

A descriptive research design methodology was used. It involved using a 30 year historic data that covered 3 non-overlapping climatic periods made up of 10 years that is, 1982 - 1991, 1992 – 2001 and 2002 - 2012. Farmers who had at least 30 years of experience in farming were targeted using a survey questionnaire. This was administered in sentinel. The male respondents formed the highest percentage with 58% while female respondents formed 42%. The study found that only 11% of the respondents utilized some form of irrigation while the remaining 89% used rain-fed methods together with livestock rearing. An experimental design was also carried out to

compare conventional farming and conservational farming methods; this was done in personal farms which produced sorghum, green grams and cowpeas over a period of four seasons.

Gaussian Kernel analysis, moments, regression and non-parametric approach based on Mann Kendall were used to justify changes in the both mean monthly temperature and rainfall. Food security was determined through multivariate analysis using the Statistical Package for Social Sciences (SPSS); which was used to discover net effects of the variables. Themes and frequencies were also used. Duncan's Multiple Range Test (DMRT) was used together with themes for the final objective. Duncan's Multiple Range Test was used because is best suited for comparing possible pairs of experimental means.

It was established using data from Kenya Meteorology that annual temperature in Tharaka had increased approximately by 0.4°C per decade during 1981-1990 period, increased by 0.3°C per decade for the period 1991- 2000 and 0.25°C per decade for the period 2001 - 2010. For the 30 years that were studied in Tharaka Nithi it was established that the average rainfall per season was between 100 mm to 1250 mm. In the first period of the study (1982-1991) the average rainfall ranged from 100 mm to 1250 mm, the second period comprising of years 1992-2001 the range was between 150 mm and 1150 mm while the final period of the study the range was between 100 mm and 1100mm. This confirmed climate change had occurred. The study analysed household food security status and what determined it. The results showed that households having heads with secondary level of education were more food secure. Further to this households with lesser number of family members were also food secure. The size of the household and food security had a negative relationship. The results showed that conservation agriculture practices yields from the demo plots ranged between 2.0 tonnes and 2.3 tonnes per hectare which therefore meant that the conventional methods yielded 1 tonne less per hectare compared to conservational agriculture.

Agricultural practices are altered by erratic rainfall patterns. This in turn affects the socioeconomic importance and even ground water resources and hydrological sector. From the study the probability of a household being food secure increased with increase with the level of formal education for the household head and also with the number of people contributing to labour increasing. The size of land and food security had a positive relationship, it was also noted that a small scale farmer would produce more and even surplus through using conservation agriculture.

The study therefore recommended that small holder farmers should be assisted to establish conservation agriculture, which would in turn meet their demands and would be relevant to their situation. It was established that the approach of conservational agriculture possibly will help peasant farmers increase productivity by one tonne more per hectare and also steady outputs in marginal lands in punishing climatic conditions, poverty and drought and where there is limited labour occasioned by old age, migration and ill health. Conservation agriculture investment is seen as an apt methodology of supporting food security in the same agro-ecological regions. The level of producing crops reached through farming under conservation agriculture had surpassed conventional farming levels in every season since the beginning of the study. Therefore, conservation agriculture provide insurance against punishing climatic deviations. The study also recommended the use of the analysed climate information, seasonal calendar for agricultural development and general socio-economic improvement by developing strategies for adaptation to climate change.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
ASALs	Arid and Semi-Arid Lands
CA	Conservation Agriculture
CAN	Calcium Ammonium Nitrate
CIDP	County Integrated Development Plan
DJF	December January and February
DMRT	Duncan's Multiple Range Test
EWS	Early Warning System
FAO	Food Agricultural Organization
HDI	Human Development Index
IFAD	International Fund for Agricultural Development
ILO	International Labour Organization
IPC	Integrated Phase Classification
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
JJA	June-July-August
KEPP	Kenya East Pilot Project
KFSSG	Kenya Food Security Steering Group
KFSSG-LRA	Kenya Food Security Steering Group- Long Rains Assessment
KNBS	Kenya National Bureau of Statistics
KMD	Kenya Meteorological Department
LZ	Livelihood Zone
MAM	March-April-May
MF	Mixed Farming
MMF	Marginal Mixed Farming
MK	Mann Kendall
MUAC	Mid Upper Arm Circumference
NDMA	National Drought Management Authority
NPK	Nitrogen, Phosphorus and Potash

RFC	Rain Fed Cropping
RFE	Rainfall Estimates
SON	September October and November
SPSS	Statistical Package for Social Sciences
UN FAO	Food and Agriculture Organization of United Nations
UNEP	United Nation Environmental Programme
URTI	Upper Respiratory Tract Infection
VCI	Vegetation Cover Index
WB	World Bank
WFP	World Food Programme
WFS	World Food Systems

STRUCTURE OF THESIS

This Thesis comprises of two parts: Part A and Part B. Part A gives an overview of the Thesis and is divided into Eight Chapters. These are; Introduction, Literature Review, Methodology, Data and Methods, Findings, and Summary of Conclusions and recommendation. The preamble captures the research questions, problem statement, justification and the objectives. The literature review outlines the key ideas and theories that helped to understand this and clearly established where the knowledge gaps were in the intended area of the study. The theoretical framework explains the theory underlying the methods to be employed in the study. The conceptual framework shows the variables included in the study. The methodology gives an account of how the research was carried out by clearly specifying the procedures that were followed in meeting the objectives of the study. The results set out the key findings. The synthesis and discussion chapter brings together all the key findings in the preceding chapters (those that relate to the specific objectives), makes connections across and between the specific objectives, and derives a higher order discussion that leads to a clear demonstration of the achievements of the overall objective. The final chapter in this thesis is conclusion and recommendation. This chapter summarizes the findings of the whole thesis and gives conclusions and recommendations. Part B of this Thesis consists of three research articles: three papers that have been published in peer-reviewed international Journals, and one submitted manuscript.

CHAPTER ONE: GENERAL INTRODUCTION

1.0 Introduction

The background of the thesis is provided in this chapter and includes problem statement, a list of research questions and study objectives. The chapter also provides justification of study, its significance and the scope of the study.

1.1 Background

The World Food Summit (1996) defined a population that was food secure as one that had available food that was easily accessible; the supplies were stable and constantly utilized (Foresight, 2010). A food secure population is one that had safe, physical, economic, nutritious and sufficient food to be able to meet their dietary requirements. However, the dilemma for humanity by the 2050 will be feeding a projected population of 9 billion persons. A study done by (IFAD, 2012) showed that 925 million persons were starving transversely worldwide and these therefore show the urgency of double production of food by year 2050. This report also indicated that farming worldwide was highly degraded and this was linked to climate changes. The gap amid supply and demand of nourishment produces and the always increasing inflation rates implied that 50% to 80% of underprivileged people income was used on foodstuff (IFAD, 2012).

Growth in population in Africa has been fast; between 2000 and 2005 ten nations with average maximum yearly growth rate in the world were in Africa. Sub-Saharan African countries are 18 out of 20 countries with highest fertility level until 2055. An example is that in the said period, Nigeria was projected to have a population growth rate which was globally third largest. It is currently in the top ten of the world most populous nations and anticipated to endure. This population growth rates in African countries point to an important fact that, the continent's population is estimated to virtually duple to two billion from the current almost one billion in the next 40 years (United Nations, 2012).

Current food security in Africa is through domestic food production and imports from overseas. It has been established that 40% of rice imported from Thailand is destined for West Africa to guarantee adequacy (FAO, 2010). According to FAO (2013a) Africa imported a total of 66 million tons of cereals in 2010, indicating that 30% of the consumed cereals were imported. African cereal exports are negligible and it would be right to argue that even without exporting, imports will still make 28% of the internal intake of cereals (FAO, 2013b). Wheat export from US to Nigeria forms highest trade flows (FAO, 2013a). Even with efforts put in production and importation of food, 239 million people were found to be undernourished in Africa more specifically sub-Saharan Africa in 2012. This number has been increasing by 35% in the last two decades (FAO, 2012). Food insecurity is significantly on the increase hence causing a lot of concerns. Africa has three options to deal with increasing food demand due to increase in population growth: escalate internal food production, increase foreign food imports and finally rise both importations and food production.

Modern agriculture has been viewed as one way of sustaining the world population. Contemporary agriculture encourages the usage of chemical fertilizers, irrigation systems, large-scale monoculture farming which raises efficacy and yield and lastly usage of equipment. According to Cordell *et al.*, 2009; UNEP (2011) and Gleick and Palaniappan (2010) these methods of agriculture have proven unsustainable. The main reason being that these modern methods are water intensive for irrigation purposes and use a lot of fossil fuels for production of fertilizers, machinery and transportation. Phosphate rock used in fertilizer production and fossil fuel are finite resources and are becoming scarce. An increase in projected rock production of phosphate will top in the course of the century but are declining hence creating a demand gap (Cordell *et al.,* 2009).

Conferring to Fader *et al.,* 2013 opinions that a larger number of countries in African will have to increase efficiency in agriculture coupled with agricultural land use expansion so that increasing consumption requirements is gratified even with conservative population growth having been adopted. Crop production is affected by changing climatic condition leading to lower productivity and a reduction in land that is suitable for production. To offset negative effects caused by climate change, Africa needs to adopt extraordinary agricultural efficiency improvements and hence increasing agricultural productivity.

According to Nelson *et al.,* 2009, inconsistent rainfall patterns coupled with high temperatures had played a significant role in reduction of crop yield, proliferation of food by pest, an increased probability of on farm crop failure and consequentially a decline in production. It is therefore necessary globally to step up food security due to the ever-growing population and hence increased demand for food. Parry *et al.,* (2009) estimated that 10 million or more children in the sub-Saharan Africa will be malnourished due to climate change. This shows that climate change indeed has an impact on children. A report by International Panel on Climate Change (IPCC) (2007) showed that Africa was warming faster than the global average. As compared to the year 1990 surface temperature is projected to increase with a range of between 1.4°C to 5.8°C by the year 2100; this will be accompanied by a 10 to 90 centimetres rise in mean sea level.

There was a significant decrease in the contribution of the agriculture sector to the Kenyan GDP from 35% to 24% from 1964 to 2004 respectively; despite Agriculture being a major sector in Kenya. However, it is still a significant contributor to development (Republic of Kenya, 2002). Kenya has a total of 56.9 million ha of land with agricultural land covering 90% of it. Agriculture remains the main economic driver and is expected to maintain its primary role. Main agricultural commodities in Kenya include food crops (roots and tubers, pulses, sorghum and millet), cereals (rice, wheat and maize), livestock (eggs, milk and meat), exports crops (coffee, horticulture and tea) and traditional industrial crops (pyrethrum, sugar, tobacco, sisal and cotton) (Nyangito, 1998).

The agricultural sector in Kenya is majorly in the hands of smallholder farmers and their contribution in terms of agricultural output is over 65%. Pastoralists in Arid and Semi-Arid Lands (ASAL) and agro pastoral regions have the prospective of growing cotton as one of their cash crop while they can also grow millet, maize, pigeon peas and sorghum for sustenance. Maize, tea, wheat and coffee are crops cultivated in agricultural estates. Amount of rain and its distribution in Kenya greatly influences agricultural production since agriculture in Kenya is predominantly rain fed. According to Short and Gitu (1990), the scarcity of land is further sensationalised by episodes of prolonged droughts. Decline in food production and shortage of food has been concomitant with the intermittent drought.

Conservation Agriculture (CA) is one of the eco-based farming practices that promote increase in food production under changing environment. Least soil disturbance, useful crop rotation and associations are the three basic CA principles. Developing countries are using the principles of conservation agriculture to enhance agricultural performance and sustain food resilience. Conservation agriculture aims at conserving the environment, maximizing on agricultural productivity and preserving the ecosystem. Further conservation agriculture promotes minimum utilization of external agrochemical inputs which ensure soil conservation is maintained. According to Rockstrom *et al.,* (2009) conservation agriculture enhances food production while conserving the environment thus promoting sustainability for future generations.

1.2 Problem Statement

There are 17 Sustainable Development Goals (SDG). The second being end hunger, achieve food security and improved nutrition and promote sustainable agriculture. Strategies have been put in place to achieve the SDG which includes ending hunger by 2030 and ensure access of food by all persons and in particular the poor people and those in susceptible situations such as infants. The accessed food must be nutritious, sufficient and safe, all year round. By 2025, all the globally agreed targets on wasting and stunting in less than 5 years old children must have been met to end all forms of malnutrition by 2030 The import of this is that nutritional needs of lactating and pregnant women, older persons and adolescents must be addressed. This can be achieved by 2030 through collective production in agriculture and increase of incomes of smallholder producers of food, particularly fishers, indigenous persons, women, pastoralists and family farmers. This can be achieved through equal and secure land access, knowledge, markets, financial services, other productive resources and inputs and openings for non-farm employment and value addition to food crops.

It is also important to safeguard sustainable systems for food production and operationalize resilient agricultural activities. This has the effect of increasing output, which assist in the maintenance of ecosystems that support capacity for climate change adaptation. It also helps adaptation to other disasters including drought, extreme weather and flooding. This could be achieved by progressively improving land and soil quality by 2030 and by 2020 preserve genetically diversified seeds, farmed and domesticated animals; their related species and cultivated plants. Output can further assured by creating banks for plant at global, regional and national levels besides ensuring access to equitable and fair sharing of benefits accruing from the use of genetic resources and attendant traditional understanding as agreed globally.

The conventional agricultural method of farming entailed: preparing land at least two weeks before the onset of the rain season. This was followed with bush clearing burning, ploughing using un- mechanized techniques then planting. This exposed the land minimal soil retention capability and minimal productivity rendering the areas to be exposed to food insecurity. The SDG number two which is to "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" distinguishes the relationships among supporting sustainable agriculture, promoting gender quality, tackling climate change, ending rural poverty, empowering small farmers and other issues addressed within the 17 SDG in the Post-2015 Development Agenda.

Enhancing on the system and strategies by individuals and households in food security allows more resources and time to be channelled to economic situations through investment on improved means of education, production and other societal issues. Hunger and famine are deeply rooted to food insecurity. The categorization of food insecurity can be either chronic or transitory where chronic situation refers to high degree of susceptibility to hunger and famine, chronic food insecurity has linkage to malnourishment and poverty. Hence the need to understand the root causes of food insecurity. To this end this calls for assessing the determinants of food insecurity.

Frequent droughts are common in Tharaka Nithi County especially in Tharaka South and Tharaka North Sub Counties which are usually worst hit by the droughts (KFSSG- LRA, 2014). Thus with the frequent droughts, households whose main source of livelihood is livestock are left vulnerable. This vulnerability state is exacerbated by the constantly changing climate. Climate change enhances challenges on food production, hence limiting the societal, economic and physical growth (Nelson *et al.,* 2011). Tharaka North and Tharaka South Sub Counties as previously noted, besides having changing weather conditions which in turn has affected crop production, malnutrition levels have increased, there is decrease in the water levels, livestock production has decreased which has also affected school attendance and enrolment (KFSSG-LRA, 2015).

According to (KFSSG- LRA, 2014) the communities' livelihood strategies have been interfered with by the declining rainfall amounts according to the seasonal calendar and the increasing temperatures. These factors were considered not to be favourable to crop production and animal husbandry. Low rainfall amounts and above normal temperatures have considerably affected food security through reduction in food production in the region (KFSSG- LRA, 2014). Frequent droughts, little ground cover and other environmental factors have led to land degradation. Analysis done by (KFSSG- LRA, 2014) in Tharaka Nithi County showed that 16,300 more people needed food aid in comparison to the number of people who required food aid in 2013. Conflict, resource management and policy have been some of the other factors that have contributed to food insecurity in Tharaka Nithi County. This study set to evaluate conservational agricultural practices to cushion the impacts of change in climate and build resilience. The community in this area mainly concentrate in the farming of Small East African type of goats whose milk production, growth rate and live weight is low. Browsers such as goats are favoured by the vegetation in the area which is majorly acacia bushes and little grass cover as opposed to grazers such as cows.

According to the (World Bank, 2010) a combination of factors increase the stress on livelihood, some of these factors include; increase in population, decreasing land space and water supply, constantly changing climate and volatile food prices. This clearly indicates that food security is at a complex scenario. A single explanation cannot elucidate the occurrences and their solution and hence the trans-disciplinary approach. The study was also initiated since food security status in the county has not yet been examined besides any indicated study on a trans-disciplinary approach to studying the effect of change in climate on livelihoods.

1.3 Research Questions

1) What are the trends in the 30 years of climate historical data and their implication to household food security in Tharaka Nithi County?
2) What are the determinants of the household food security status?
3) What ways can be used for adaptation to be promoted and be made more resilient at policy and community level with preference on conservational agriculture?

1.4 Overall and Specific Objectives

The overall objective of this study is to assess food production resilience using eco-based farming practices in Tharaka Nithi County in Kenya under changing climate. The specific objectives are:-

1) Examine historical climate data and its implication on household food security in Tharaka Nithi County.
2) Assess household food security status and their determinants.
3) Assess conservation agriculture practices to buffer the effects of climate change and build resilience.
4) Provide policy recommendations on building community resilience to climate change.

1.5 Justification of the Study

Browsers such as goats are driven from home in search of pasture and water during the drought periods; this leaves the households without enough food since they provide both milk and meat. Implying there is need for economic community empowerment, building resilience and protection of households from climate extremities that expose them to food insecurity. Some of the measures for food security would be use of effective safety net measures and proactive coping response as opposed to reactive responses. The study sought to address issues of food shortage as illustrated with the number of persons in need of food aid (figure 1.1 and 1.2) with the knowledge that climate was constantly changing so that technology could be adopted to exemplify food crop resilience.

The following were some of the areas that were studied; long term historical climate data and its implications to food security, building sustainable practices to increase food availability through eco based farming practices. The study finally made recommendations on ways to improve the above factors to achieve a positive effect on household food security. Frequent droughts, little ground cover and other environmental factors have resulted to land degradation. To address the issues of forage shortages during drought, the community needs to adapt strategies that exemplify pasture development. The community also needed to be trained on food diversification and through this will be able to increase their granaries and excesses can be used for income generation in the household.

Figures 1.1 and 1.2 displays the total number of people who were considered in need of food aid for the period 2005 to 2014 for both short rains and long rains assessments, respectively (KFSSG SRA and LRA, 2015)

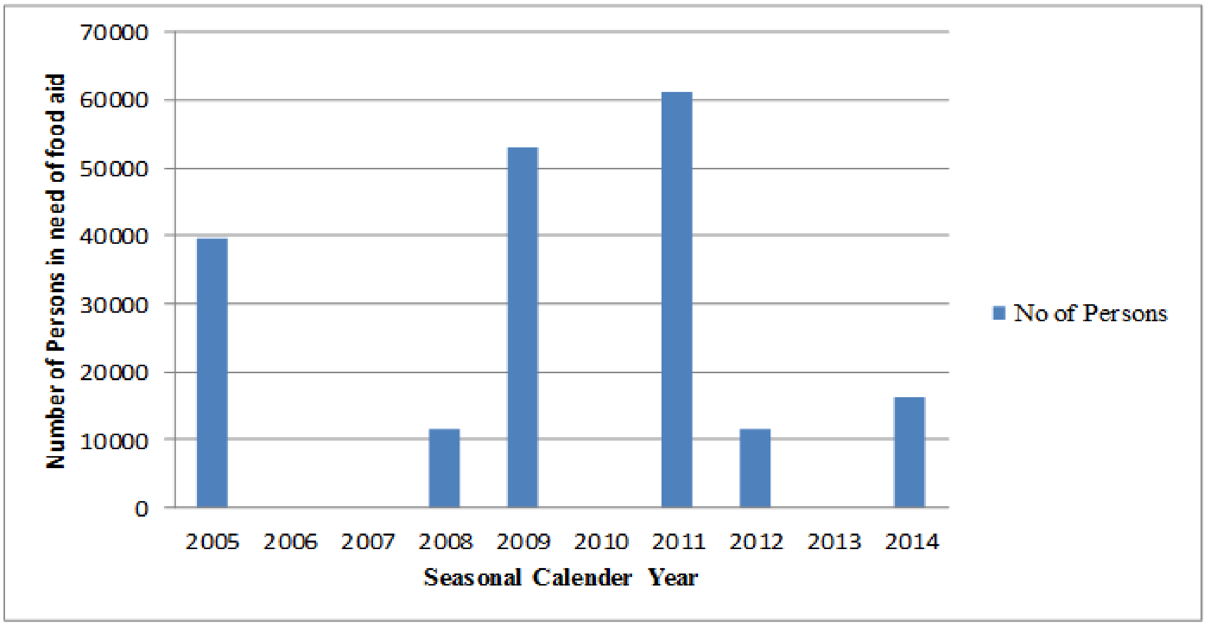


Figure 1.1: Number of Persons in Need of Food Aid after Short Rain Assessment (Source: KFFSG Report, 2015)

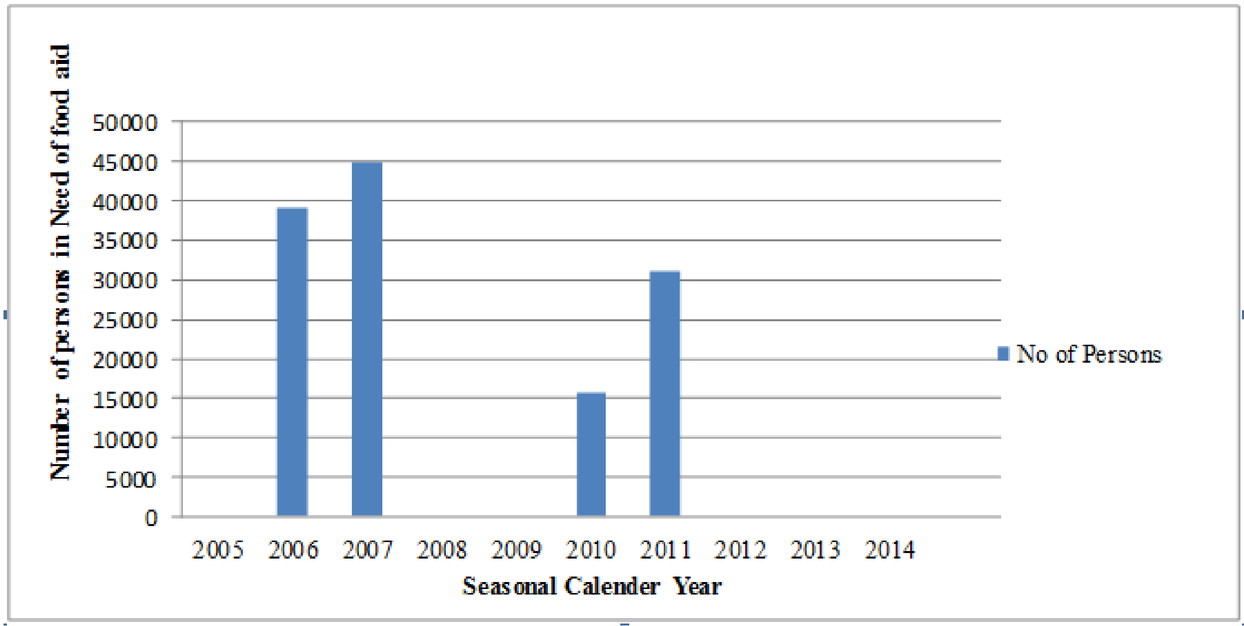


Figure 1.2: Number of Persons in Need of Food Aid after Long Rains Assessment (Source: KFFSG Report, 2015)

1.6 Significance of the Study

Food security has many aspects which are interrelated through natural resource use, consumption and production chains and interactions amongst Countries and thus these calls for a holistic and integrated approach. It has been established that SDGs have taken a more integrated approach as opposed to Millennium Development Goals (MDGs). However, it is not enough. It is clear how goals are interconnected, however there is no clarity on how SDG context addresses them to decrease inconsistencies and augment synergies in the hunt of diverse goals. To make the SDG framework sustainable there is need to link food security and other goals. While there is principally agreement around food security objectives, the approaches to realize them need to be developed. To achieve this, climate smart agriculture, agro-ecology, agro-forestry, conservation agriculture, biotechnology and individual inputs have been suggested. Nevertheless the suggestions mostly speak in general terms about policy, investment and technical conditions. This study on increasing food production resilience using eco-based farming practices under changing climate in Tharaka Nithi County is deeply relevant in light of the foregoing.

1.7 Area of the Study

The study area lies amid latitude 0.00^{0} 07'S and 0.00^{0} 26' S and linking longitudes 37^{0} 19'E and 37^{0} 46' E. Located in Eastern Kenya, Tharaka Nithi County borders Meru County to the North East, Embu County to the South West, Kitui County to the South East and finally Kirinyaga and Nyeri Counties to the West (Figure 1.3.)

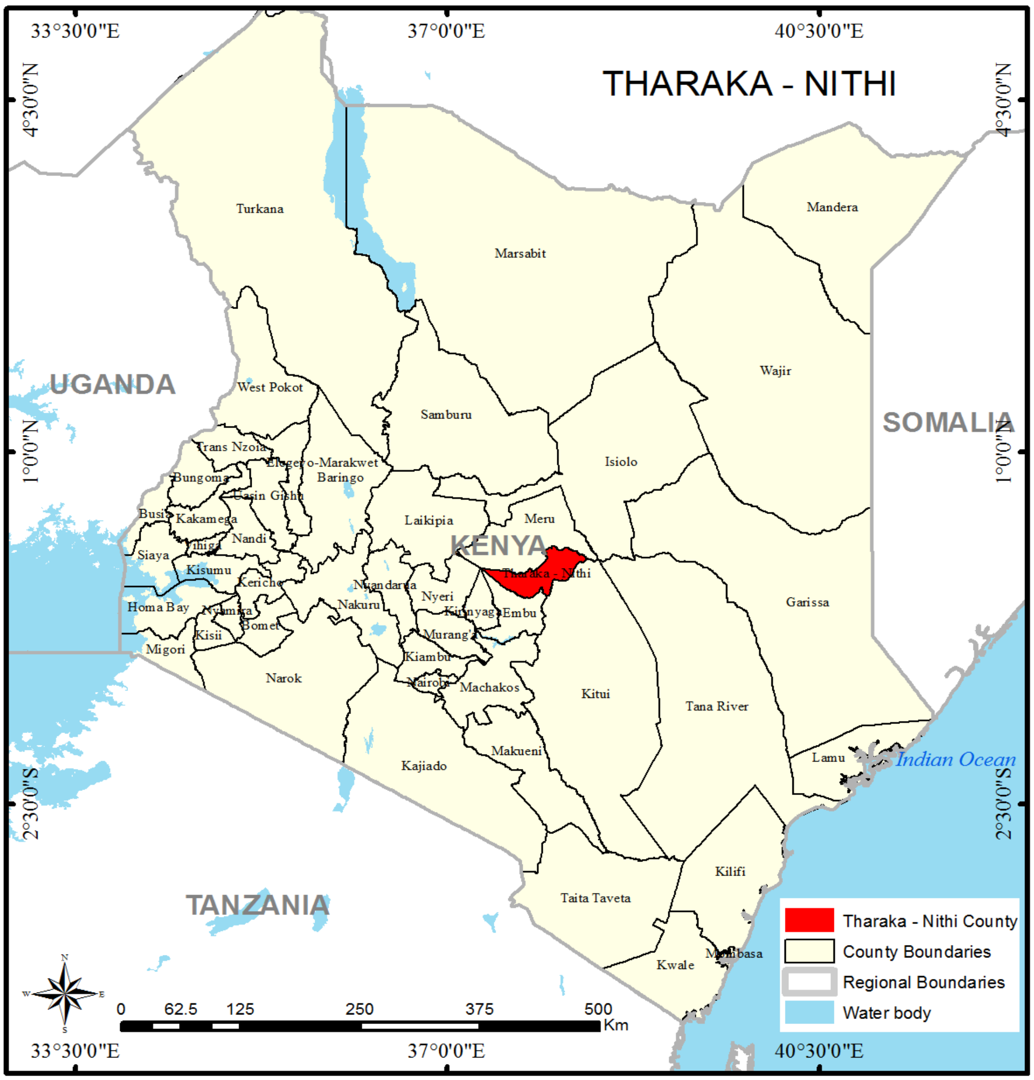


Figure 1.3: Map of Kenya Highlighting Tharaka Nithi County

(Source: CIDP, 2014)

The study covered Tharaka South and Tharaka North Sub Counties. These two Sub Counties are semi-arid and they cover 1,569 (km^2) with a population of 158,023 persons (KNBS Projections, 2013). The three main livelihood Zones (LZ) include; Mixed Farming (MF), Marginal Mixed Farming (MMF) and Rain-fed Cropping (RF) with population's percentages of 52%, 10% and 38% respectively. The rainfall is cyclic which is bimodal; long rains (March, April, May (MAM)) as well as the short rains (October, November, December (OND)). Cumulatively the rainfall is unpredictable and poorly distributed as illustrated in figures 1.4a to 1.4c.

1.8 Biophysical Settings

This section presents the biophysical settings of Tharaka Nithi which includes climate, vegetation, land uses and resources, physiographic and drainage, water resources, socio-economic settings, political and administrative context, local economic setting, health setting and socio-economic vulnerabilities.

The figures 1.4 a, b and c illustrates the 10-year spatial distribution of the annual average rainfall over a 30-year period in Tharaka North and Tharaka South Sub counties in Kenya. These spatial maps depict rainfall variability within each of the 10-year period thus showing changes in the average climatic conditions in this County.

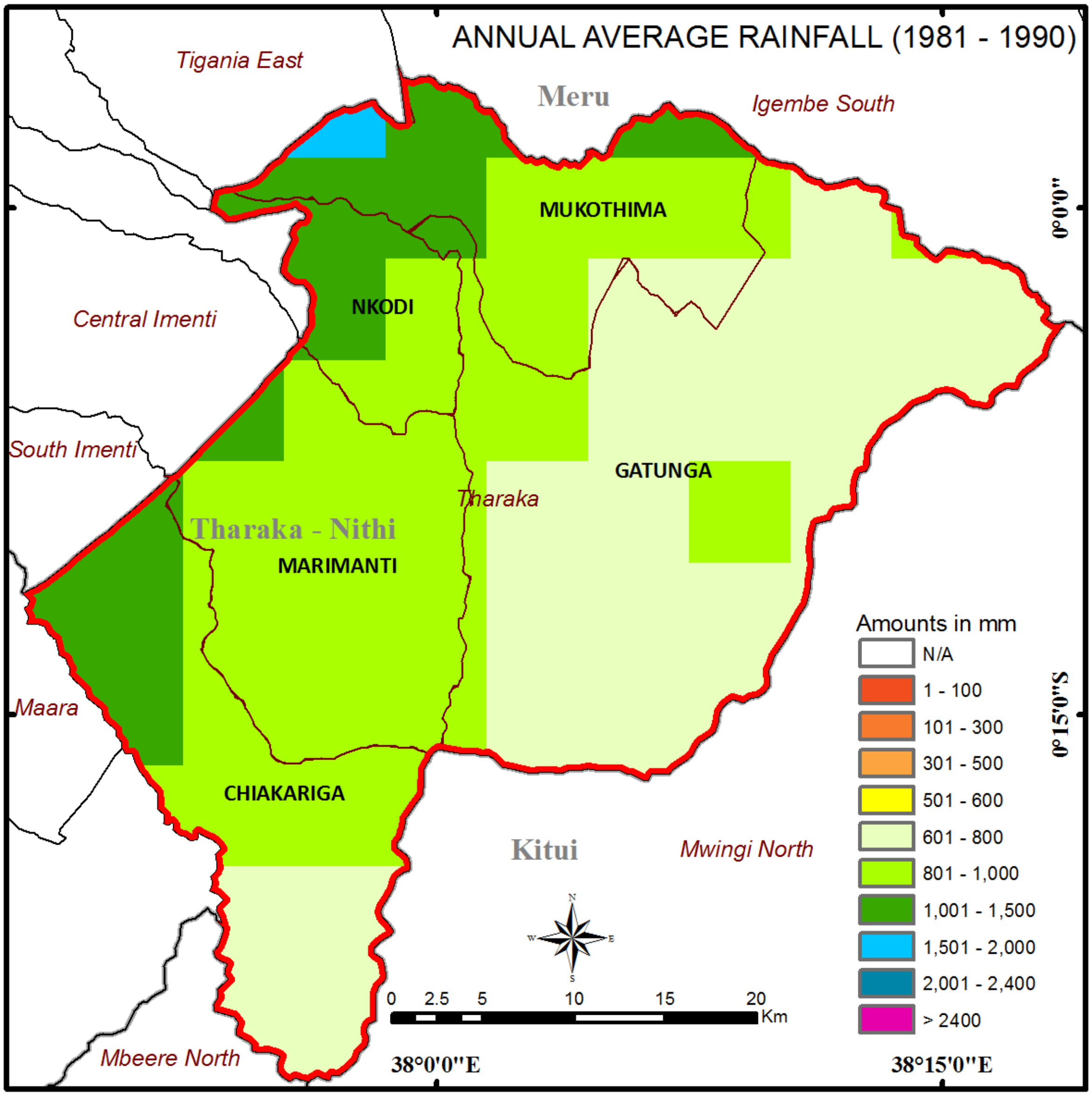


Figure 1.4a: Spatial Distribution of Annual Rainfall over Tharaka Nithi Between 1981-1990

Source: Research data on Rainfall (K M D, 1981-2012)

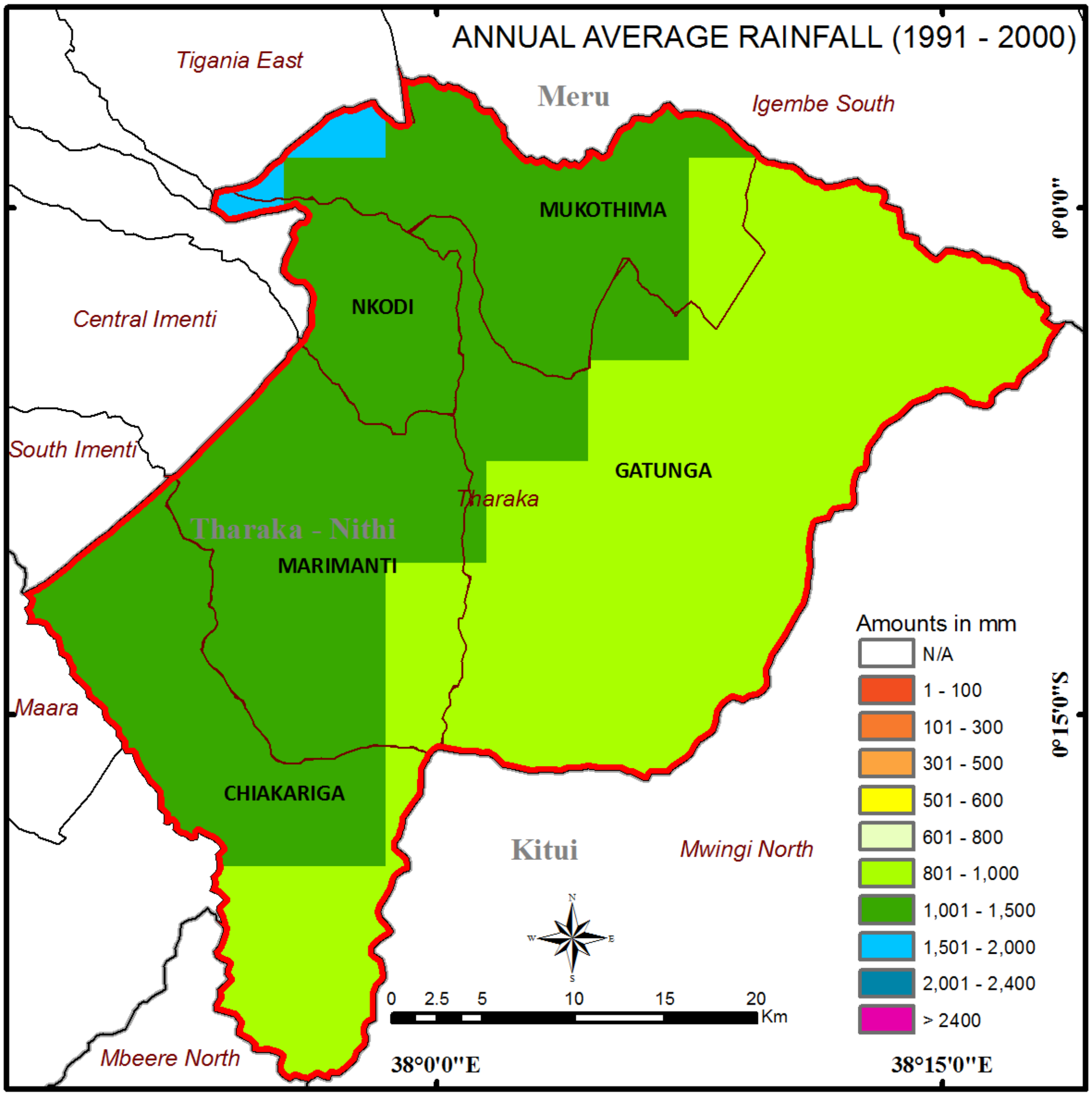


Figure 1.4b: Spatial Distribution of Annual Rainfall over Tharaka Nithi Between 1991-2000

Source: Research data on Rainfall (K M D, 1981-2012)

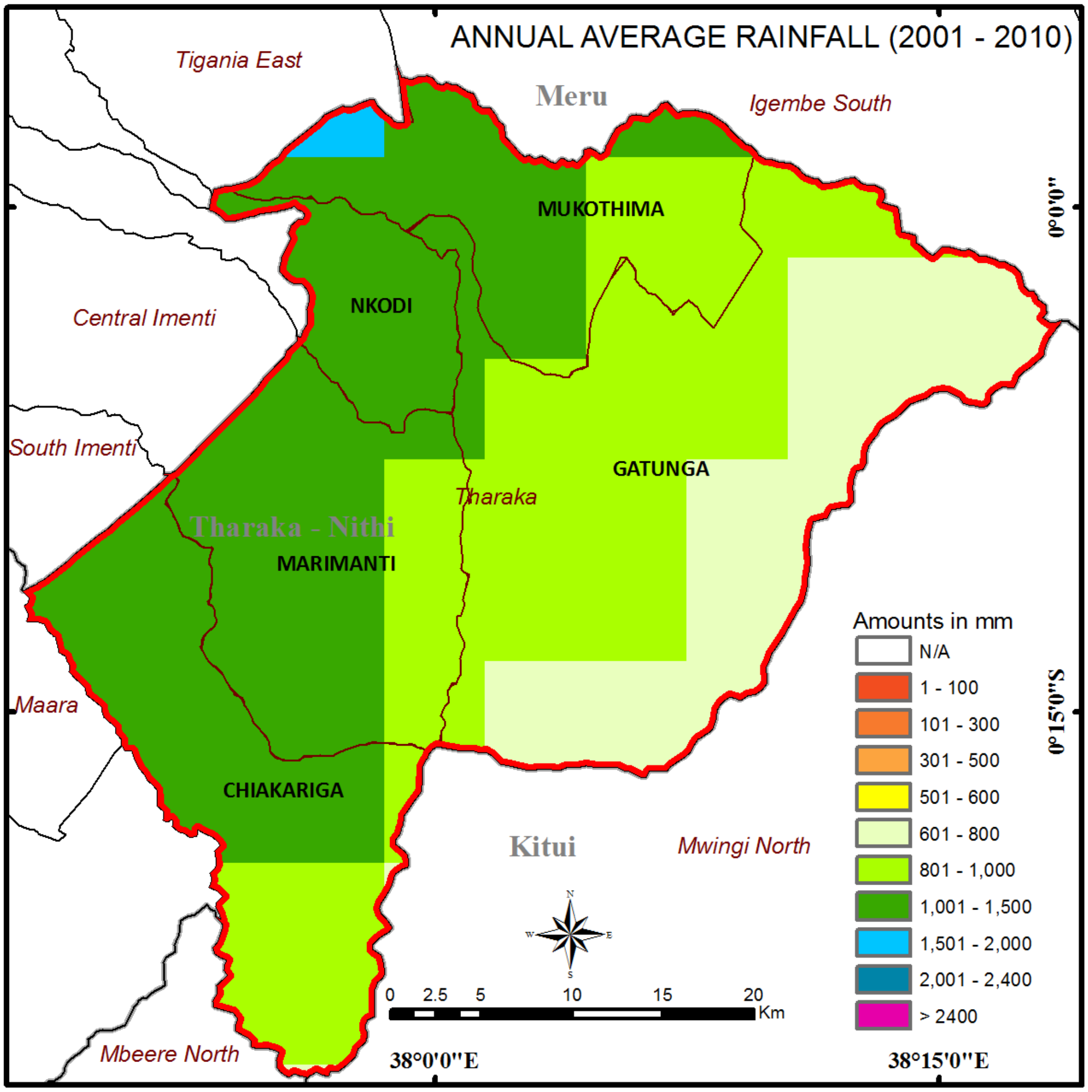


Figure 1.4c: Spatial Distribution of Annual Rainfall over Tharaka Nithi Between 2001-2010

Source: Research data on Rainfall (K M D, 1981-2012)

1.8.1 Climate and Vegetation

Temperature range is between 22°C to 36°C in the low lands and in some seasons as high as 40°C since Tharaka area, is situated at the southern side. The two-season rainfall pattern that is the MAM and the OND rains cumulatively amounts to 500mm. Vegetation is predominantly acacia bush land with little grass cover which favours browsers as opposed to grazers. Also, evident in the area is land degradation resulting from frequent droughts, little ground cover and other environmental factors (CIDP, 2014). The matrix below Figure 1.5 exemplifies the duration between February 2001 and April 2017, which was categorized as an agriculturally drought period based on threshold of Vegetation Cover Index (VCI). The matrix demonstrates a retrospective examination of the vegetation outlook as correlated to drought.

Figure 1.5 shows that as of April, 2017, Tharaka was in a great vegetation shortage band within the limit of 10. There was a decline from 18 in March 2017 to 10 in April 2017 in the 3-month VCI index meaning that the County's vegetation condition worsened; which is attributed to poor rainfall performance in the period March - April (KFSSG - LRA, 2014).

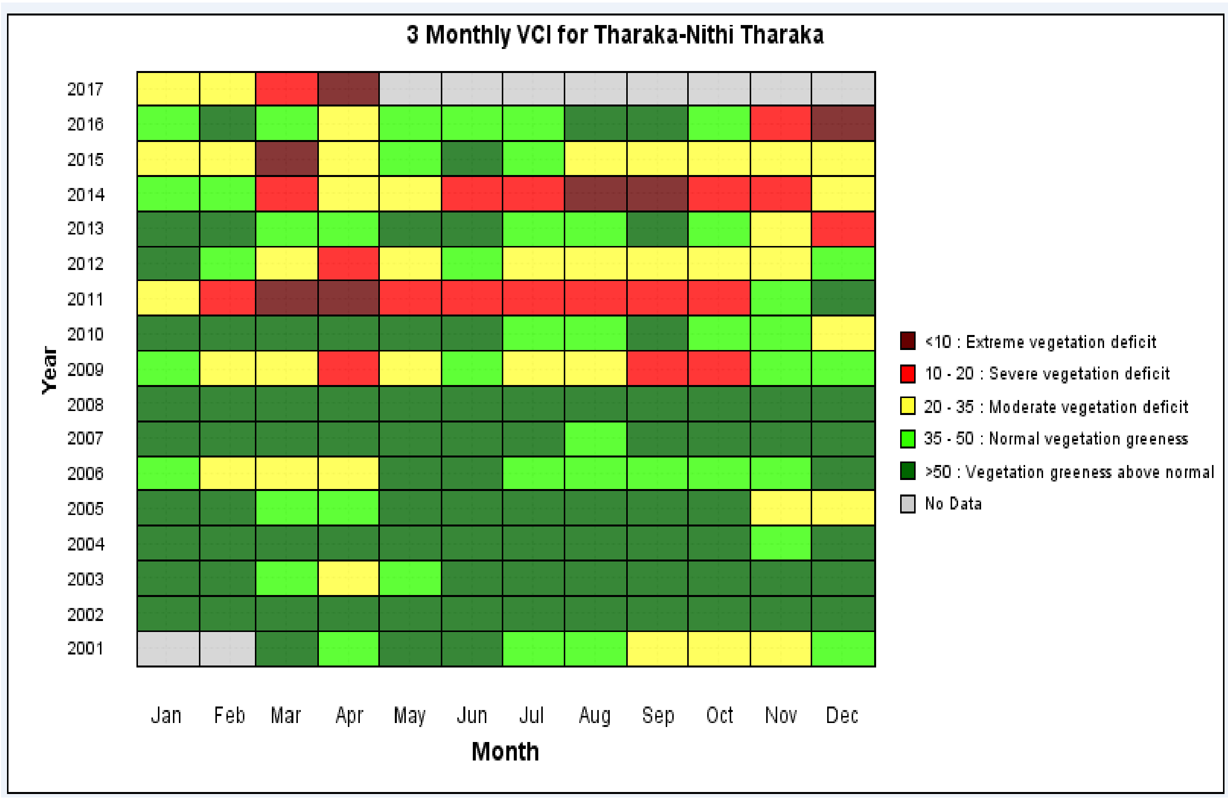


Figure 1.5: Monthly Vegetation Condition Index

(Source (NDMA bulletin, April 2017)

1.8.2 Land Uses, Resources, Physiographic and Drainage

Majority of the study population were farmers in different areas. Other land uses include construction and forest conservation. Most of the community members practise small scale agriculture, at approximately 3 acres for small stock and crop husbandry while the large-scale land owners have approximately seven acres, leading to a mean of 5 acres per household. The challenges on land issues include slow land demarcation, boundary resource disputes and inter conflict on the pasture field areas. The semi-arid area is characterized with minimal rainfall, and high temperatures best suitable for livestock rearing. The continuous charcoal burning, poor farming methods has exposed the land to soil erosion, deep gullies and more vulnerable, hence low productivity. The rivers and streams form beautiful scenery that drain to Tana River and eventually to Indian Ocean (CIDP, 2014).

1.8.3 Water Resources and Socio-economic Settings

The major sources of water are: permanent and seasonal rivers, boreholes, pans/dams, sand dams, springs and piped water system. The long rains and the short rains recharged water sources are between 50% and 80%. During the dry spells, the water is abstracted up stream rendering household downstream vulnerable. The Nithi Water and Sanitation Company and Tana Water Services Board are the key water developers and supplier scheme in Tharaka Nithi. Latrine coverage is above 60% across the Sub Counties while the utilisation ranges between 50% and 60% (KFSSG - LRA, 2014).

Interference on the normal livelihood and a decrease in the goods and services provided by the ecosystem has resulted to the continuous interference of the ecosystem. An example is when that land that was used for agriculture was significantly reduced due to increase in population hence reducing its productivity. The land that was left can only cater for single family subsistence needs and little that is sold for income purposes. The agricultural activities and the resulting output have significantly been dictated by soil erosion and leaching. Community empowering is needed to embrace range land management coupled with sensitization on the dangers of degradation of the forest in order to improve on secure livelihood. Social-economic setting of the ecosystem has largely been disturbed by the continuous deforestation without replacing the cut down trees. Rural-Urban migration will result from low food production, increased diseases and all those will be as a result of changing climate (CIDP, 2014).

1.8.4 Political and Administrative Context

The County is made of four Sub Counties, Tharaka North which is the largest occupying 803.4 Km^2 followed by Tharaka South with an area of 766.1 Km^2, then Meru South Sub County and lastly Maara Sub County. The first two Sub Counties have a total of twenty-one (21) Locations and forty-five (45) Sub Locations. Table 1.1 gives an illustration of the approximate cumulative coverage of the Sub Counties, Locations, Sub Locations and Wards in Tharaka area.

Table 1.1: Administrative Subdivision

Sub County	Area (km^2)	Wards	Locations	Sub Locations
Tharaka North	803	2	7	12
Tharaka South	766	3	14	33
Total	1,569	5	21	45

(Source: CIDP, 2014)

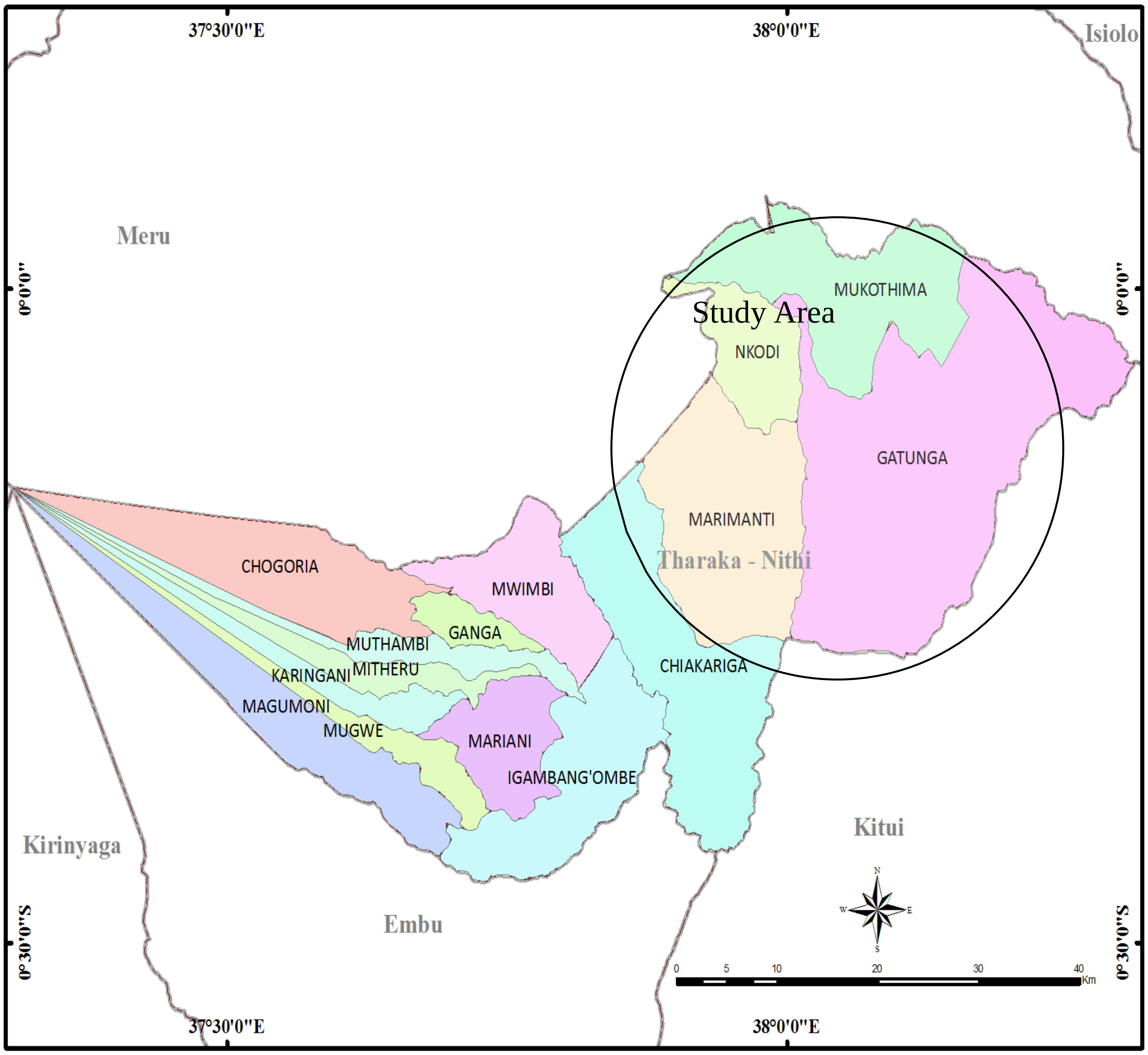


Figure 1.6: Boundary Demarcations Involving Three Constituencies in the County

(Source: CIDP, 2014)

1.8.5 Local Economic Setting

Ecological and climatic factors determine population density. The population density of the County is around 150 people per square kilometre. Table 1.2 shows population densities.

Table 1.2: Population Density and Distribution by Constituency

Constituency	2009(Census)		2012 (Projections)		2015 (Projections)		2017 (Projections)	
	Density (Km^2)	Population	Density (Km^2)	Population	Density (Km^2)	Population	Density (Km^2)	Population
Tharaka	83	130098	87	137316	92	144935	96	150248

Source: KNBS, Population and Housing Census, 2009

Sex in Tharaka can also be used to determine the population distribution. The composition of the population based on the different sexes was used to determine sex ratio.

Table 1.3: Population Projections by Constituency

Constituency	2009 (Census)			2012 (Projections)			2015 (Projections)			2017 (Projections)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Tharaka	62887	67211	130098	66376	70940	137316	70059	74876	144935	72627	77621	150248

Source: KNBS, Population and Housing Census, 2009

Table 1.4: Human Development Index at National and County Levels

	Life Expectancy (years)	Adult Literacy (%)	School Enrolment (%)	GDP (%)	HDI (%)
National	56.6	71.4	70.5	0.4447	0.5608
County	63.7	69.75	78.1	0.3882	0.5533

Source: KNBS, Population and Housing Census, 2009

From table 1.4, it can be seen that the County's life expectancy level was 63.7 years which is higher to the National Level of 56.6 years, the literacy level stood at 60.75% which is lower than the national percent of 71.4% with enrolment being 78.1% which is higher than the national rates of 70.5%. Human Development Index (HDI) mean score was approximately 0.553 compared to the National level of 0.561 (KNBS, 2009).

1.8.6 Health Setting and Vulnerabilities

The most common diseases affecting the population in Tharaka Nithi, especially children under five years are diarrhoea, Upper Respiratory Tract Infections (URTI), Malaria, Rheumatism, Pneumonia and intestinal worms and skin diseases. Due to the frequent droughts in Tharaka, the pastoral communities are forced to move their herds to the lower parts of Meru National park in search of water and pasture. Through moving, the cattle are exposed thefts from the neighbouring communities and diseases. This compromises the livelihood since livestock is their main source of income (KFSSG – LRA, 2014)

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter reviews the relevant literatures that were used in the study. It begins by discussing the theoretical statement and reviews literature on change in climate and bionetworks, livestock and agriculture. The chapter also looks at comparison between climate change and sustainable practices, poverty, adaptation and the impacts of studies done on climate change.

2.1 Literature Review

The segment below is literature review on climate change and ecosystems. According to Devereux and Maxwell (2001) food and nutrition is not portrayed as it was portrayed before as a cave in of agriculture that would ensure food availability and sufficiency nationwide but a point of livelihood and a guarantee of adequate food availability at the households. It therefore implies that the troubles for food insecurity are strongly connected to the universal dilemma on livelihoods. The third evaluation by Intergovernmental Panel on Climate Change (IPCC) (2001b) affirms that presently the arid zones have higher capacity for food production on average than before in the midst of global warming. Winters *et al.,* (1999) argued that food security was directly associated with changes in climate, this is because production of food was highly dependent on the changes in climate coupled with physical environment among other food security shaping variables (Parry *et al.,* 2004).

The effects on food production by climate changes are a key priority area for the Countries food security situation (Bryant *et al.,* 2000). This is because climate changes resolutely have an effect on availability of food and farm production. This is because farming is naturally disposed to weather conditions and thus amongst the greatest vulnerable areas to hazards as well as to impact of worldwide climate change (Parry *et al.,* 2004). Hence conservation agriculture cushions the loss of soil moisture.

Conservation Agriculture is conservatively and perhaps most regularly distinct as pull of field stage agronomic practice which revolve around three ideologies; direct seeding to reduce soil disturbance, avoidance of great compressing by the use of equipment, animals or humans, no or minimal tillage. Secondly maintain permanent cover soil via usage of intercrops, cover up crops, or mulching by crop left over and other organic sources in addition to diversification of crop rotation to plant environment suitable sequence of plants frequently together with nitrogen fixing variety that aid maintenance of soil dynamism, minimizing diseases and pest (Derpsch *et al.*, 2010).

2.2 Climate Change and Ecosystems

Plants, animal, microorganism community and the environment of the non-living relate with every other forming a practical harmony in a bionetwork. People benefit from an ecosystem through the ecosystem services such as quality and quantity of water, soil conservation, food, biodiversity, forest products, cultural values and recreation. Mechanisms should be put in place to ensure that there is maintenance of nutrient cycles, production and soils formation and through this the ecosystem is able to provide services for human. Ecosystem may break down its functioning in case there is a disruption or loss of natural ecosystem.

Climatic changes and extreme events such drought and forest fires lead to having large portions of species in danger of extinction. Included here is the purification of water enabled by forests and wetlands, the fortification of coastline from storm flows by coral reefs and mangroves, the control of diseases and pests and the recycling of undesirable nutrients and removal of carbon from the air (Warren, 2011). Bolin *et al.*, (1989) brought out the dissimilarity among universal bionetwork of the earlier and future times; in the latter human action and involvement in normal environment will add to agriculture, over grazing and deforestation that will hasten the desertification procedures particularly in semi-arid lands and sub tropics.

Global climatic changes affect directly and indirectly both the ecosystem and the ecosystem services. Researches have revealed that an upsurge in Carbon dioxide has direct effect on the crop productivity; this is because higher levels of Carbon dioxide enhance photosynthetic activities which in turn increase productivity by a process called Carbon dioxide fertilization. Stomatal closure result to increased water use efficiency and in the process decreasing transpiration. However, this differs in different species of plants. In the long run species in terrestrial ecosystems may indirectly react undesirably to rises in concentration of Carbon dioxide. Elevated Carbon dioxide concentration causes indirect responses in the ecosystem like temperature or radiation change, precipitation, humidity or other climatic factors. The change in climatic factors in most cases can be the reason for an effect on bionetworks (Bolin *et al.,* 1989).

The Global Environmental Change (GEC) has increased with better environmental exploitation by humans' in turn increasing level Carbon Dioxide in the atmosphere leading to fragmentation hence loss of natural habitats. This has led to rapid changes in ecosystem in the world. Many studies have been carried out showing the effect GEC on population abundances, composition of the community and organism physiology and therefore network of interactions among species may be less obviously alerted by GEC. Parasitism, predation and pollination are ways in which bionetworks interact. As such they play an important role in the maintenance of biodiversity, the stability (resistance and resilience) of those ecosystems and ecosystem mediation responses to GEC on which the well-being of human reliant on (Tylianakis *et al.*, 2008). Climate change impact ranges from the variability in rainfall performance to changes in temperature ranges thus impacting on the crop performance. Changes in the rainfall performance can lead to floods or drought scenarios. This brings about variations in the duration of crop growth, change in markets, changes in prices of food and finally the supply infrastructure. Climate changes have had significant impact on food security in different regions. Researchers have brought forward a number of opinions as they tried to clarify the underlying factors accelerating food insecurity.

According to Nelson *et al*., (2009), due to climatic changes, the cost of most cereals would increase which would eventually result in a drop in consumption. This would reduce the calories available in food and hence malnutrition in children. In addition Nagarajan *et al.,* (2010) argued that some dietary value of food which would mainly be cereals would be exaggerated by effects of climate change. Change in Climate will also have an effect on usage of food by persons, due to changing situations of food safety and exposure to water borne diseases and food (Shmidhuber & Tubiello, 2007). The variations in climate are recognized as influencers of food safety and post-harvest losses for the period of storage. This may be through the alteration in the number of fungi that produce aflatoxin (Cotty & Jaime-Garcia, 2007). It is anticipated that infrastructure will be dented by recurrent severe weather changes, this will impact on food storage and distribution and those who will be deprived will be made most susceptible (Costello *et al.,* 2009). Appreciating changes in climate and ecosystems leads us to discuss the literature review on Agriculture and Livestock in the following section below.

2.3 Agriculture and Livestock

Socio economic characteristics, physical and biological responses are some of the causes of vulnerability to climate changes. According to Grasty (1999), severe hardship due to climate change is experienced by low income population who rely on non-irrigated and rain-fed agriculture systems in semi-arid and arid regions. Climate change directly affects agricultural productivity in both developing and developed world (Alexandrov & Hoogenboom, 2000). Suggestions made by IPCC(2007) report on the fourth assessment detailed that the effect on crop response from higher temperatures at the plot level, minus changes in the extreme events frequency with reasonable warming may help in pasture and crop productivity in temperate areas, though it may decrease productivity in semi-arid and tropical areas. Researches have shown that temperature has beneficial impacts which correspond to the local average temperature rise in the range of 1-3^{o}C; with link to a rise in rainfall changes and Carbon dioxide which are small. This is contrasted with tropical regions models which indicate a negative harvest effect for major crops with reasonable increase in temperature that is between 1 - 2^{o}C, therefore as warming increases as estimated in all areas by the end of 21st century the undesirable impacts will have increased (Tubiello *et al.,* 2008).

Crop yield is majorly determined by climate by reducing or increasing from an international perspective from the tropics to temperate. According to Tgubiello *et al.,* (2008) Carbon dioxide is considered to be a limiting factor when the concentrations of Carbon dioxide is high thus affecting crop growth and photosynthesis and hence transforming nutrients and water cycles.

Carbon dioxide and Phosphorus have been associated with rise in cells number in the endosperm leading to an increased rate of cell multiplication during the development of grain or by larger grain filling at the ripening stage (Uprety *et al.,* 2010). However, elevated concentration of CO2 level has adverse effects on the quality of grain and in protein content in wheat (Pleijel & Uddling, 2011). It alters lipids and duples mitochondria in wheat besides lowering concentration of seed nitrogen and decreases flower and grain protein (Qaderi *et al.*, (2007) argued that climate change would have an impact on effectiveness and delivery of irrigation. Lengths of drought duration were increased by evapotranspiration as a result of hotter mean temperatures and forecasted rainfall variability. This has led to increase in the need for irrigation, even if total rainfall throughout the growing season remains constant.

Progress has been made in current years on combining models for climate with models for crop in order to comprehend and project impacts of climate (Challinor 2009). In spite of inbuilt reservations, response of yield to change of climate has been established both empirically (Schlenker & Roberts, 2009) and harvest based models (Challinor, 2009). Uncertainties in precipitation are not factors that confine the ability to predict crop production; however, temperature variations are likely to be of importance in some of the cases (Thornton, Jones, Alagarswamy & Andresen, 2009b; Lobell & Burke, 2008b). Climate changes affect livestock productivity both directly and indirectly, for instance a rise in temperature directly affects production and in this case production losses. However, indirect impacts include, for instance variation in the quality, availability and prices of input which are energy, fodder, housing and ability to manage disease and water dependency (Thornton, 2010).

2.4 Climate Change and Sustainable Practices

Industrialization and increase in population have resulted in the world being warmer. Thus activities must be accomplished which utilize and conserve normal resources in an efficient manner through the approval of development that is sustainable and by trying to guard ecosystem and resources services. Actions for climate change adaptation should be effected by considering situations and locations of extreme events. It should not only consider individual households farming activities and livelihoods, but also problems solving, food security approval and poverty reduction on the wider range. With increasing population, agricultural food production has to be intensified. Systems applied in agricultural are supple on condition that correct information is given to farmers besides technical advice, support and tools. This would enable the farmer have an outlay of many options. Nevertheless, with poor soil quality, inadequate water supply, cultural and institutional barriers, scarcity of investment capital money it would be problematic for practicing options in farming (Stalker, 2006). In this case it is important for the government to provide technologies and knowledge with technical and economic support.

According to Food and Agriculture Organization (FAO) (2007), systems in agricultural cropping that are related to climate change adaptation need concentrating on solving problems in circumstances of both lack of and surplus water due to high rainfall and extended periods of drought (FAO, 2007). This is because in both cases it was found essential to develop the structure of soil and the soil holding capacity for water. Modern, local and better organization practices of improvement in genetic crop have been circulated in numerous studies. Irrigation and other inputs use results into the current improvement in yield in some areas of the world. Furthermore, technology main goal is gratifying the wellbeing of all sectors (local communities, stakeholders, plant breeders, individual farmers and others). Even with fresh skills that are suitable for local conditions, peasant farmers have a difficulty in adopting them. This is attributed to their small size farms and restricted credit access meaning that they neither have the ability nor possibility to spend on emerging technology (Stalker, 2006).

Adaptation is cross-regions and between regions, therefore the mechanism used to deal with change in climate effect in a region can directly affect the other. When one region experiences loss of human or natural capital another is also affected hence mitigations measures adopted in one region can have consequences in another. According to Warren (2011), a reduction in agricultural yield in one region could cause a rise in demand for food products imports from another region. This has an effect on the worldwide prices of food. There is a global impact on climate by changing land use. An example is that surface change due to deforestation which results to a rise in carbon amount let from logged vegetation and soil. Thus mitigation towards climate change should significantly involve reducing deforestation. This is taken to be the greatest effective means of decreasing discharge as per the concerns noted in Reducing Emissions from Deforestation and Degradation (REDD) projects (Warren, 2011).

Agricultural practices that are sustainable should be embraced since they bring about food security hence increase in the food that the community consumes in addition to providing the starting place of livelihood for approximately 36% of total workforce in the world. In the heavily populated nations like sections of Asia and Pacific, the workforce ranges between (40% -50%), whereas 70% of the productive workforce in Sub-Saharan Africa survive on crop and livestock husbandry (ILO, 2007). In developing countries production of food is mostly impacted by climate changes, thus there is increased vulnerability of malnutrition and hunger to the rural poor (Paroda, 2009). Sustainable crop production includes scaling up crop production practices that maintain the resource of which farmers depend, in order to sustain food production security for the future generation. According to FAO, (2009a) competitive economic earnings, having a life sustaining environment, resilience to changes in climate, coming up with a smaller ecological footprint and increasing food security would form a basis for a green agricultural structure. A community's adaptation to changing climate would determine food security. This adaptability is majorly linked by access to resources such as information and knowledge on climatic changes, management of water for irrigation and rangeland resources (FAO, 2009a). This leads us to a discussion of literature reviewed on poverty and climate change.

2.5 Climate Change and Poverty

Climate change challenge needs synchronised act and unified backing of the whole worldwide community. Global establishments such as International Fund for Agricultural Development (IFAD), FAO, World Food Programme (WFP) and other development organizations can get their shared resource to support poor smallholder farmers alongside their knowledge for support. For example, they have experience of engaging with the rural poor people at field level on ordinary resource management, water preservation and flood control through water-harvesting technologies and other projects in semi-arid and arid regions in various part of the world founded on the standard of differentiated but common responsibility (FAO, 2009a). at the local and national level, International Fund for Agricultural Development have an understanding to react to challenges to changes in climate via capacity building. This can be done by conniving investments that are climate proof through mobilized resources. Generally, Food and Agriculture Organization works in agriculture but in forestry sector, technically, FAO is a reputed source of international information concerning extreme events and climate change coping. Food insecurity is a concern to WFP and the organisation tries to solve it by giving backing in climate caused disasters and during conflicts. Rahman (2008), affirms that funds for mitigation and adaptation are provided by the private sectors.

Some of the causes of food security issues in Tharaka include; over dependence on over utilized soils coupled with lack of mechanized agricultural system; post-harvest losses; lack of proper storage facilities; pest and diseases; environmental degradation and lack of farm input. These factors have the consequence of insufficient food storage which leads to high food prices coupled with high price fluctuations. According to Inter Academy Council (2004), 95% of food cultivated in Africa is rain fed. Food crop production is of significance to satisfy high demand. However, the susceptibility of the poor coupled by high cost of living might hinder them from accessing food despite some areas being food abundant (Barrett, 2010). Productivity of food and livestock is usually altered by changes in the climate (Nelson *et al.,* 2009). The next section introduces reviewed literature on climate change and adaptation.

2.6 Climate Change and Adaptation

Adaptation is the ability to deal with changes in climate, eliminate factors that lead to disaster risk, being able to manage environmental rangeland and reduction in poverty level. Adaptation can be achieved by carrying out activities that aim at reducing poor community's susceptibility. A common platform can be developed through which the community deals with issues that it is susceptible in with an aim to reduce them such as rangeland and environmental management, risk reduction and poverty lessening. A technology is considered resilience if it aims at building resilience to hazards and shocks and at the same time brings about sustainable adaptation, in addition to representing trans-disciplinary change (Biagini *et al.*, 2014).

Sufficient knowledge is important to ensure that technology that is adapted is effective and unharmful in the future and it is also capable of dealing with the climate in future (Biagini *et al.*, 2014). Both bottom-up and top-down methods to adaptation are more recommended to studies since they lead to advanced effectiveness, equity, efficiency, elasticity, authority, replicability and sustainability (Ford & Sherman, 2014). In the context of climate change the term "adaptation" was used since early 1990's. Though there is no specific definition of the term, Glick, Staudt and Stein (2009), defined it as measures and ingenuities to decrease the susceptibility of human and natural schemes against expected or actual effects of climate change.

It has also been defined as changing to augment the feasibility of economic and social actions that would in turn decrease their susceptibility to change in climate. Included here are the current capriciousness and great events besides long-run changes in climate (Smit *et al.,* 2000). Grothmann and Patt, (2003) defined it as the acts by persons to evade the effect or to profit from chances concomitant to change in climate.Both community and individual have to come up with methods of dealing with diverse and extreme weather conditions like drought, storms and floods. It is important for small hold farmers to uphold adaptations such as use of varieties that are tolerant to climate changes, use of different inputs and changing the rate at which fertilizers are applied to improve quality of agricultural products.

Other adaptation methods include usage of other practices of water management such as improving water-holding ability in little rainfall regions thus taming water-holding ability and conserving moisture of the soil, changing the timing and amount of irrigation and developing physical infrastructure for conserving water and soil (Grothmann & Patt, 2003). In ecosystems with excess rainfall, to prevent logging and leaching of nutrient by erosion, they would also make use of weather forecasting and early warning information which would help lessen climate events effects like disease and pest outbreak or drought in each season. Cultural practices adjustment, creation of more income from forestry, poultry production, livestock fattening, bee keeping and other agro-industries through diversification would also help besides using other technical choices like new farming techniques and change in land use. Rahman (2008) stated that planned approach must include appropriate incentive structures. An example is the environment service payment which can enlarge the options for indigenous or communities in such a way that they find it helpful in both adaptation and mitigation.

According to Adger *et al.,* (2005) adaptation is inclusive of the different actions by the society and governments which is motivated and manifested through different factors, by the actions of individuals, organizations and the government in an aim to protect its citizens. By adapting to climate changes individuals aim at reducing their extent of being vulnerable. Adapting to changes in temperature and climate changes include anticipatory and reactive actions to expected changes. It should therefore be an on-going process reflecting many stresses. Examples of adaptations include diversifying crops and form of livelihood, regular seasonal forecasting and supplementary irrigation and water storage which are community based disaster risk reduction measures. Adaptation measures are undertaken by individuals while others are undertaken by the government on behave of the society since they are expensive to plan and implement (Adger *et al.,* 2007). The section below provides literature review on necessity of climate change impacts studies.

2.7 The Need for Climate Change Impacts Studies

Climate change effects not as pronounced in developed countries as they are in developing countries. Therefore, it is good to emphasis questioning in poor countries. Weather and climatic occurrences have varied influences in different regions in the universe. This is due to dissimilar incidents in the regions. In some regions drought is often generally as a result of little amount of rainfall thus affecting growth of plants and the living habitation and bionetwork while in other ecologies great rainfall and flooding result to disasters that affect human life, plantations and habitat. Plans have to be put in place after assessing and identifying problems frequently affecting specific regions. In regions that are affected by drought, improved varieties of plants that are drought resistance should properly be worked upon until the rural poor are reached. Techniques of water harvesting when coupled up with other options can be applicable by individuals (Rahman, 2008).

Poor families have their well-being improved by having diversification plans in place that would improve their adaptation to climate changes. Solutions should be long term and short term and well integrated and organized such as working toward capacity building of the community. Adaptations measures should also be put in place since poor families have no way of dealing with hazards. And therefore constant evaluation should be put in place to assess whether the strategies employed work or not. Scientific modifications should be made on the traditional methods, hence helping the society easily practice without requiring time for innovation and making new technologies acceptable to the society. Since modern technology requires sophisticated equipment that are capital and labour intensive, borrowing adaptation mechanisms from communities that are better adapted would be a good approach that would be acceptable in underdeveloped world. Adger *et al.,* (2007) contended that the need for technology transfer to developing countries could be limited by change in climate change; leading farmers, based on their ability to choose to stick to modified traditional technology that are easily adoptable.

Adaptations also face limitations and barriers, cost effectiveness being one of them. An example of such barriers is when farmers prefer the cheapest method of soil conservation and one that takes the least time to implement and consumes the least labour. For example planting grass strips and hedge row plants as opposed to terracing or building cut off drain that would change or decelerate the downward movement and collection of water; shielding plantation and land for farming from soil erosion.

It is therefore important to increase and continue to increase capacity of practicing adaptation options more specifically to poorer countries and social groups in order to realize suitable development. This is because the capacity to challenge hazards for the poor people is limited. It has been realized that poor people are unable to buy farm inputs and improved crop varieties hence are unable to save their families from drought and hunger. This challenge is lower in developed countries as opposed to the developing countries, this is because change in climate occurs repeatedly and the agricultural systems that are used are local which are highly dependent on rainfall and traditional equipment. There are therefore no intensive farming activities within the community coupled with no stored crop products for consumption. Research has also shown that cultivated agricultural land productivity are not proportional to population growth hence there is an imbalance, hence making the society that is poor extremely susceptible to changes in climate; this is worsened by deforestation and unsuitable use of land.

Tharaka has undergone changes owing to climate variability and might in future undergo more changes because of change in climate. The KFSSG LRA study (2014) which was conducted after the short rain season concluded that Tharaka is a high potential area in sorghum, Cowpeas, green grams and millet. To deal with drought in Kenya, which had slowly crept in without early warning, the government in 2004 established a project by the name Arid Lands Resource Management Project (ALRMP) which was later renamed National Drought Management Authority (NDMA) through an Act of Parliament with a vision of drought management and climate change adaptation for sustainable livelihood.

CHAPTER THREE: DATA AND METHODOLOGY

3.0 Introduction

This segment provides information on the basis of data that was used and the methodological approach applied for the analysis of the data. Food security needs trans-disciplinary responses since it is a complex issue. Trans-disciplinary approach matches up with the experiential knowledge or social knowledge which is significant in addition to science based knowledge that aid in the resolution of constant problems in the society such as food insecurity (Regeer & Bunders, 2009). Food insecurity is a case in point of a problem in which ecological effects and social act are strongly linked, meaning that the difference between nature and society is unclear (Jahn, 2008). This is because they are embedded along dissimilar spatial, temporal and communal scales. Such as from global to local level causes, from the existing proceedings to medium and long period consequences besides pointing from action in day to day situation to policies of a world regime and organizations that are multinational. Malnutrition and stunted growth in a Tharaka child is usually associated with a multifaceted food chain. This chain has aid agencies, coupled with additional multiple players involved in compound linkages and feedback cycle throughout the structure.

Much capability is enhanced through the appliance of trans-disciplinary approach. This is enabled when societal and other scientist and actors oblige to co-learn to conquer the gaps on knowledge production, and the pursuit for knowledge to give the answer to societal issues. This commitment adds up to new knowledge and solution which will give directions to the origin of hunger in lots of settings. Through scientists and societies coming up with a joint learning process together with relevant stakeholders across disciplines, research becomes a fraction of the larger society (Hirsch *et al.*, 2008).

3.1 Methodology

The prevailing structure allows solving of problems using attitude transformation, increasing individual competences, possession and reflection. In the process it builds capacities of those involved and concerned mainly in guidance. Both qualitative and quantitative data was collected to complement each other and for triangulation.

3.2 Conceptual and Analytical Frameworks

3.2.1 Integrated Phase Classification Analytical Framework

Contributory variables have unwavering impact on scope of food security, utilization, accessibility, availability and stability and they have a connection. Food utilization is determined by availability of food and the household has to have a right to use it and utilization has to be sustainable; hence the whole organization must be firm (Barret, 2010). As a pillar, Availability addresses concerns such as food potentially or really exists, aspects of food reserves, production, wild foods, transportation and markets. Whether food is in reality or potentially there is Access. The subsequent question is; are households in procession of sufficient access to the food, including financial (purchasing power), physical (infrastructure, distance) coupled with social (religion, ethnicity or aspects of political affiliation).

The ability of households to get food and sufficient access to it is utilization. This therefore brings about the question of utilization of food by households in terms of food preferences, storage, preparation and usage of right water structures. According to "Integrated Food Security Phase Classification Analytical framework" these refers to physical utilization of food by a given household without counting on the biological utility of food at a person's point of view. Natural utility of food at personal level, in reference to Integrated Phase Classification (IPC), is a significant factor in thoughtful insight to nutrition outcomes. In defining stability and assuming pillars of access, availability and utility are adequately met and the household have adequate quantity and quality of a plate of food. The question is the steadiness of the whole system, thus always guaranteeing food adequacy at the household level.

Food stability also refers to time variability hence leading to severe per capita food insecurity or long or medium term variability that leads to chronic food insecurity of a person. Other sources of instability include climatic, social, economic and political variables. Contributing variables have a contact that include underlying variables that impact food security pillars which direct to the risk of worsening or optimistic variation on the food security output. The operational framework clearly encompasses a feedback apparatus where variations in outputs of food security are recorded. The framework includes the feedback system where food security output variation generally result in changes to succeeding food security-people causal variables; like the enhancement or deterioration of vulnerability or severe or chronic factors; resulting to changes in the food security pillars outputs.

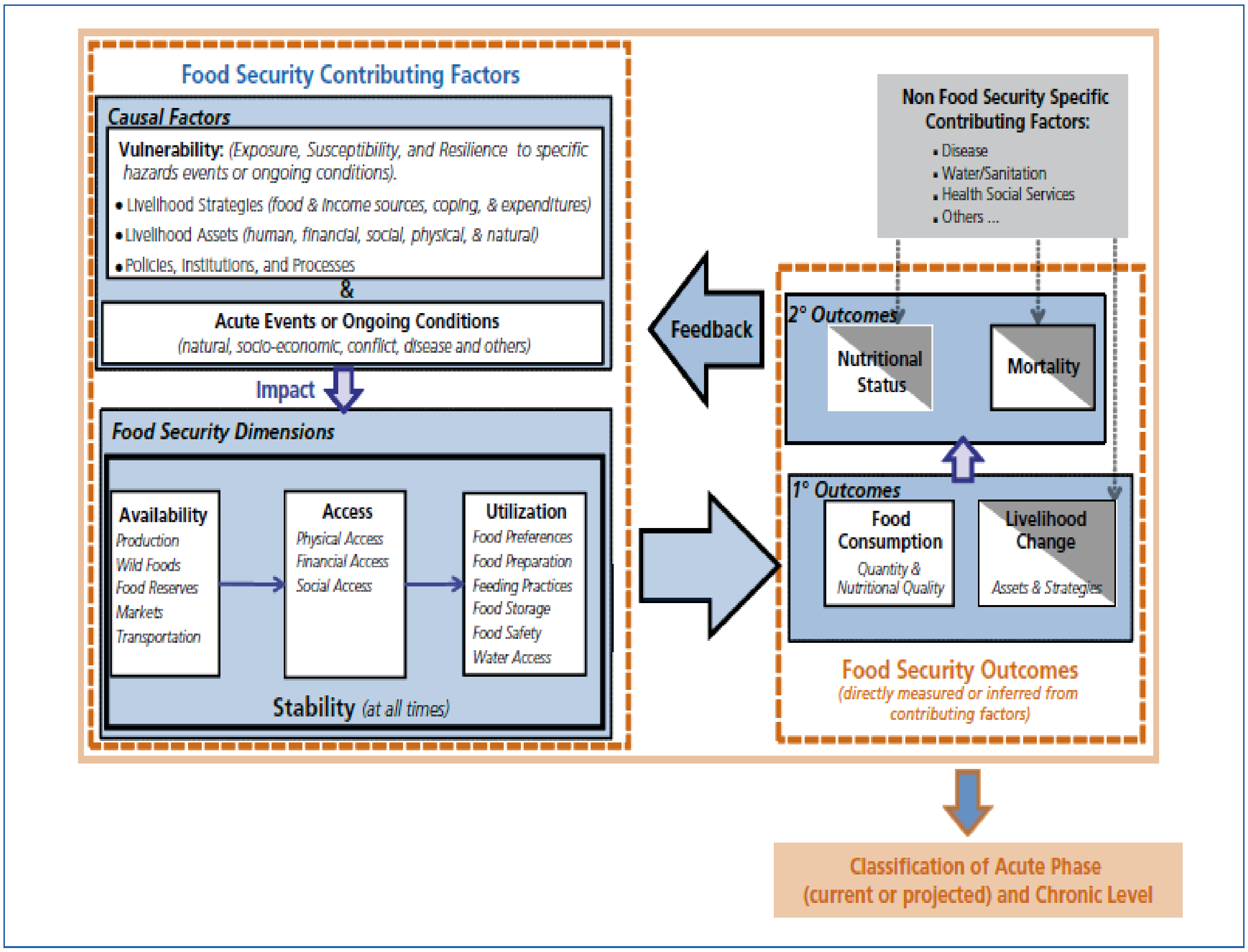


Figure 3.1: Integrated Food Security Phase Classification

(Source: IPC, 2012)

3.2.2 Conceptual View of Several Variables Influencing Food Security

Focussing on the view of variables, Figure 3.2 provides the assessment of variables including food security. It demonstrates the additive and dependence of variable. Climate variability impacts on livelihood, which impacts on the community way of life however if the resilience is built the households are cushioned and they can bounce back to their normal way of life.

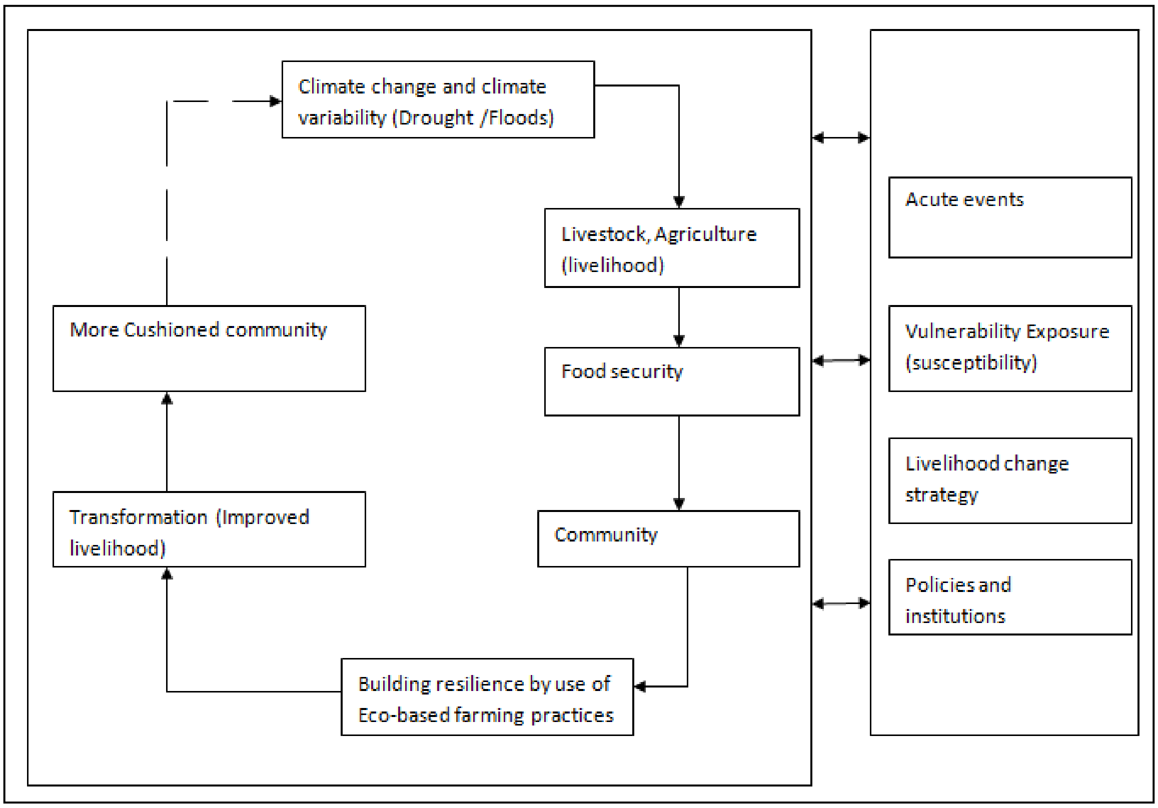


Figure 3.2: The Conceptual Framework

(Source: Adopted from IPC)

3.3 Objective 1

Amongst others, one of the specific objectives was; examine historical climate data and its implication on household food security in Tharaka Nithi County.

3.3.1 Time Series Analysis

Historical climate data indicates that in Kenya, the long rains commence in March and end May while the short rains commence in the month of October through to the month of December annually (Funk *et al.,* 2010).

3.3.1.1 Methodology for Examining Historical Climate Data and its Implication on Household Food Security in Tharaka Nithi County

Tharaka Nithi historical climate data was examined; IPCC (2007) suggested a statistical method to studies in change in climate. This shaped the principal point of this research. Data for 39 years (1976-2015) was collected from the Kenya Meteorological Department archives. The study established changes in rainfall and temperature patterns in Tharaka with the use of Gaussian Kernel analysis coupled with moments and regression analysis and also non-parametric approaches based on Mann-Kendall statistics. The periods that were looked at were three non-overlapping climate periods which consisted of 30 years (1982 - 1991, 1992 – 2001 and 2002 - 2012). This enabled the researcher to observe rainfall and temperature increase and decrease. Mann-Kendall analysis is an arithmetic test that is commonly used to study trends in climate changes and also trends in hydrology (Yue & Wang, 2004). The benefits Mann-Kendall test use include; it has a small reaction to unexpected disruptions due to non-uniformity time series arithmetic. Secondly it is non-parametric arithmetic test which does not require a normally distributed data (Tabari *et al.,* 2014).

In Mann-Kendall test, a null hypothesis H_0 takes the assumption that there was no trend series and therefore the tabulated data was randomly ordered and was independent. This is therefore subjected to testing not in favor for the alternative arithmetic hypothesis H_1 that takes an assumption that trend is in existence (Onoz & Bayazit, 2012). Computation procedure of Mann-Kendall arithmetic puts in place time series of data at points in the order n_iT_i and T_j as separate subsets of tabulated data where j = i+1, i+2, i+3, …, n and i = 1, 2, 3, …, n-1.

The evaluation of values is ordered time sequential series. For every figure in the data value is compared with the all the succeeding values of the data. An example is data figure from a later time (T) is greater than a data value of a previous time (T_i), the statistics of the arithmetic is increased by 1. If the arithmetic data figure from and afterwards a period (T_j) is lesser than previous sample, *S* is decreased by 1. According to (Drapela & Drapelova, 2011) cumulative increment and decrease would yield a concluding value of S.

The climate data (Rainfall and Temperature) used in this study were obtained from the Kenya Meteorological Department (KMD). The following equation was used to calculate the annual values,

$$\sum_{i=1}^{12} Ri \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 1}$$

Value R represented the amount of monthly rainfall per station, i represented the number of months in a year while R_i represented amount of rain annually. The period of 30 years was divided into 3 non-overlapping climate periods as follows; 1982 - 1991, 1992 - 2001 and 2002 - 2012. Gaussian Kernel analysis and non-parametric analysis were used basing them on the Mann-Kendal statistics as a way to justify the changes in annual average rainfall and temperature trends. An average rainfall per zone was obtained using (1 to j) in equation 2 for zones that fell on the same zone.

$$\overline{R_z} = \frac{\sum_j^n A_j}{\text{n}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 2}$$

Where $\bar{R}_z$ was used as a representation of the mean annual rainfall and n was the total number of meteorological stations in the study area, the likelihood of an arbitrary variable coming about at a given chance explained the Probability Density Function (PDF). A is the amount of the annual rainfall at that meteorological station. The probability of having random variables in a particular area was increased by the range of variable’s density across a region.

Density of a function is non-negative universally and its integral across the whole space is equated to one. A variable *X* has density f, where f is a non-negative Lebesgue - integral function, if

$$p_{a(a \le x \ge b)=}^{b} \int_a^b f(x)dx \quad \text{………………………………………………………Equation 3}$$

Function *f*(x) is referred to as the integrand while the variable *x* is the variable of integration. The letters *a* and *b* are referred to as the limits of integration with *a* being the lower limit of integration while *b* is the upper limit of integration. The symbol ∫, is used with the indefinite integral. If a function *f*(*x*) is continuous on a closed interval (*a, b*), then the definite integral of *f*(*x*) on (*a, b*) exists and *f* is said to be integrals on (*a, b*). In other words, continuity guarantees that the definite integral exists. The standardized distribution of (0, 1) has likelihood density function of f(x) = 1 for interval 0 ≤ x ≤ 1 as well as f(x) = 0. The normal distribution has a likelihood density.

$$f(x) = \frac{1}{\sqrt{(2\pi)}} e^{\{\frac{(-x)^2}{2}\}} \quad \text{………………………………………………………… Equation 4}$$

Given a chance factor X is known and the distribution admit a likelihood density function, Therefore, predictability of X is equal to:

$$E_{-\infty}^{\infty}(x) = \int_{-\infty}^{\infty} xf(x)dx \quad \text{……………………………………………………… Equation 5}$$

3.4 Objective 2

This objective was to assess household food security status and its determinants.

3.4.1 Analysis of Household Status on Food Insecurity

Advance categories of education were linked to access of information to higher productivity on strategies that could be used in adapting to climate changes (Norris, 1987). There is evidence from different sources that points towards affirmative relationship amid improved adaptation and the education rank for the head of the household as noted by Igoden *et al.,* (1990) and climate change adaptation (Madison, 2006). Consequently, a farmer with an advanced education level is likely to adapt to climate change. Households headed by male have a high likelihood to get information concerning emerging strategies as well as commence risky businesses in comparison to feminine headed households (Asfaw & Admassie, 2004).

Besides, Tenge (2004) showed that to have household headed by female could have unconstructive effect on adaptation on water and soil conservation strategies, since access to land, information and other resources by women might be limited due to social cultural and traditional barriers. Research by Nhemachena (2007) established divergent results that households headed by female had a higher likelihood to adapt since they are accountable for a large amount of agricultural cores hence improving of the household's skill which would be as a result of access to information on different farming management practices. Adapting the changing strategies was more specific to the situation.

The farming practices adopted by a household were also depended on the head of the household's age. Studies show an affirmative association between the experience in farming and duration (years) and the positive adaptation of enhanced agricultural practices (Kebede *et al.,* 1990). However, research by Shiferaw (1998) showed an unconstructive relationship amid adaptation of better soil conservation actions and a person's number of years. Previous research findings by Madison (2006) coupled with Nhemachena (2007) indicated that experience for agricultural production enhanced the likelihood of uptake for adaptation strategies for climate change. The study came up with a hypothesis that adaptation to changes in climate was enhanced through experience. Adaptation of strategies can also be influenced by the size of the household based on two perspectives.

Yirga (2007) noted that the first assumption would be that a household which had larger families needed to redirect section of the labour to off-farm actions in effort to receive proceeds for ability to relieve the consumption strain by a large sized family. The additional assumption was generally large size family is usually linked with higher endowment of labour; this would facilitate households to achieve various farming duties. Case in point, Croppernsted *et al.,* (2003) opined that families with large members have an enhanced pool of manual labour hence more higher probability for adaptation to change in climate and increases the frequency of on-farm activities attributed to plenty of labour opportunities needed most in farming seasons. At this point, households with large size of family are likely to manage well to changing climate. Constraints on the availability of currency have been eased with availability of credit institutions give away for households to purchase inputs, fertilizer, drought tolerant crops and enable them also to purchase irrigation equipment. Availability of credit has direct relationship to the level of adaptation (Yirga, 2007).

Some research done to climate change adaptation strategies point towards the conclusion that farm size has both positive and negative effect to adaptation, indicating that effect of size of the farm on adaptation plans was uncertain (Bradshow *et al.*, 2004). Nevertheless, owning size of the farm is linked with a pool of wealth, it is assumed to enhance climate change adaptation. Income generated from both the nonfarm and farm activities coupled with ownership of livestock represents wealth. Some research done assumed that climate change adaptation strategies call for adequate financial ability as illustrated by Knowler (2007). Several studies that examined the influence of income on adaptation to climate change noted a positive trend correlation (Franzel, 1999). Households with ability of high wage labour income have greater access on information for climate change in addition could simply afford a variety of climate change plans and activities (CIMMYT, 1993). Livestock production contributed to a bigger extent by serving as stock up of value in addition to giving traction and manure necessary for fertility of the soil safeguard (Yirga, 2007).

There are institutional existences having attained a high level of resilience. According to Yirga (2007) structures are made up of cognitive, cultural, regulative and normative constructions that jointly are linked with resources and activities which enable stability and sense to social life. Comprising of training and extension services on livestock and crop production and data coupled with information on climate, correspond to access for information which is essential for decision making on climate change adaptation. A number of researches for developing countries, Kenya included indicated a strong constructive relationship amid access for information in addition to adaptation characters of households (Yirga, 2007). Getting of information and data through field extension services enhances the probability for climate change adaption (Nhemachena, 2007).

3.4.2 Methodology for Assessing Household Food Security Status and its Determinants

The study used cross sectional survey design. All communities in Tharaka Nithi were included in the population of the study but specifically those living in Tharaka South and Tharaka North Sub Counties. Ten (10) sentinel (a geographical demarcation based on household similarity in source of livelihood) sites were Randomly Sampled from stratification in the Sub Counties that had different forms of livelihoods as well as agro ecological zones.

Solvin's sampling formula was used to determine the study sample size (Ewens, 1972). This is given by:

$$n = \frac{N}{\{1+N(e^2)\}} \quad \text{……………… Equation 6}$$

Where:

n = Sample size (399)

N = Total population (Area of Study based on 2009 Census Population) (130,098)

e = Error tolerance (0.05)

n = 130,098/ (1+130,098(0.05^2)

n =399

Checklists and questionnaires were utilized in collecting both primary and secondary data. The study used both qualitative and quantitative approaches. The key informants included the Agricultural officers, the Administrators of the area (village elder), the community and the extension officers. The research assistants identified were qualified individuals; they were given a two days training before commencing on familiarization of the data collection tool and interviewing skills.

3.4.3 Content Analysis and Multiple Regression

An in-depth thematic analysis was used in the analysis of the determinants. The themes were arrived at through a process of contents analysis of the responses as put forth in the questionnaires. This gave viewpoints of the concerns as they unfolded. Food security was the explained variable which was studied against five independent variables. The social economic variables included education level, household size, age of household head, farm size, gender of household head and farm and non-farm income. Figure 3.3 shows the field collection points illustrating where data was gathered.

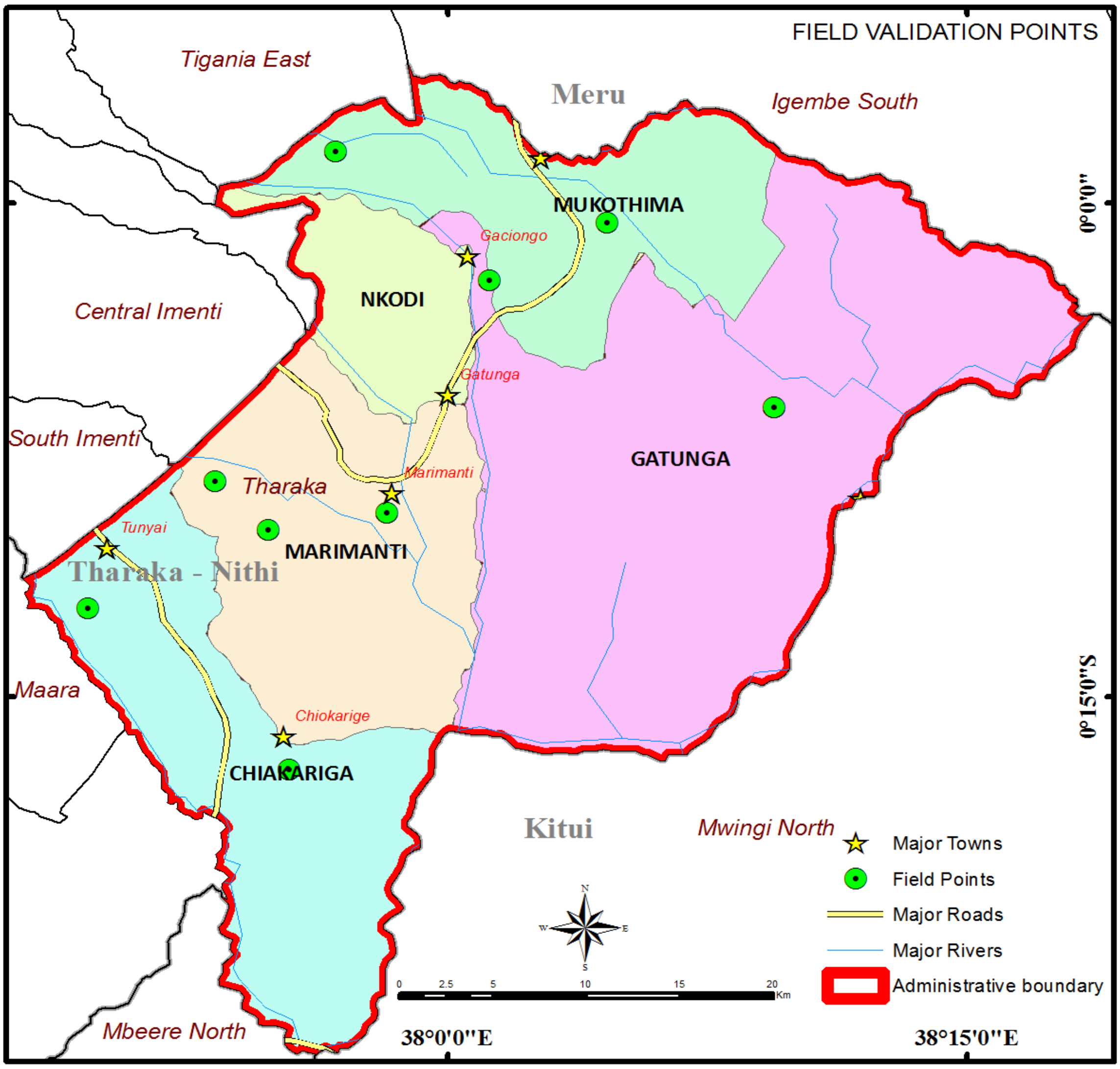


Figure 3.3: Field Corroboration Points

(Source: Author, 2017)

Table 3.1 shows the sentinel sites (geographical demarcation based on household similarity in source of livelihood) in the area of study; that had dissimilar livelihood forms and agro ecological zones. It also indicates the GPS coordinates measured in terms of latitude, longitude and altitude.

Table 3.1: Geographical Positioning System (GPS) Coordinates for the 10 Sentinel Sites

S/no	Sentinel Sites	Zone	Latitude	Longitude	Altitude	Accuracy
1	Kathangachini	37M	0^{0}5.7261’S	38^{0}9.266’E	440M	+/-12M
2	Thiiti	37M	0^{0}0.9523’N	37^{0}56.4734’E	719M	+/-16M
3	Karocho	37M	0^{0}7.8748’S	37^{0}53.1807’E	704M	+/-12M
4	Kithino	37M	0^{0}11.7907’S	37^{0}49.0384’E	844M	+/-16M
5	Kanyuru	37M	0^{0}9.5451’S	37^{0}54.5033’E	652M	+/-12M
6	Chiakariga	37M	0^{0}16.7307’S	37^{0}55.2726’E	760M	+/-16M
7	Kamanyaki	37M	0^{0}19.3733’S	37^{0}59.0314’E	429M	+/-16M
8	Kanjoro	37M	0^{0}0.36’S	38^{0}4’37”E	691.6M	+/-4.9M
9	Gaciongo	37M	0^{0}1.8146’S	38^{0}1.1273’E	690M	+/-12M
10	Marimanti	37M	0^{0}9.2478’S	37^{0}58.156’E	623M	+/-16M

(Source: Author, 2017)

Plate 1: Ongoing Training of the Field Monitors on Household Data Collection

(Source: Author, 2017)

Quality assurance was done for all the questionnaires and determined whether complete or incomplete, this was followed by the serialization of the complete questionnaire. The questionnaires were subjected to coding with the quantitative data being predetermined while the qualitative data were thematically grouped and coded. Data analysis was done using SPSS version 16. Analysis was done at two levels: descriptive statistics and regression analysis. Descriptive statistics was used in the background demographics. Multivariate regression was used to establish factors that influence food security. Frequency distributions are usually used to measure how often a variable occurs and its values in a data set. In this study, frequencies were used to give summary of food security by selected independent and dependent characteristics. This information is important because it helps the researcher to understand the skewedness of the selected variables, considering that it is acceptably difficult to obtain a normal distribution in social sciences.

Microsoft Excel was preferred due to its ability to present data in forms of graphs, pie charts and tabular presentation. The qualitative data was extracted from open ended questions, document analysis, interview guides and the focus group discussions that filled the gaps in explaining the themes and also in capturing the vice of both the local community and the stakeholders in the neighbouring Counties. This study used Food security (availability, utilization, access and stability) as dependent variable taking the value 1 and 0 otherwise; regression models were utilized to estimate the dependent variable. Multivariate regression entails the inclusion of all independent variables to test their effect on the dependent variable. This helps to reduce the stochastic error – the effect of many omitted variables on the dependent variables - that might be experienced in regression. This study thus utilised multivariate regression equation (Hazewinkel, 2001), expressed as

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ldots \beta_n x_n + \varepsilon \quad \ldots\ldots\ldots\ldots \text{Equation 7}$$

Where $\beta_0 \ldots \beta_n$ = Regression coefficients

$x_1 \ldots\ldots\ldots x_n$ = independent variables, expressed in series illustrating Age of the respondent, relationship to the household head, sex of the respondent, marital status, number of children (daughters), number of children (sons), size of land cultivated, place of birth and education level. ε is the error term.

Availability is well-defined in terms of production, wild foods, transportation, markets and food reserves. Access is defined in terms of social access, physical access and financial access. Utilization is well-defined in terms of food preferences, food preparation, food safety, food storage, feeding practices and water access. Stability is well-defined in terms of political and social-economic variables. For inferential analysis, four models were run, to establish determinants of household food security status.

3.5 Objective 3

The objective 3 is to assess conservation agriculture practices to buffer the effects of climate change and build resistance. To achieve this objective, farmers were grouped into 25 to 30 who could organize smallholder farmers to enable effective dissemination and uptake of conservation agriculture practices were formed by farmers who were willing from learning training concept. Already trained extension officers facilitated the formation of voluntary groups. They went ahead to identify agricultural problems and the possible solutions and involved the smallholder farmers in selection of different methods to be tested. They then trained smallholder farmers on conservation agriculture practices in a manner which encourages experimentation and learning. Farmers were trained on conservation agriculture principles and on the use and maintenance of conservation agriculture implements for direct planting and crop residue management. This promoted an environment in which farmers could share knowledge and Experience; Field days were organized for farmers to visit other farms with the main aim of sharing knowledge and experience with other people in the Community.

The study sought to establish ways through which adaptations would be promoted in order to have more resilience at the community level through the adaptive agricultural conservation. The crops planted were Gadam sorghum, green grams N26 and Cowpeas M66 which are best suited in sandy loam soil. The availability of market for the proceeds was also a contributing element.

3.5.1 Methodology for Assessing Conservation Agriculture Practices to Buffer the Effects of Climate Change and Build Resilience

The section below discusses the Agro ecological zones and land preparation, farmyard manure and fertilisers, Insects pest and cover crops, weeding and crop rotation, seasonal calendar and finally the experimental design.

3.5.1.1 Agro Ecological Zones and Land Preparation

The Agro Ecological Zones (AEZ) closely defines areas of common characteristics of annual mean temperatures, vegetation, humidity or moisture availability and thus the economic activities within the zone. Tharaka South and Tharaka North Sub Counties comprises of three ecological/ livelihood zones; Mixed Farming (MF) zone, Marginal Mixed farming (MMF) zone and Rain fed Cropping zone. Land preparation was done at least two weeks prior to rain onset for the season. The traditional land preparation in this community entailed bush clearing burning and this was followed by ploughing then planting using simple hoes. Farmers were trained on minimal tillage using conservation tools and prevention of compacting via machinery, humans and animals. The five treatments that were on conservational agriculture practices ensured adherence to minimum tillage.

3.5.1.2 Farmyard Manure and Fertilizers

Farmers were guided and used well decomposed farmyard manure to improve on the soil productivity, though the farmyard manure was minimally available. The Manure was applied at 0.2 - 0.5 tons per acre. The treatments of conservation agriculture were subjected to soil amendment of 60 Kilogrammes of CAN (Calcium Ammonium Nitrate) per ha coupled with to 60 Kilogrammes NPK (Nitrogen, Phosphorus Potash). The picture illustrates presence of sorghum left over’s for mulching purposes.

Plate 2 : Mulching
(Source: Author, 2017)

3.5.1.3 Insects Pests and Cover Crops

If the treatment is infected by insects pest, the score was rated on a range of scale of 1-3 where 1 was Less than 5 pests per sample plant or no signs of pests attack- low, 2 was 5-10 pests per sample plant or onset of signs of attack- Middle and 3 was more than 10 pests per sample plant or clear signs of pest damage- high.

Sorghum was the main crop in this trial, secondly farmers were trained and they maintained permanent cover soil via usage of intercrops, mulching and cover crops assisted by left over organic sources or other crops and species that fix nitrogen in the soil thus help in upholding soil strength, reducing diseases and pest as demonstrated by cowpeas and green grams.

3.5.1.4 Weeding and Crop Rotation

Weeding was done to the Conventional control treatment and this occurred after two weeks of germination followed by second weeding at two weeks after the first weeding. The treatments were subjected to crop rotations accordingly. For example sorghum was rotated with pulses (green grams and cowpeas). This upholds soil fertility levels and breaks diseases cycle. The Latitude was -0.10952961 (S) and the Longitude was 37.856373 (E). The soils were sandy loam type (CIDP, 2014).

3.5.1.5 Seasonal Calendar

Farmers were taken through the seasonal calendar and the early warning monthly bulletin sampled at appendix 1.The monthly bulletin was produced by the Government through the National Drought Management Authority. This helped the farmers to understand the seasonal calendar and early warning information on the drought status.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Short rains harvests Short dry spell Reduced milk yields Increased HH Food Stocks Land preparation			Planting/Weeding Long rains High Calving Rate Milk Yields Increase			Long rains harvests A long dry spell Land preparation Increased HH Food Stocks Kidding (Sept)				Short rains Planting/weeding	

Figure 3.4: Seasonal Calendar

(Source National Drought Management Authority) Tharaka Nithi 2017

3.5.2 Methodology: Experimental Design

In carrying out the study of increasing food production resilience using conservation agriculture practices under changing climate in Tharaka Nithi County, Kenya, there were 6 treatment groups in two sites mapped in four demo plots (blocks). Using a randomized block design, the treatments were assessed and put in layout of six according to study design. The four demo plots (blocks) were then randomly assigned as illustrated in table 3.2. The numerals 0.672 in the first column block 1 to 0.896 last row in block 4 are random numbers generated by the random number generator application to guide on which crop to plant as illustrated in Table 3.3 and 3.4 respectively.

Where $\mathbf{T^1}$ = Sorghum

$\mathbf{T^2}$ = Sorghum/ Cowpeas

$\mathbf{T^3}$ = Sorghum/green grams

$\mathbf{T^4}$ = Green grams

$\mathbf{T^5}$ = Cowpeas

$\mathbf{T^6}$ = Conventional Control (Sorghum)

With T^1 to T^5 adhering to conservation agriculture practice hence the method of land preparation adhered to minimal land tillage.

Table 3.2: Treatment Blocks

Treatment		Block 1	Block 2	Block 3	Block 4
T^1	Sorghum CA	0.672	0.964	0.421	0.634
T^2	Sorghum/ Cowpeas	0.081	0.458	0.438	0.727
T^3	Sorghum/green grams	0.349	0.182	0.921	0.897
T^4	Green grams	0.396	0.95	0.178	0.463
T^5	Cowpeas	0.212	0.634	0.739	0.896
T^6	Conventional Control (Sorghum)	0.833	0.355	0.439	0.027

(Source: Author, 2017)

Conservation agricultural trial of 2015/16 consisted of 6 trials. The plot size was 10 by 10 metres. Enough seed were provided for each entry to plant a plot of 10 rows with row spacing of spacing of 0.6 m. Thinned plants to with a spacing of 20 cm between plants in the row 2-3 weeks after emergence. All observations were taken for the entire plot.

Plate 3: Planting
(Source: Author, 2017)

Pictorial presentation on the right illustrating farmers planting the crops, which were Sorghum, cowpeas and green grams in the randomized treatment blocks.

Table 3.3: Randomized Treatment Blocks

Treatment		**Block 1**	**Block 2**	**Block 3**	**Block 4**
T^1	Sorghum CA	T^5	T^6	T^2	T^3
T^2	Sorghum/ Cowpeas	T^1	T^3	T^3	T^4
T^3	Sorghum/green grams	T^3	T^1	T^6	T^6
T^4	Green grams	T^4	T^5	T^1	T^2
T^5	Cowpeas	T^2	T^4	T^5	T^5
T^6	Conventional Control (Sorghum)	T^6	T^2	T^4	T^1

(Source: Author, 2017)

Table 3.4: Randomized Treatment Blocks with Assigned Crops

Treatment		**Block 1**	**Block 2**	**Block 3**	**Block 4**
Latitude		- 0. 10952961		0.2662091	
Longitude		37.856373		37.8395602	
Altitude				746.659	
T^1	Sorghum	Cowpeas	Conventional Control (Sorghum)	Sorghum/ Cowpeas	Sorghum/green grams
T^2	Sorghum/ Cowpeas	Sorghum	Sorghum/ green grams	Sorghum/green grams	Green grams
T^3	Sorghum/ green grams	Sorghum/ green grams	Sorghum	Conventional Control (Sorghum)	Conventional Control (Sorghum)
T^4	Green grams	Green grams	Cowpeas	Sorghum	Sorghum/ Cowpeas
T^5	Cowpeas	Sorghum/ Cowpeas	Green grams	Cowpeas	Cowpeas
T^6	Conventional Control (Sorghum)	Conventional Control (Sorghum)	Sorghum/ Cowpeas	Green grams	Sorghum

(Source: Author, 2017)

A pictorial presentation of mono cropped cowpeas plot flourishing well under conservational agriculture practices, (minimum tillage, crop rotation and promotion of soil cover crop).

Plate 4: Cowpeas under Conservation Agriculture
(Source: Author, 2017)

A pictorial presentation of Conventional trial of sorghum, after second weeding

Plate 5: Sorghum Under Conventional
(Source: Author, 2017)

On the right the investigator advising on importance of record keeping the data collected on ground with some of the community members.

Plate 6: Data validation
(Source: Author, 2017)

The six treatments were subjected to ANOVA analysis, whose basic goal was to estimate the variance components relating them to zero and other alterations. The second goal was to approximate and condense the reservations of the distinct coefficients; an example being the effects of the six treatments. The estimates of the components of variance and standard errors were found from the data, minus any need to stipulate contrasts founded on the design. The treatments were further subjected to Duncan's Multiple Range Test (DMRT). The DMRT is suitable for experiments requiring the comparison of all possible pairs of treatment means. All the treatment means were ranked in decreasing order thus it compares difference between means.

CHAPTER FOUR: RESULTS AND DISCUSSION FOR EXAMINING HISTORICAL CLIMATE DATA

4.0 Introduction

This chapter discusses the results that were obtained in this study. The first specific objective of the study was to investigate the chronological climate records and its effect on food security at household level in Tharaka Nithi County. In this objective, the study pursued the question: what are the trends in the 30 years of climate historical data? To gain insights on the foregoing question, an analysis of 30 years of historical rainfall and temperature data was done.

4.1 Results and Discussions on Examining Historical Climate Data and its Implication on Household Food Security in Tharaka Nithi County

The Kendall package has a function named Mann-Kendall which implements the non-parametric test for monotonic trend detection known as the Mann-Kendall test (A monotonic trend can be either an upward trend or a downward trend). The results in figures 4.1a, 4.1b, 4.1c and 4.1d were obtained after running the Mann-Kendall test on temperature data for Tharaka.

4.2 Temperature

Figures 4.1a, 4.1b, 4.1c and 4.2d display periodic variants of temperature for 30 years. The charts indicate the average temperature observations for the 12-month in each of the seasons June, July, August (JJA); September, October, November (SON); (December, January, February (DJF) and March, April, May (MAM).

The results in the section below were derived when linear trend line for Tharaka was plotted.

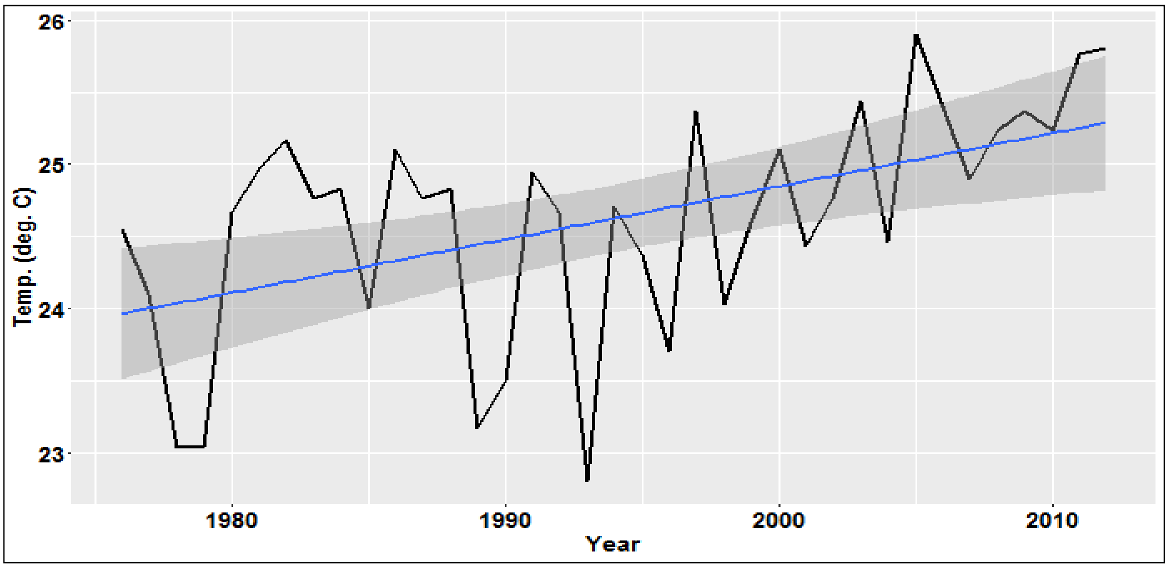


Figure 4.1a: DJF Temperature Variations (1981-2012)

(Source: Temperature data from K M D (1981-2012)

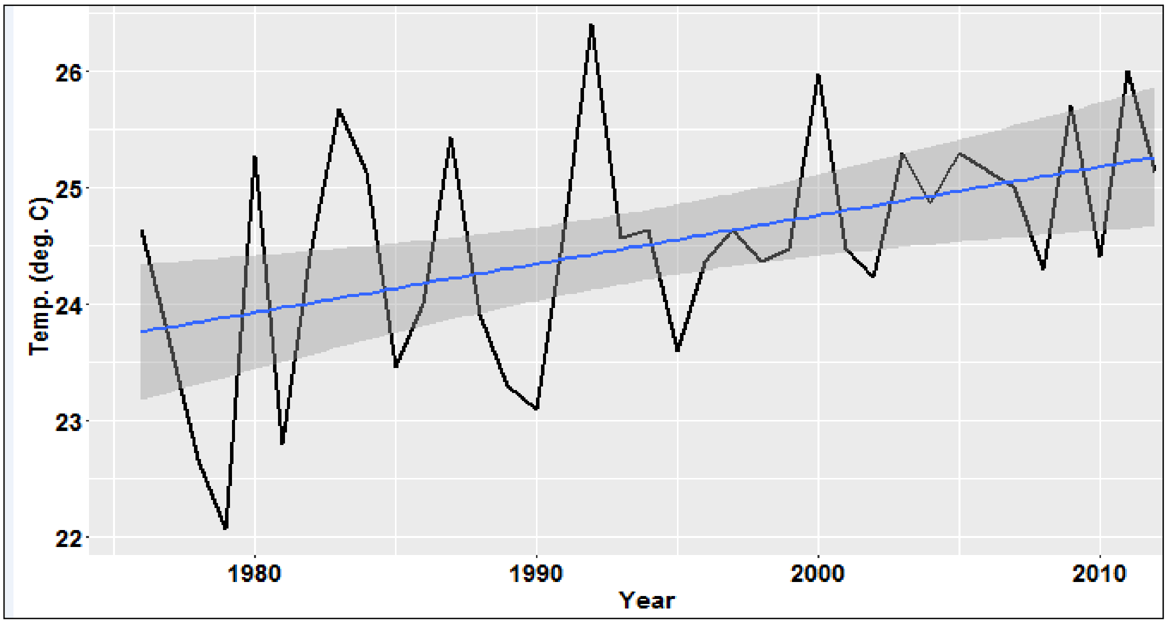


Figure 4.1b: MAM Temperature Variations (1981-2012)

(Source: Temperature Data from KMD (1981-2012)

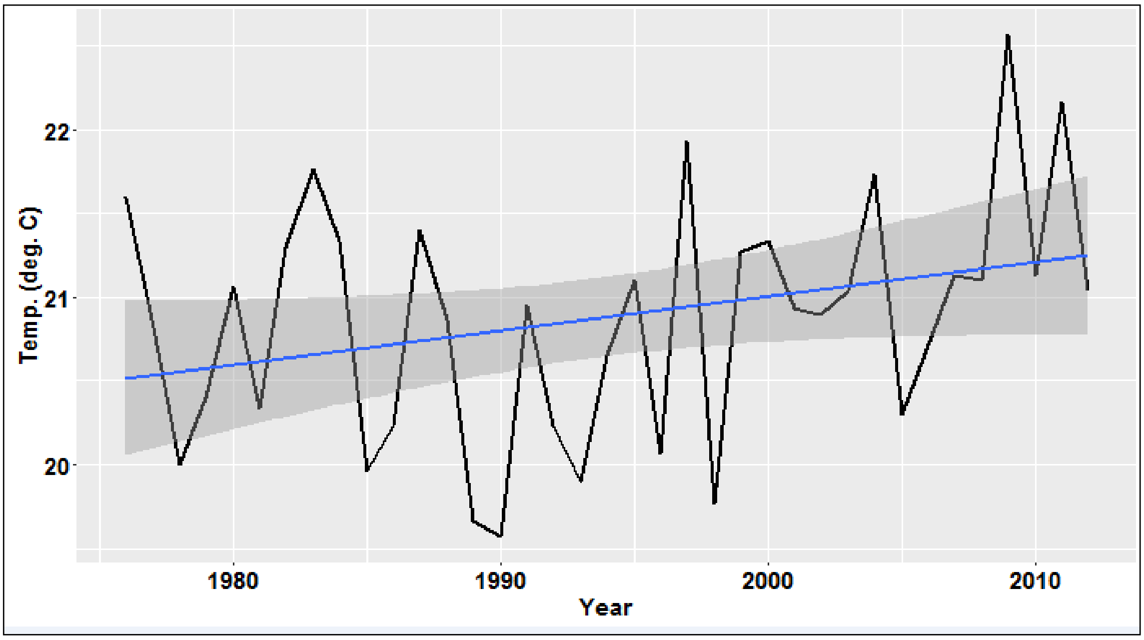


Figure 4.1c: JJA Temperature Variations (1981-2012)

(Source: Temperature Data from KMD (1981-2012)

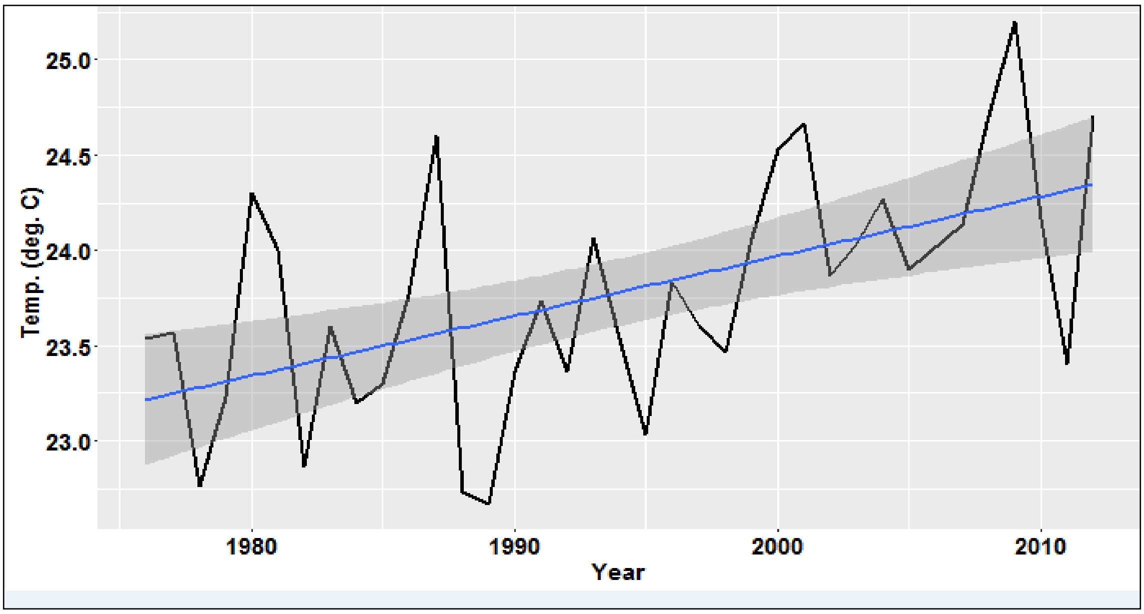


Figure 4.1d: SON Temperature Variations (1981-2012)
(Source: Temperature data, KMD (1981-2012)

Temperature data corresponding to linear trend line for every season showed a positive trend in the time series for all the seasons illustrated in Figure 4.1a, 4.1b, 4.1c and 4.1d above. As per the maximum temperature data in figures 4.1a, 4.1b, 4.1c and 4.1d, the Mann-Kendall test demonstrated that there was a trend which was increasing for New DJF, JJA, MAM and SON. Except for JJA, DJF, JJA and MAM were statistically significant for maximum temperature after running the MK test. For temperature minimum it was statistically significant for SON, DJF and MAM with the exception of for JJA. June, July and August minimum and JJA maximum indicated there was no trend. The S statistic recorded does not show any connection amongst seasons for temperature data. In all seasons, there was an increasing trend in temperature as shown by the linear trend line, although the gradients are small in terms of size. Despite inter annual variability in study area temperatures, mean temperatures have been increasing overall since 1980 (Figures 4.1 a, 4.1b, 4.1c and 4.1d).

According to the Kenya Metrological Department, in Tharaka the annual mean temperature improved in the region of 0.4°C per decade between 1981 and 1990. It increased by 0.3°C per decade between 1991 and 2000 and by 0.25°C per decade between 2001 and 2010. The temporal patterns and trends match the general trends globally whereby since 1850, there has been an average increase in temperature of about 0.8°C (IPCC, 2007). The temperature change might have resulted to a shift in the habitation of species (Evans & Perschel, 2009). In addition the increase in temperature can subsequently result to detrimental effects to the vulnerable and old persons due to extreme heat (Evans & Perschel, 2009).

4.3 Precipitation

The rainfall variations between 1982 and 2012 are shown in figures 4.2a, 4.2b, 4.2c and 4.2d. They indicate the charts for DJF, JJA, MAM and SON. Rainfall data was subjected to the Mann-Kendall test; the results are as shown in Table 4.1. If the significance level α (alpha) = 0.05 is greater than the p value, it indicates that the time series has a trend.

Table 4.1: Seasonal Mann-Kendall Test on Temperature Data and Rainfall Data

Seasonal_Mann-Kendall_Test_Tmax				
Season	**Kendall tau**	**2-sided p-value**	**Slope Score**	**var (Score)**
DJF	0.362919	0.002062	227	5380.333
MAM	0.289843	0.014093	181	5376.333
JJA	0.175441	0.13741	110	5384
SON	0.412752	0.000438	259	5385
Seasonal_Mann-Kendall_Test_Tmin				
DJF	0.425614	0.000303	266	5379.333
MAM	0.409684	0.000409	271	5837
JJA	0.26018	0.027233	163	5382.333
SON	0.474381	0.000223	296	5375.333
Seasonal_Mann-Kendall_Test_Rainfall				
DJF	0.155556	0.186426	98	5390
MAM	-0.08102	0.495803	-51	5389
JJA	-0.10476	0.375963	-66	5390
SON	-0.0127	0.92404	-8	5390

(Source: Rainfall and Temperature Data from KMD (1981-2012)

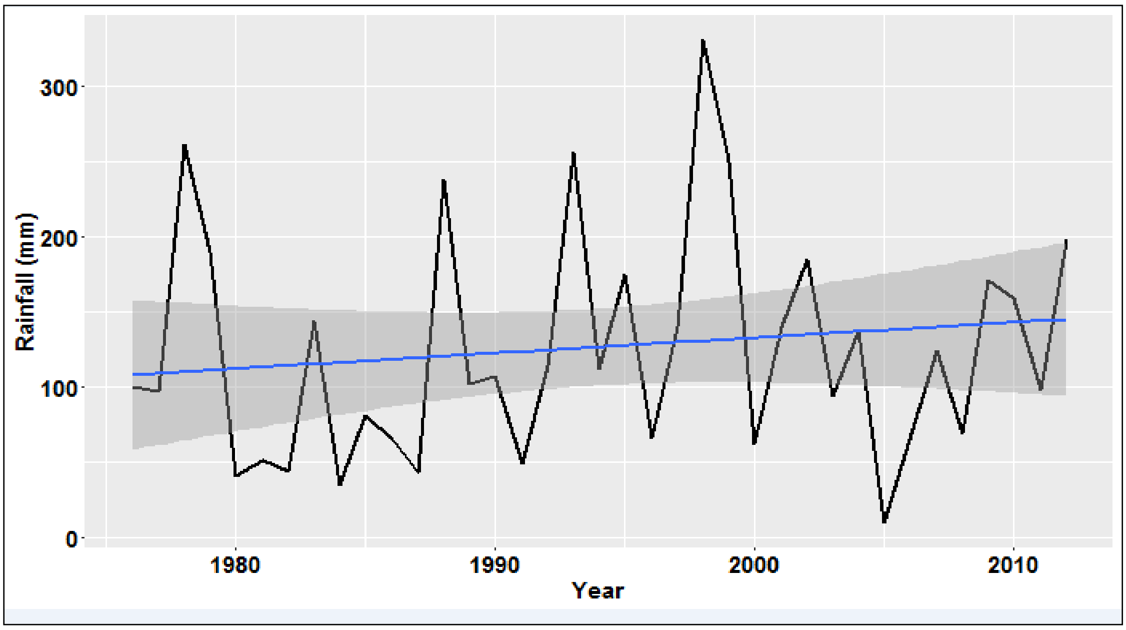


Figure 4.2a: DJF Rainfall Variations

(Source: Rainfall Data from KMD (1981-2012)

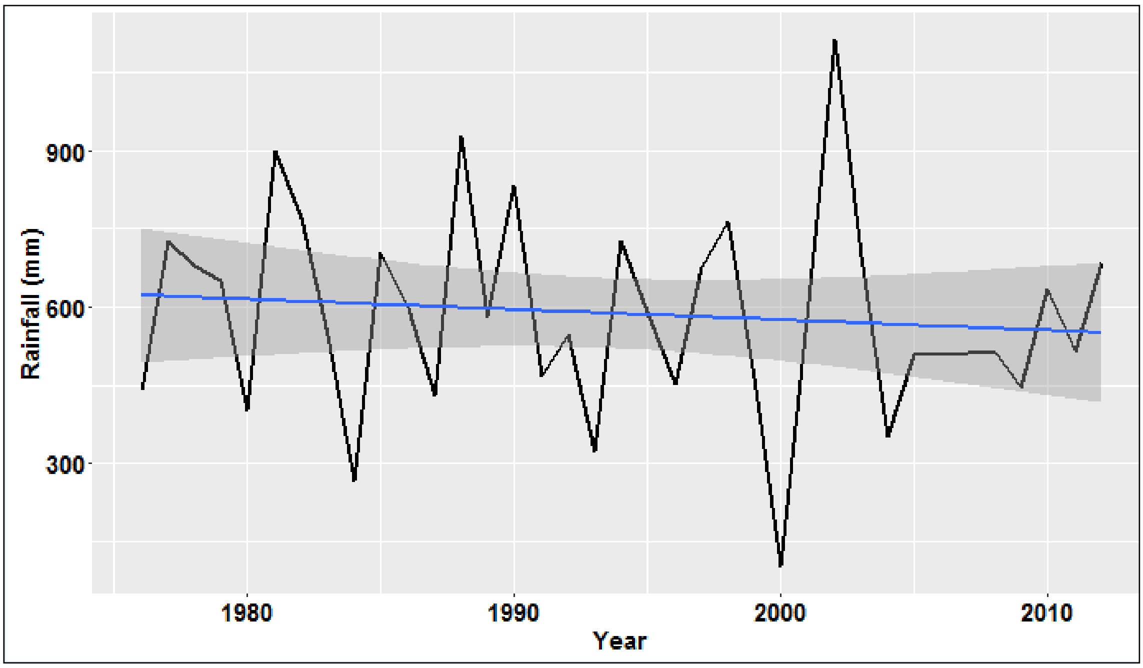


Figure 4.2b: MAM Rainfall Variations

(Source: Rainfall data from K M D (1981-2012)

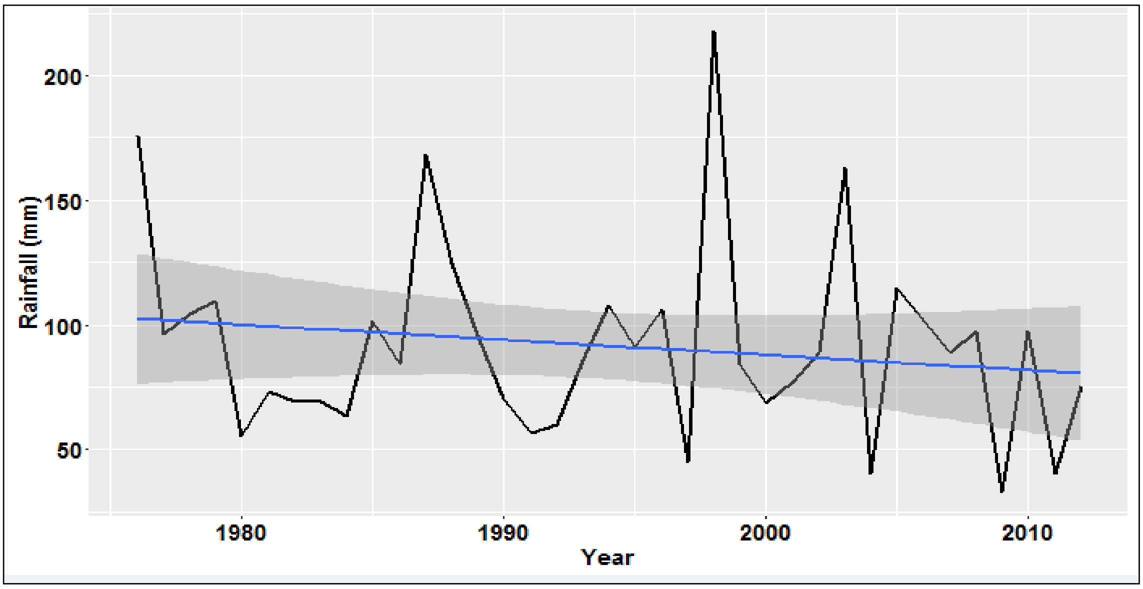


Figure 4.2c: JJA rainfall Variations

(Source: Rainfall Data from KMD (1981-2012)

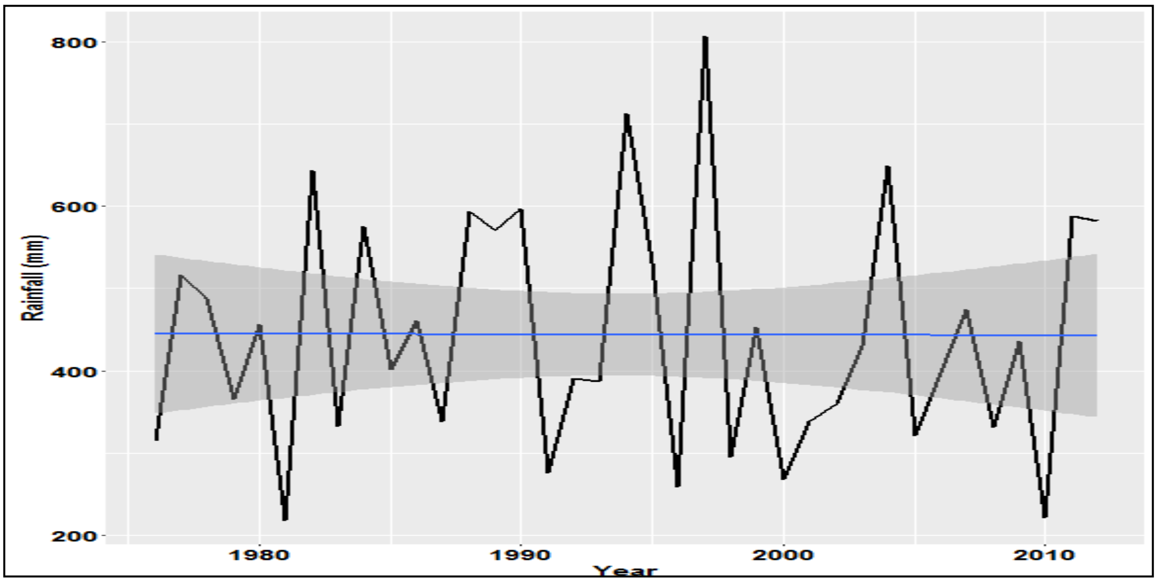


Figure 4.2d: SON Rainfall Variations

(Source: Rainfall Data from KMD (1981-2012)

Regarding the rainfall data, the Mann-Kendall test gave attractive results about annual precipitation data for Tharaka. The MK test Statistic (S) test result is weak for DJF, MAM, JJA and SON. The implication is that for rainfall there is no trend observed. On supplementary analysis of the S statistic for the four seasons, it was manifest that there was agreement in the extent of the statistic taking into account a latitudinal factor (Table 4.1). For MAM the S statistic is -51, JJA -66 and SON -8 while the statistics are small in magnitude. Further, when the linear trend line was fitted, the observation was that the trend was reducing for all. The trend line gradient is not actually large in size. Considering latitudinal factors, the fall in seasons is similar in gradient size and it ranged between -66 and 98. It is significant to deliberate the environmental, social and economic effects resultants if diminishing rainfall trends continue in future in these seasons. The vulnerability to drought might further be increased owing to decrease in rainfall in the future.

In figures 4.2a, 4.2b, 4.2c and 4.2d it is shown that the seasonal rainfall distribution across Tharaka Nithi County depicted a Gaussian normal distribution with seasonal rainfall ranging from 100 mm to 1250 mm over the whole 30 years of research. In the first period (1982 – 1991) rainfall ranged between 100 mm and 1250 mm. in the second period (1992 - 2001) rainfall ranged between 150 mm and 1150 mm, while in the third period (2002 – 2011), rainfall ranged between 100 mm and 1100 mm. Additional drop was witnessed in the third climate period whereby the smallest to largest rainfall recorded was between 100 mm and 1100 mm. The implication is that there was a reduction in yearly rainfall and this is buttressed by earlier studies (Funk *et al*., 2010). The graphs show that seasonal rainfall amounts are normally (Gaussian) spread over every region because there was no clear skewedness in the scatter curve. The implication is that there were no punishing events during the study period since they were not captured within every climate period curve. Figure 4.3 a, 4.3b, 4.3c and 4.3d illustrates the spatial distributions for Tharaka.

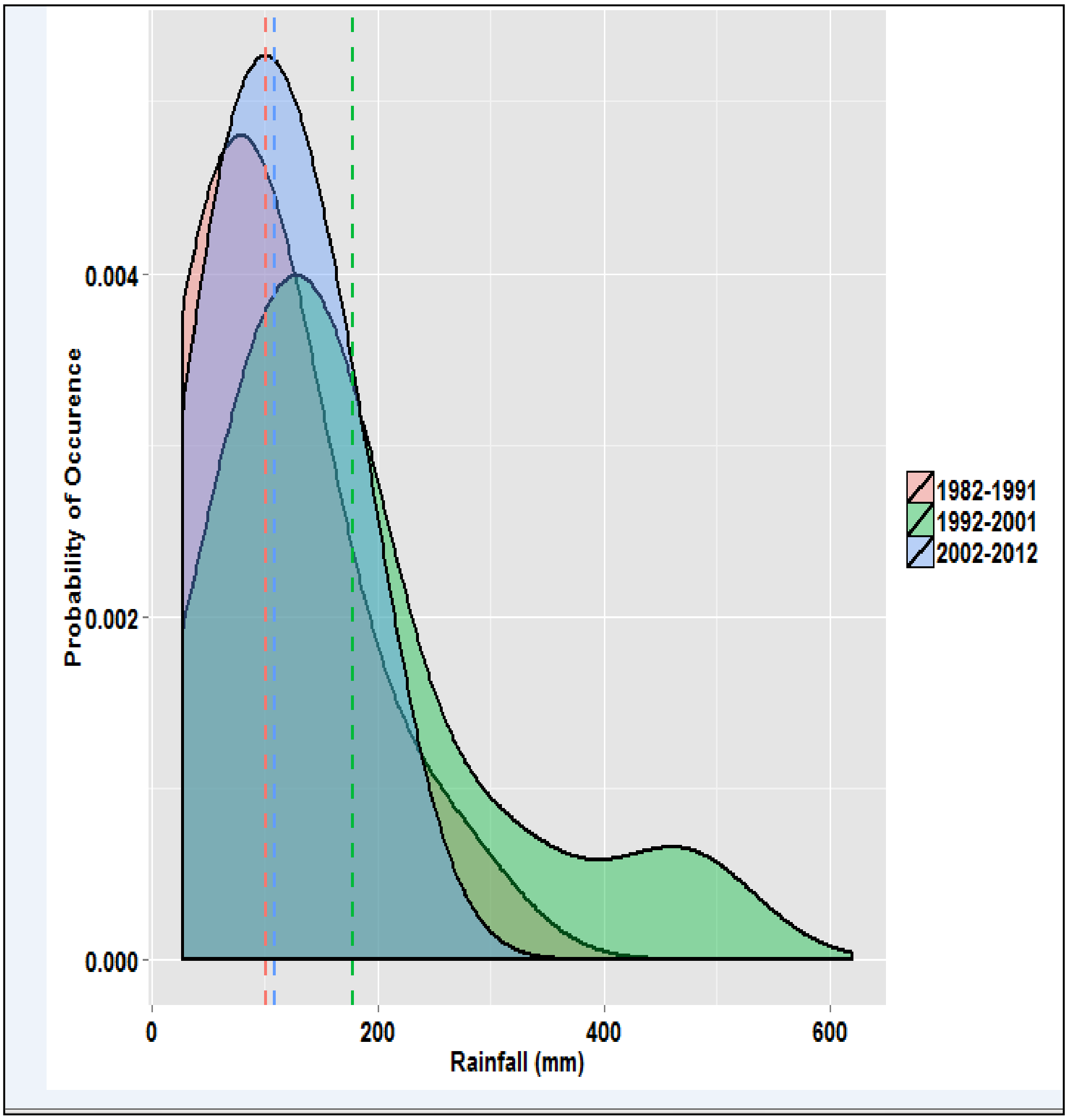


Figure 4.3a: Decadal DJF Seasonal Gaussian Distribution of Rainfall over Tharaka

(Source: Rainfall Data from KMD (1981-2012)

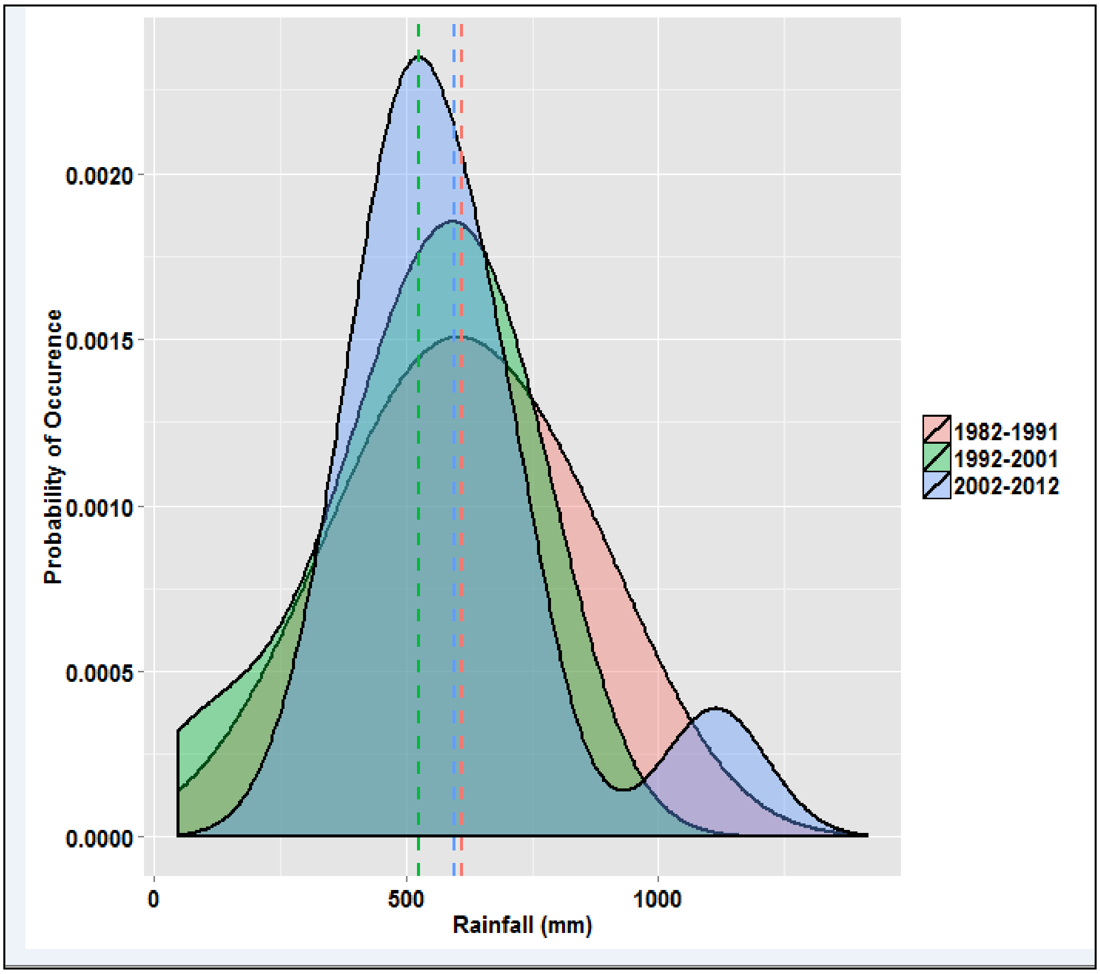


Figure 4.3b: Decadal MAM Seasonal Gaussian Distribution of Rainfall over Tharaka

(Source: Rainfall Data from KMD (1981-2012)

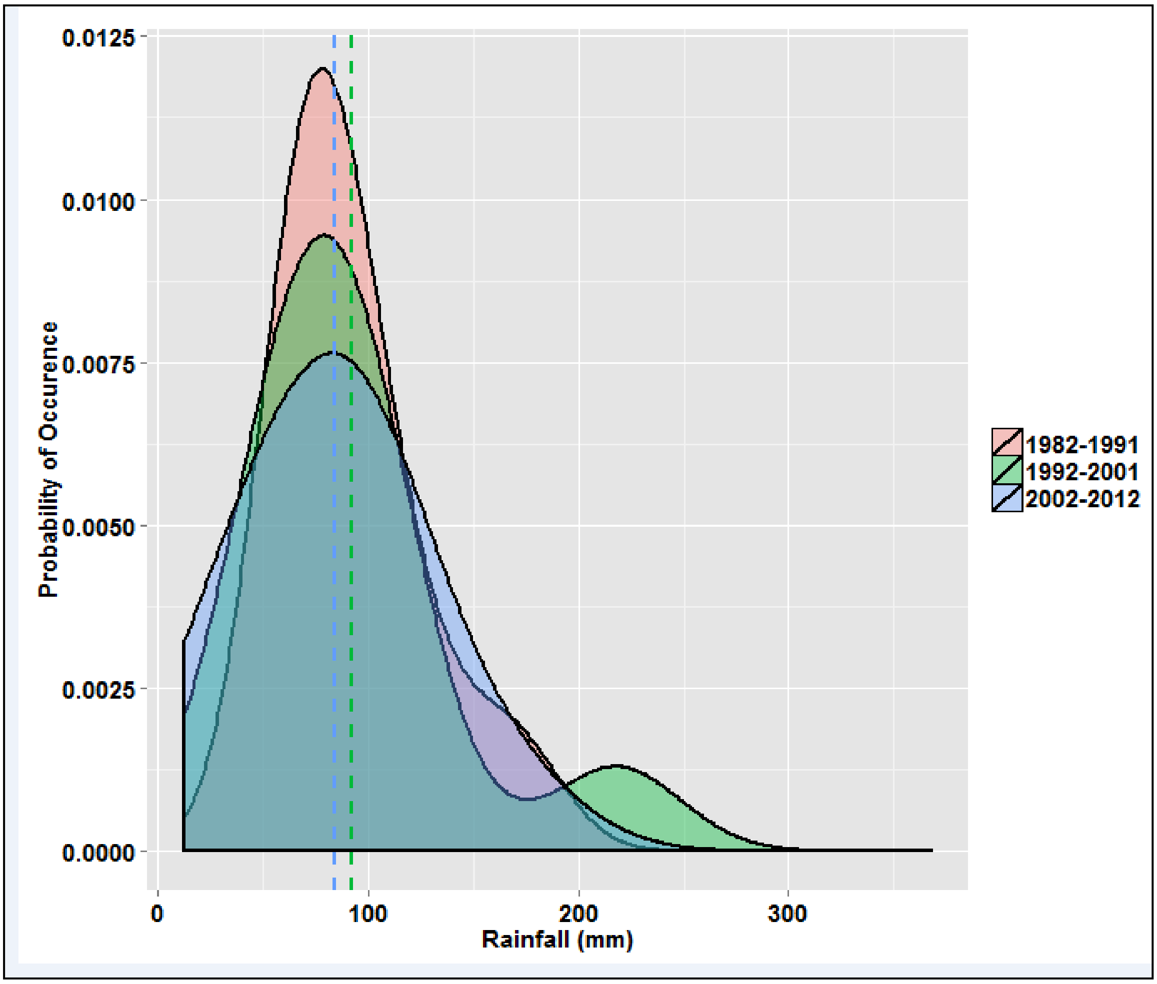


Figure 4.3c: Decadal JJA Seasonal Gaussian Distribution of Rainfall over Tharaka

(Source: Rainfall Data from KMD (1981-2012)

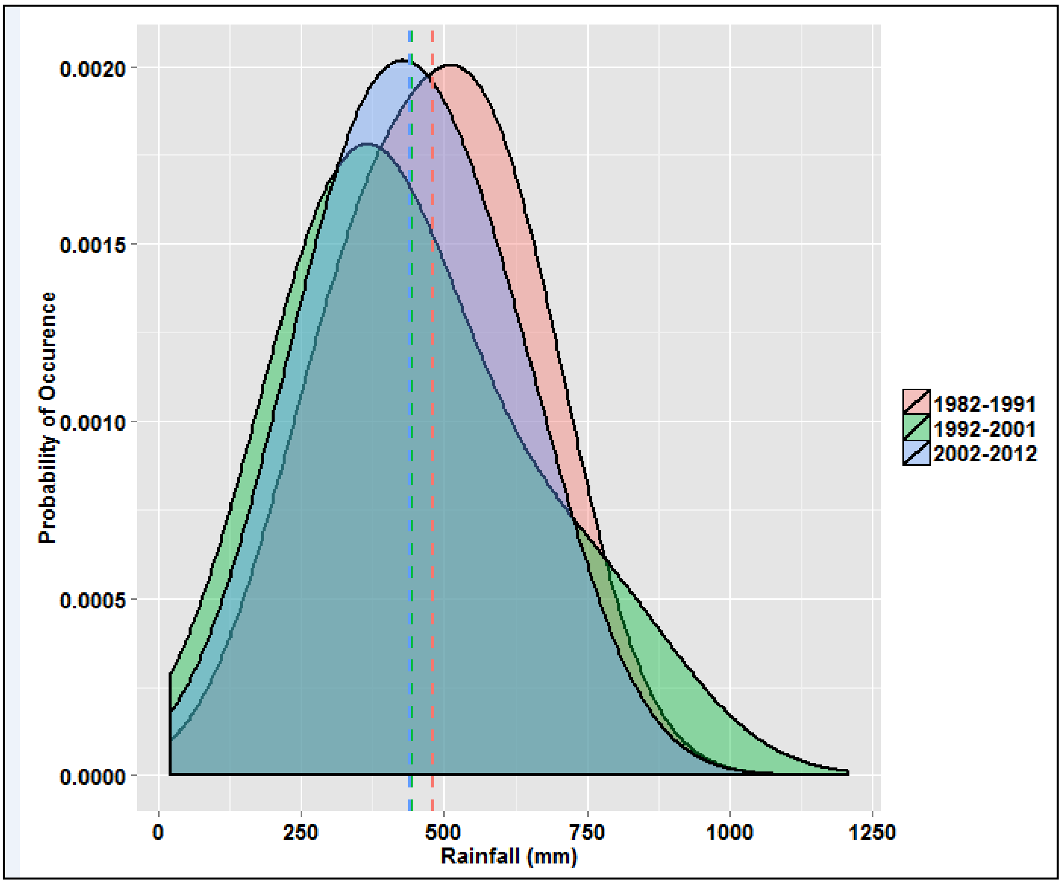


Figure 4.3d: Decadal SON Seasonal Gaussian Distribution of Rainfall over Tharaka

(Source: Rainfall Data from KMD (1981-2012)

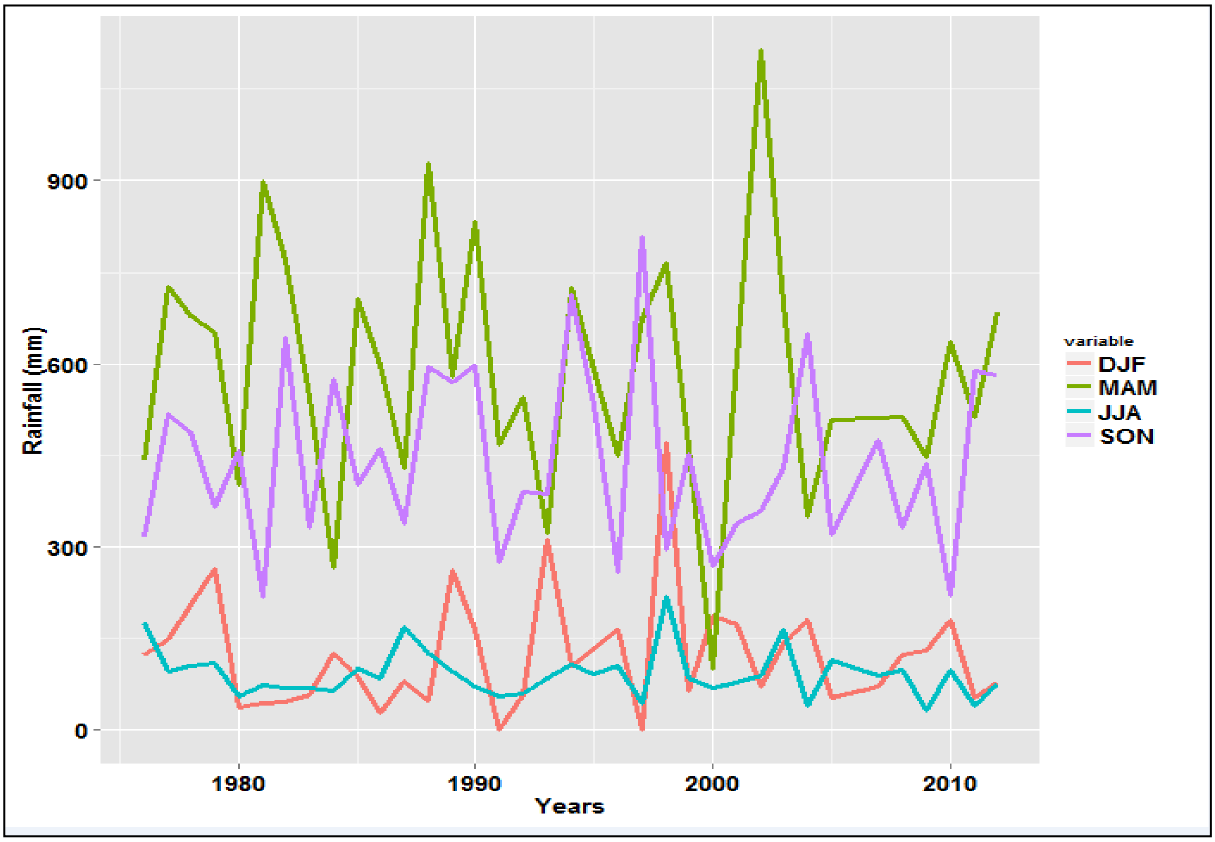
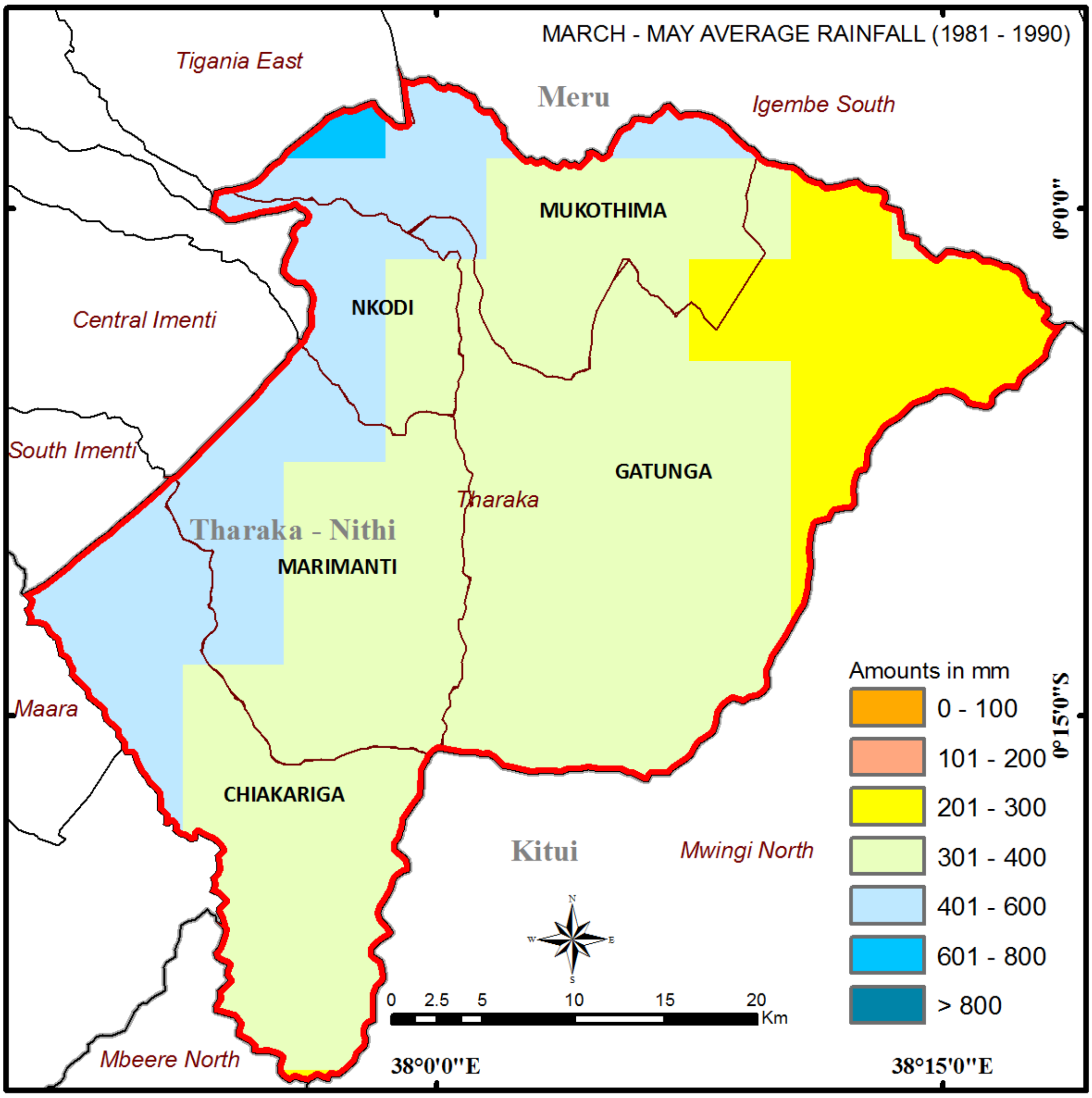


Figure 4.4 Temporal Variation of the Seasonal Rainfall in Tharaka

(Source: Rainfall Data from KMD (1981-2012)

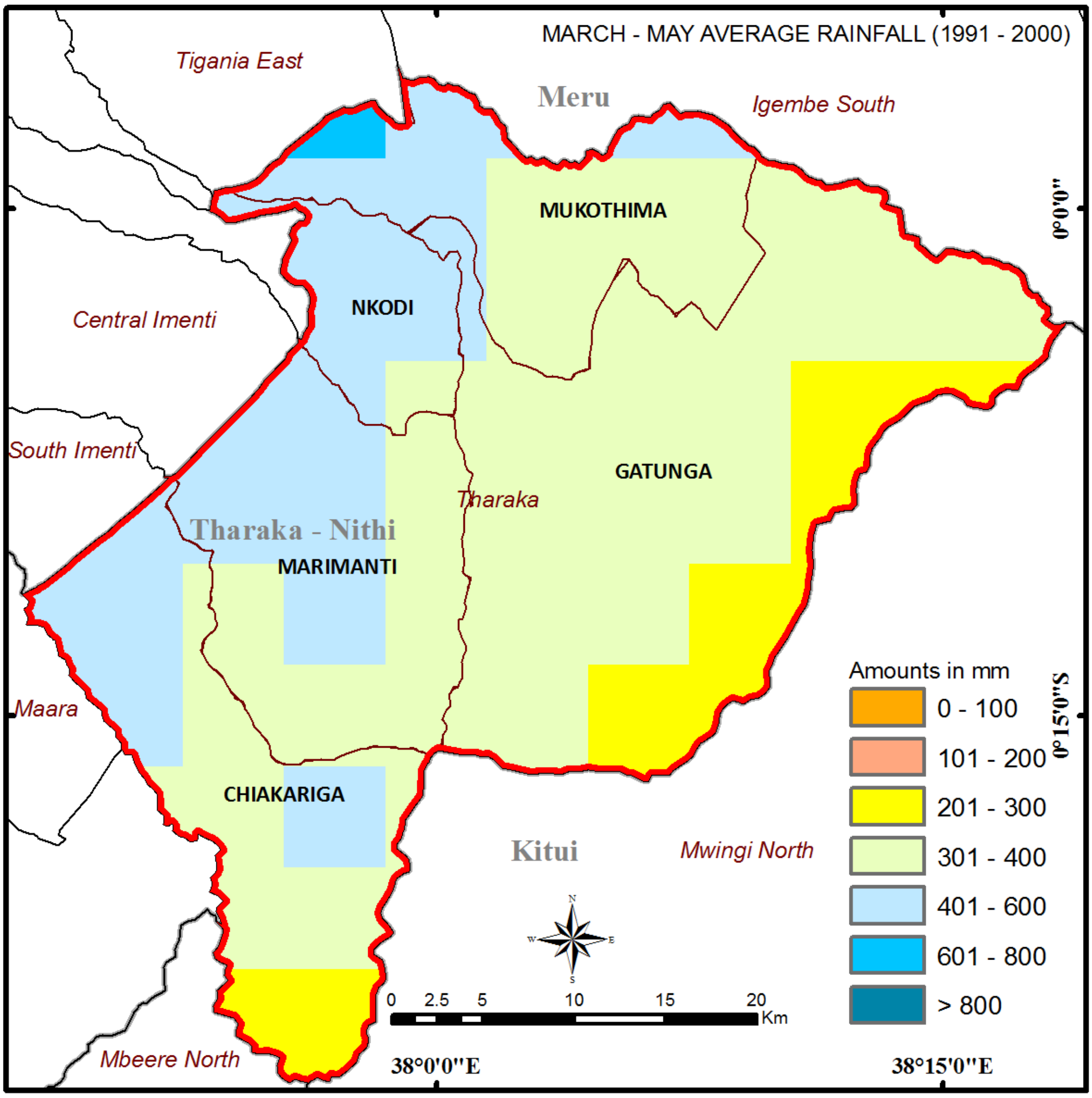
Figure 4.4 above shows the temporal variation of the seasonal rainfall over Tharaka Nithi during DJF, MAM, JJA and SON seasons between 1982 and 2012. It can be seen that there was high rainfall variability over this region for all the seasons. March, April and May (MAM) and SON contributed the highest amounts while JJA and DJF contribute the least.

Figures 4.5a, 4.5b and 4.5c give the spatial distribution of the decadal MAM rainfall over Tharaka Nithi for the decades 1981 – 1990, 1991 – 2000 and 2001 – 2010 while Figures 4.5d, 4.5e and 4.5f gave the spatial distribution of the decadal SON rainfall over Tharaka Nithi for the decades 1981 – 1990, 1991 – 2000 and 2001 – 2010. The spatial variation in the distribution of rainfall in these seasons is clearly evident. This implies the rainfall distribution is uneven displayed by different colours.



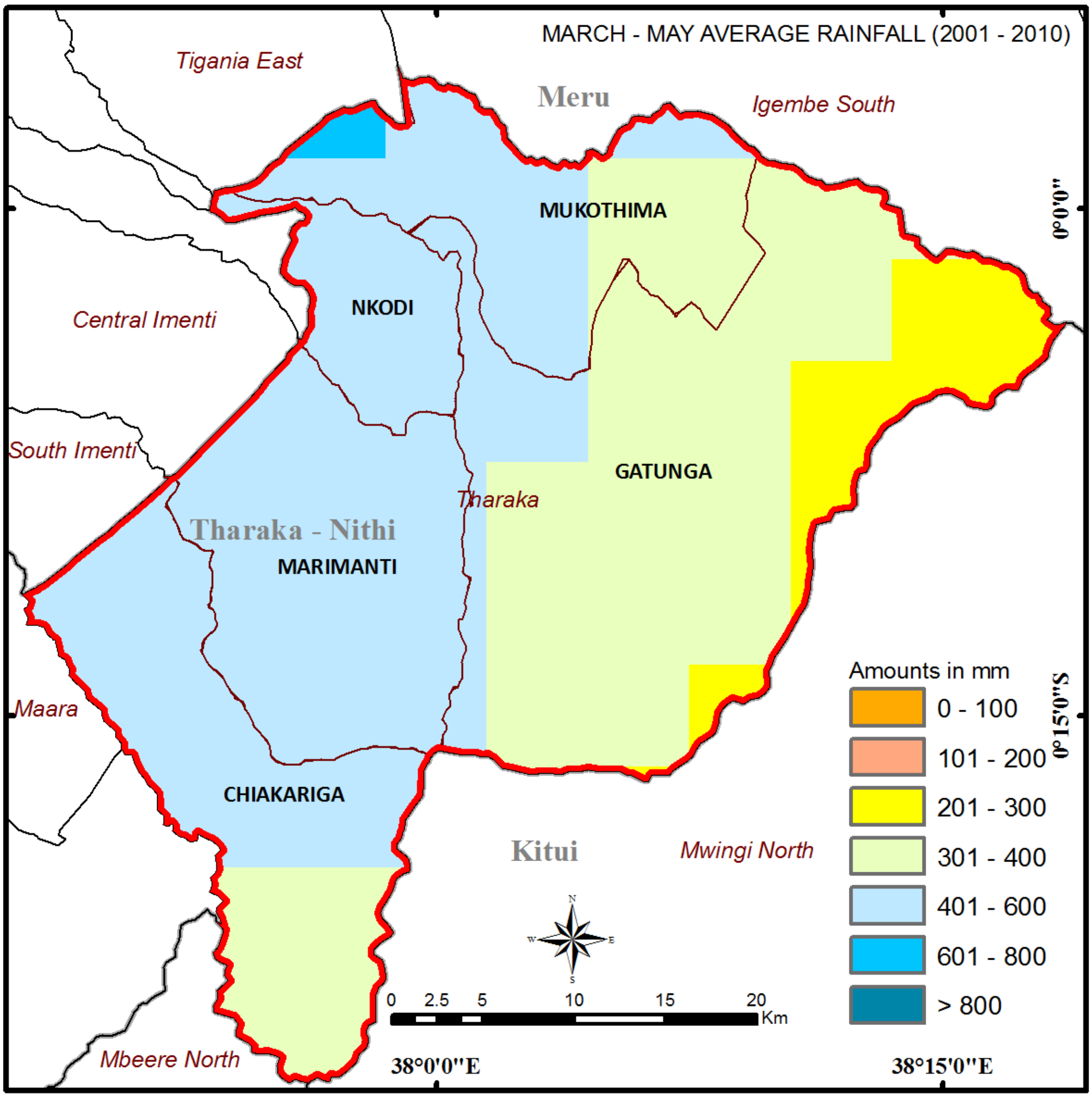
Figures 4.5a: MAM Spatial Distribution of Rainfall (1981 – 1990)

(Source: Rainfall Data from KMD (1981-2012)



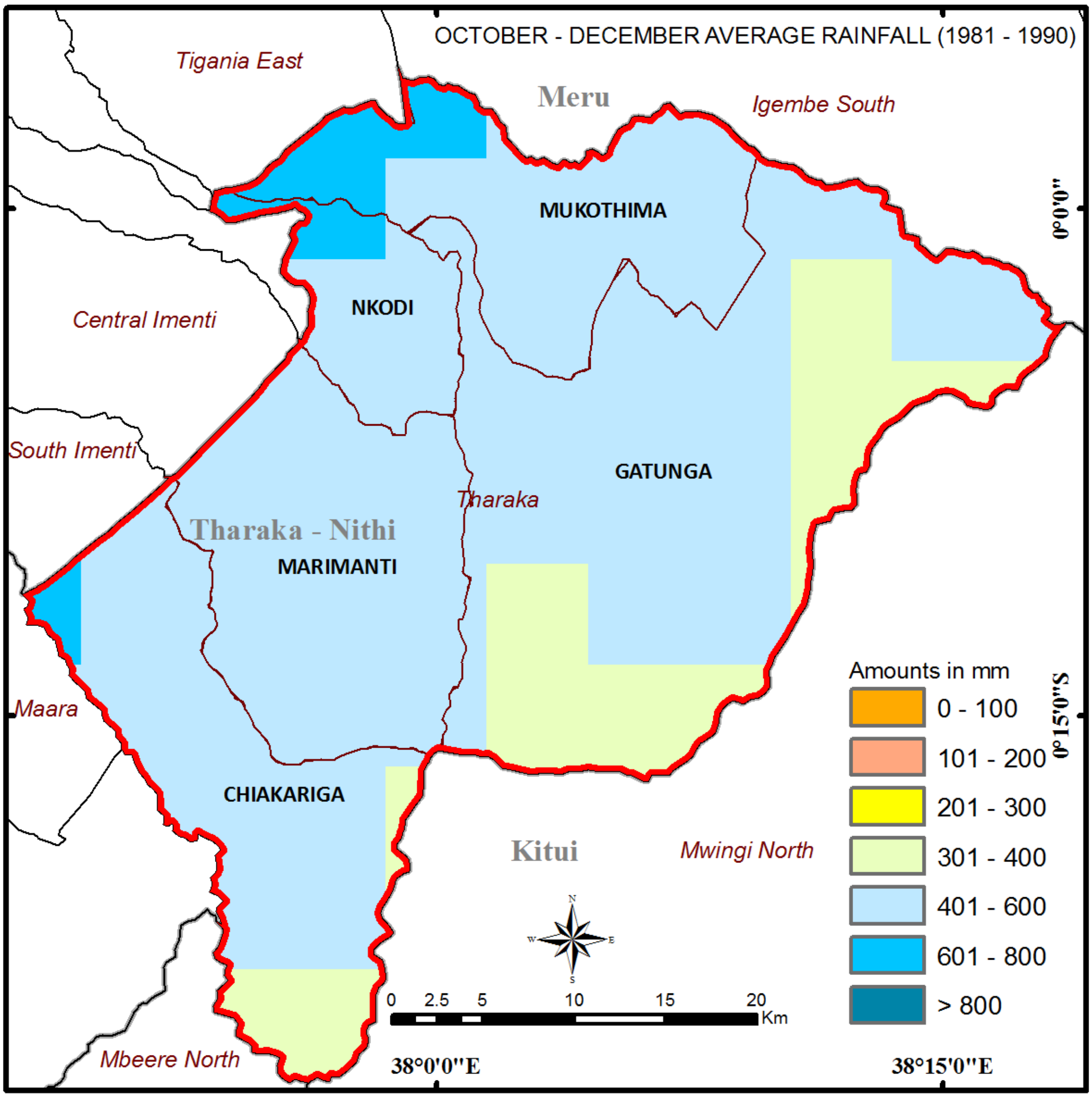
Figures 4.5b: MAM Spatial Distribution of Rainfall (1991 – 2000)

(Source: Rainfall Data from KMD (1981-2012)



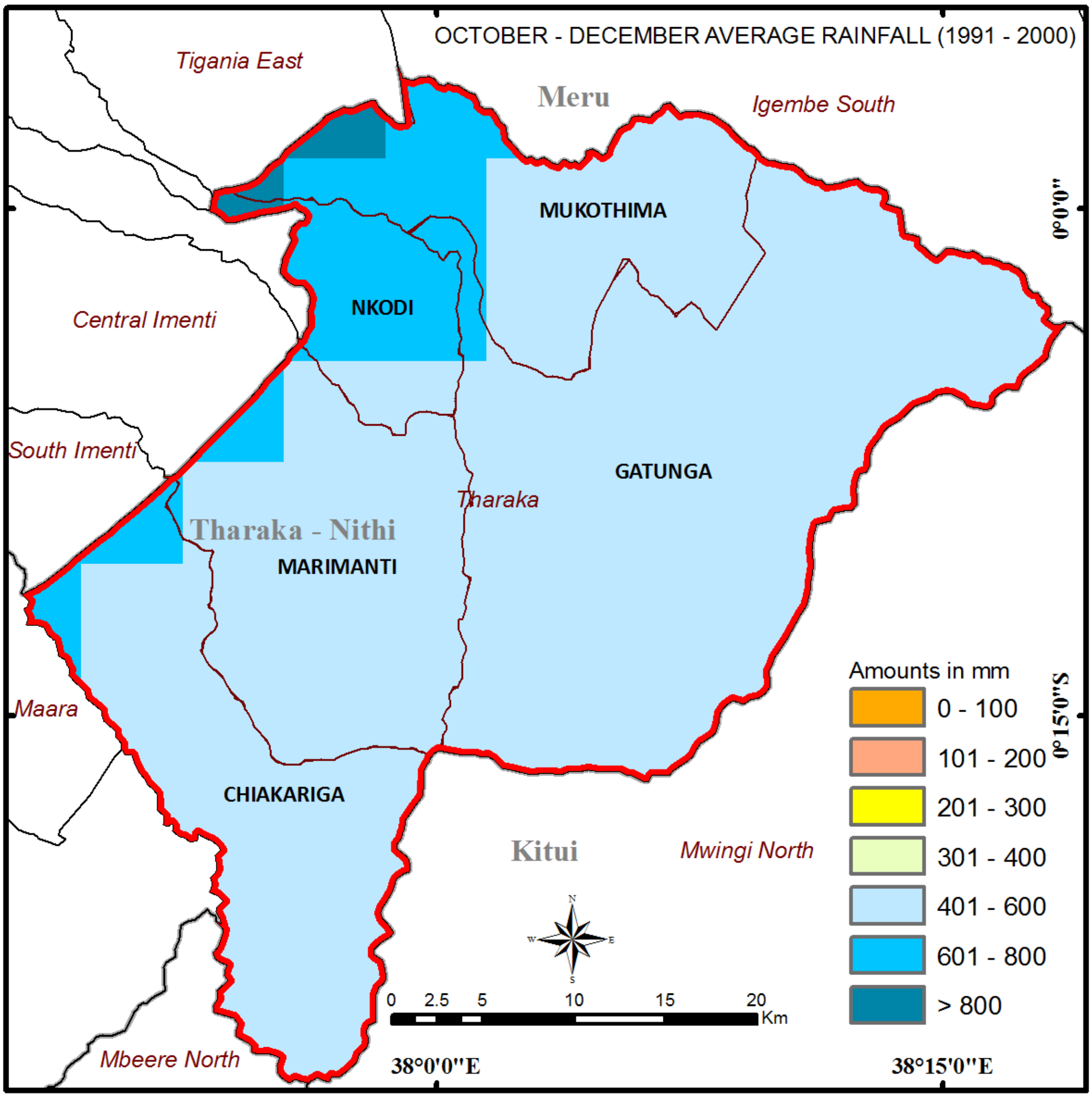
Figures 4.5c: MAM Spatial Distribution of Rainfall (2001 – 2010)

(Source: Rainfall Data from KMD (1981-2012)



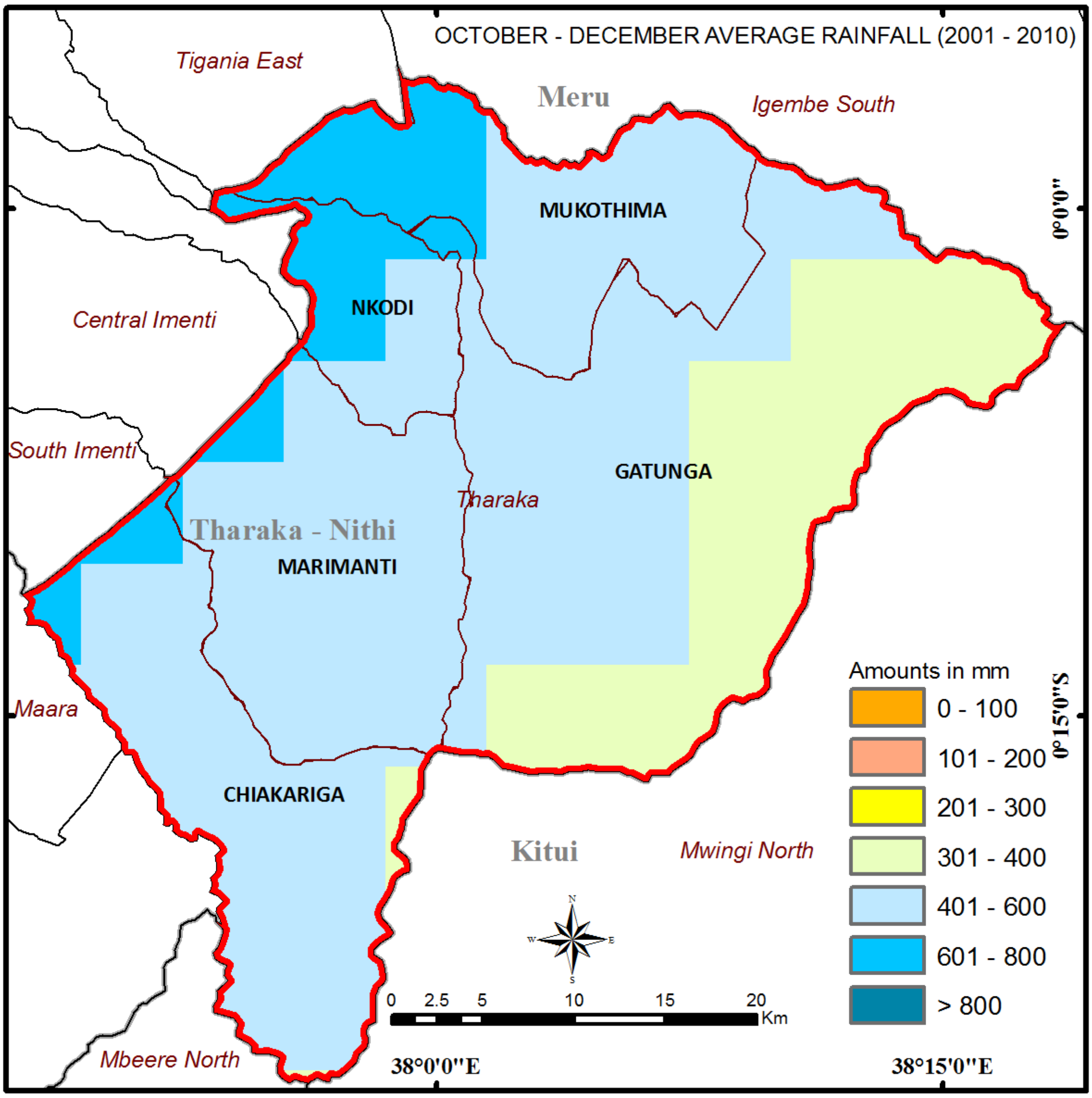
Figures 4.5d: OND Spatial Distribution of Rainfall (1981 – 1990)

(Source: Rainfall Data from KMD (1981-2012)



Figures 4.5e: OND Spatial Distribution of Rainfall (1991 – 2000)

(Source: Rainfall Data from KMD (1981-2012)



Figures 4.5f: OND Spatial Distribution of Rainfall (2001 – 2010)

(Source: Rainfall Data from KMD (1981-2012)

4.4 Implication on Household Food Security in Tharaka Nithi County

Data analysis indicates an increase in rainfall means and an increasing trend in temperature for the period under study. Tharaka Nithi County is mainly agricultural, based on the livelihood zoning data that indicates 52 percent Marginal Mixed farming, 38 percent Mixed farming and 10 percent rainfed livelihood zone (KFSSG 2015). Increasing temperature and decreasing rainfall amounts coupled with uneven spatial distribution of rain will hence negatively impact on food productivity. Exposing more household to the need of food aid.

CHAPTER FIVE: RESULTS AND DISCUSSION FOR HOUSEHOLD FOOD SECURITY STATUS AND ITS DETERMINANTS

5.0 Introduction

The discussion and results in this chapter are based on the second objective which looked at household food security and its determinants in Tharaka South and Tharaka North Sub Counties. The question the study sought to answer was; what determines the food security status of the household? The research used 425 questionnaires with a response rate of 94.12 percent. Background characteristics are provided by descriptive statistics of the study population, while the correlation analysis was used to determine the level of association while multivariate analysis was done to determine the likely impact of each of the variables to food access, the food availability, utilization and stability.

5.1 Household Information

Descriptive statistics in are shown in tables 5.1a, 5.1b and 5.1c. Table 5.1a show that almost a third 34.8 % of respondents were of ages 46 to 55 years while only a few 25.5% of cases respondents were of age 36 to 45 years. The majority of the respondents; those aged more than 65 years and those aged less than 35 years were 11.3% and 11.5% respectively. This implies that the majority of farmers in Tharaka South and Tharaka North Sub counties were not youths. On basis of sex of the respondents, majorities (58.3%) were male, while the female were (41.8 %). Interestingly, household head had the highest frequency (70.5%) while (23.8 %) of the respondents represented spouses to the household heads.

Table: 5.1a: Household Information (Age, gender and relationship with household head)

Age of Respondents	**Frequency**	**Percent**
<35	46	11.5
36 to 45	102	25.5
46 to 55	139	34.8
56 to 65	68	17.0
Over 65	45	11.3
Total	**400**	**100**
Sex of Respondents	**Frequency**	**Percent**
Male	233	58.3
Female	167	41.8
Total	**400**	**100**
Respondents Relationship with Household Head	**Frequency**	**Percent**
Household head	282	70.5
Spouse	95	23.8
No response	23	5.8
Total	**400**	**100**

As pertaining to marriage table 5.1b shows that the majority of the respondents (74.0%) were in monogamous marriage while both the single and the widowed were (5.8%). The polygamous and the divorced were (9%) and (2.8%) respectively. Those born in the village where the study was conducted were (71%). A few (26%) and (2.8 %) were born elsewhere in the region, and elsewhere in the county respectively. On the basis of education, (51.8%), (17.5%) and (14%) of the respondents had primary education, secondary education and no formal education respectively.

Table 5.1b: Household Information (Marital status, Birth place, Education level)

Marital status	Frequency	Percent
Single	23	5.8
Monogamous marriage	296	74.0
Polygamous marriage	36	9.0
Widowed	23	5.8
Separated/Divorced	11	2.8
Total	**400**	**100**
Place of birth	**Frequency**	**Percent**
This Village/Town	285	71.3
Elsewhere in the Region	104	26.0
Elsewhere in the County	11	2.8
Total	**400**	**100**
Education Level	**Frequency**	**Percent**
None	56	14.0
Literacy	34	8.5
Primary	207	51.8
Secondary	70	17.5
Tertiary	22	5.5
Technical/Vocational	11	2.8
Total	**400**	**100**

Descriptive statistics in Tables 5.1c shows that crop farmers were almost half (53%) while crop farmers and livestock keepers were (30.5%). The implication is that greatest number of respondents was keen on crops and animal husbandry.

Table 5.1c: Household Information (Occupation)

Occupation	Frequency	Percent
Farming	212	53.0
Other non-farm income (hawking)	11	2.8
Unemployed	11	2.8
Livestock raising and Farming	122	30.5
Livestock raising, Farming and bee keeping	11	2.8
Livestock raising, Farming and formal/salary work	11	2.8
Formal/salary work and Farming	11	2.8
Non response	11	2.8
Total	**400**	**100**

The respondents' numbers of children is shown in figure 5.1. The majority were daughters (29%) whereas respondents with two and three sons were 28.5% and 19.8 % respectively. The study found that all the respondents who participated in the study were all Christians from the Tharaka tribe.

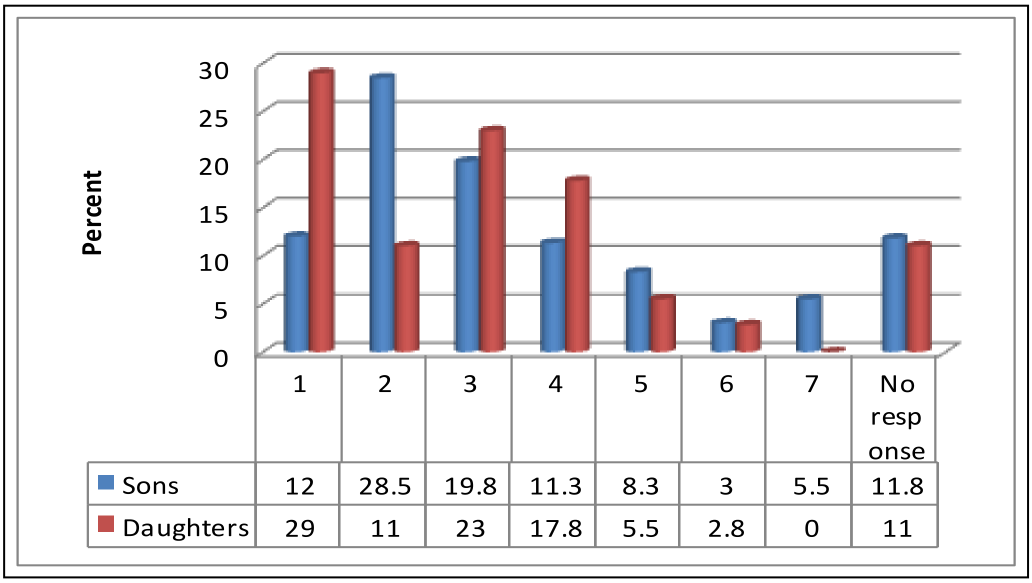


Figure 5.1: The Percent of Persons with Number of Children

The composition of household members shown figure 5.2 indicates that households with one adult men aged 18 and 65 years were 19.5% and for two adult women were the majority (25.3%) respondents. Majority of the respondents did not have boys and girls aged less than eighteen years. From the members of household involved in the study, (55%) had a single member of the household engaged in food or income activities for the family; most probably the household head.

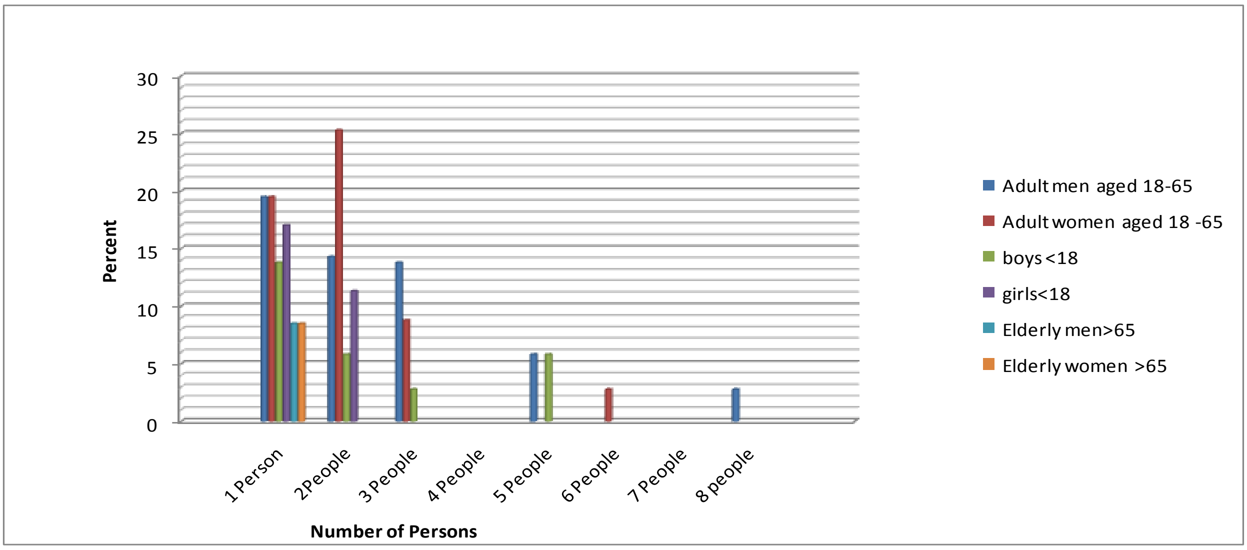


Figure 5.2: Percent of Household Composition

Table 5.2 indicates that the majority of the households who participated in the study had one household member participating in food provision activities. This has an effect on the available labour for engaging in climate change adaptability activities.

Table 5.2: Number of Household Members Involved in Food Provision Activities

Number of Household Members	Frequency	Percent
0	45	11.3
1	220	55.0
2	23	5.8
3	33	8.3

5.2 Farm Size Subjected to Farming

Table 5.3 shows that (37%) and (35%) of the respondents had 1 to 3 acres and 4 to 6 acres of land respectively. Fourteen percent of the respondents owned less than an acre. The import of this is that there is sufficient land to practice small scale farming.

Table 5.3: Farm Size

Land Size	Frequency	Percent
Less than an acre	56	14.0
1 to 3 acres	148	37.0
4 to 6 acres	140	35.0
7 to 10 acres	23	5.8
Over 10 acres	11	2.8
No response	22	5.5
Total	**400**	**100**

The above farm sizes were either fully or partly owned by the respondents which represented 91.8% (Figure 5.3).

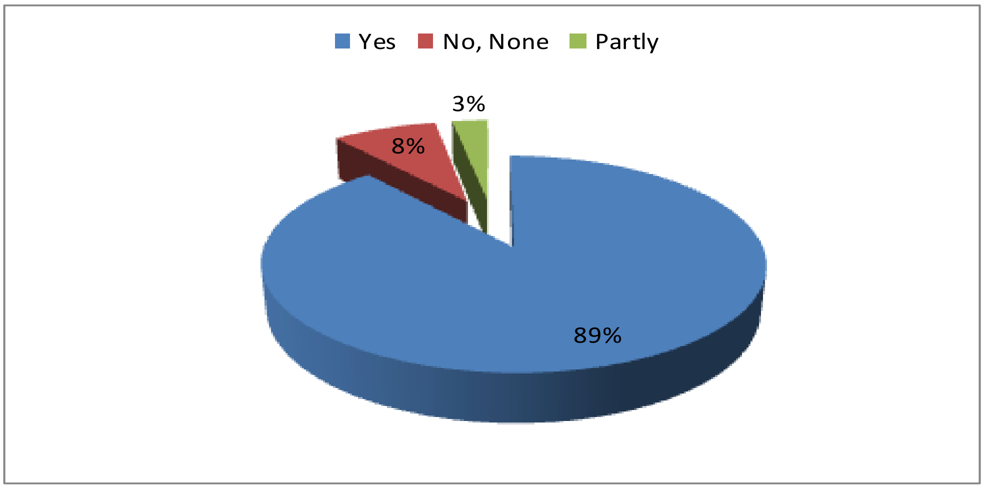


Figure 5.3: Land Ownership

From figure 5.3, 8% of participants in the study did not own land, yet they got right to use land for farming through shareholding and renting. In figure 5.4, we observe that majority of the respondents (77%) and only 11% of them did not use irrigation and used irrigation respectively.

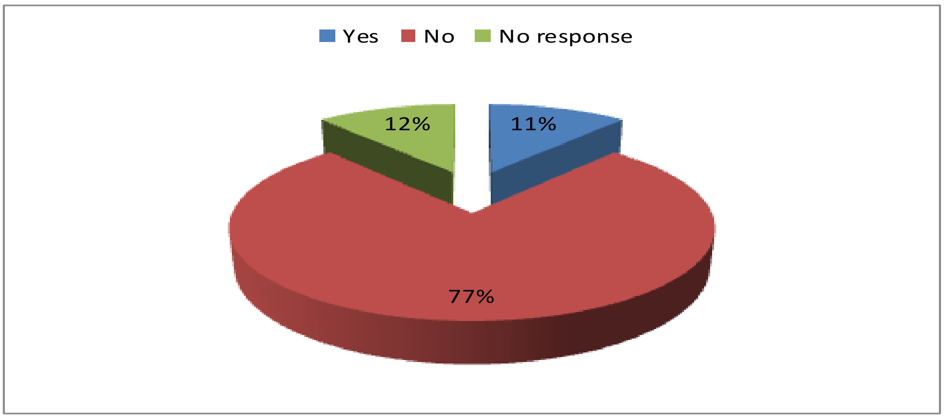


Figure 5.4: Farm Irrigation

A follow up on those who practiced irrigation (11%) indicated that the maximum size of land that they were capable of irrigating was 3 acres. The crops that were cultivated by the respondents were: pigeon peas, sorghum, cowpeas, millet, green grams, beans, maize, tomatoes, bananas, pawpaw and kales (Sukuma wiki). From the foregoing list, preference was given to millet and cowpeas farming by the majority of the participants in this study at 17.5%. Seventeen point three percent of the respondents grew maize, millet, pigeon peas and green grams while 16.8% of the respondents cultivated pigeon peas, sorghum, millet and green grams. During these farming activities, the majority of the respondents indicated that they utilized household workforce.

Basing on the purpose of crop production, majority of the respondent 64.5% used the crop for household consumption while a few 19.5 % responded the crops were sold. Crops both, sold and used for household consumption was 13.0 % of total food produced. This is shown in Table 5.4. Additionally, the table also indicates the quantity of yields sold by the households. A majority 42.8% of the participants disposed more than half of their harvest whereas 25.3% traded less than half of their harvest.

Table 5.4: Main Purpose of Crop Production

Main Purpose of Crop Production	Frequency	Percent
No response	11	2.8
Household consumption and sale	52	13.0
Sale	78	19.5
Household consumption	259	64.5
Total	**400**	**100**
Amount of crop production sold		
No response	11	2.8
Hardly anything	22	5.5
Nothing	24	6.0
Approximately half	71	17.8
Less than half	101	25.3
More than half	171	42.8
Total	**400**	**100**

5.3 Economic Activities

The income that the household derived from the sale of the crops, livestock, fishing economic trees and total annual income is indicated in figure 5.5. Greatest respondents failed to reply the questions on income generated from different economic engagements. The explanation being the fact that records on farming activities are not kept by the majority of farmers. Those who respondents indicated that rearing of Livestock gave them over Ksh. 30,000, being the highest annual income. Highest annual income from Crop production ranged between Kshs. 20,001 and Kshs. 25,000 whereas the highest income realised from economic trees was less than Kshs. 5,000. Income from Non-farm activities ranged between Kshs. 25,001 and Kshs. 30,000. Fourteen point eight percent of the respondents indicated that their total disposable income was more than Kshs. 30,000. It should be noted that (69%) of the participants did not respond to the question on disposable income. This means that that they did not budget because their deprivation makes them live from hands to mouth.

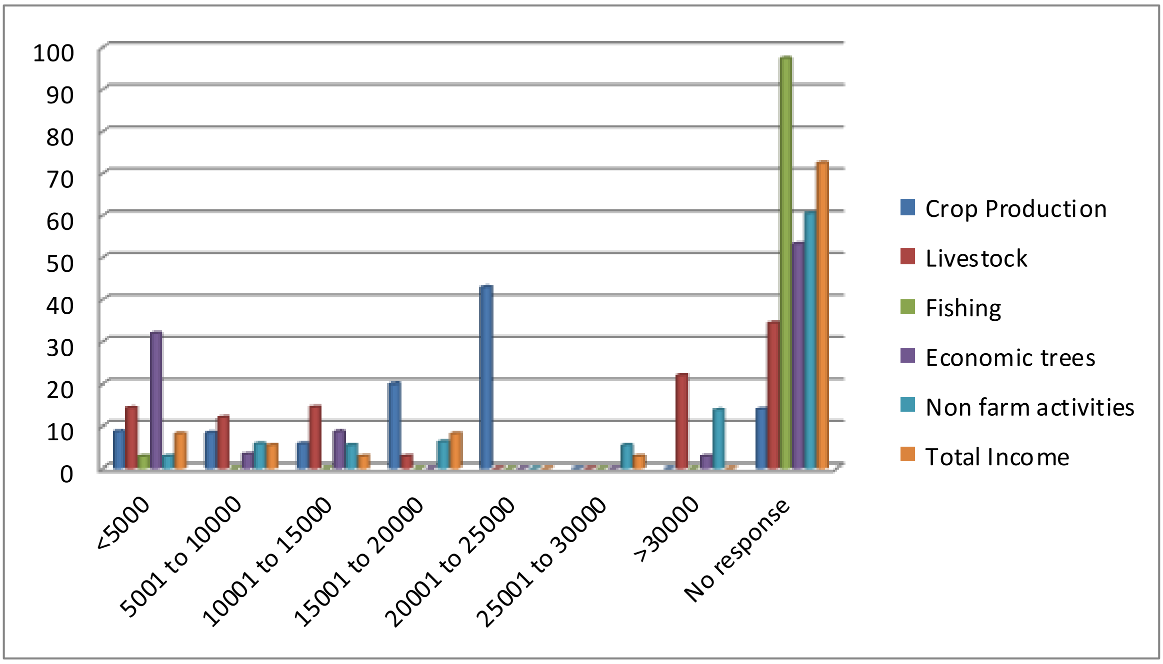


Figure 5.5: Income from Various Economic Activities

Regarding income from nonfarm activities more than half 57% of the respondents said that they did not have any other source of income other than farm activities, while 43% had income from non-farm activities as shown in Figure 5.6. Bee keeping for honey and charcoal burning for sale were the other sources of income the respondents said they had.

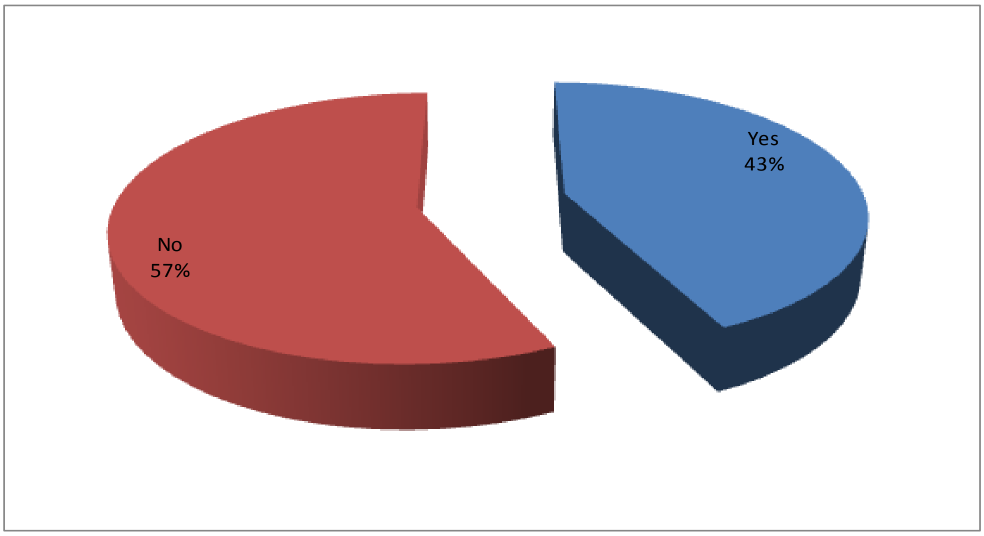


Figure 5.6: Income from Non-Farm Activities

5.4 Food Security

Several indicators or variables were used to measure food security, these was according to the four pillars of food security; utilization, accessibility, stability and availability. Basing on the pillar of utilization, the study explored daily food intake frequency per household. Figure 5.7 shows their responses. Most adults at 63% had 3 meals in a day while children were at 46%.

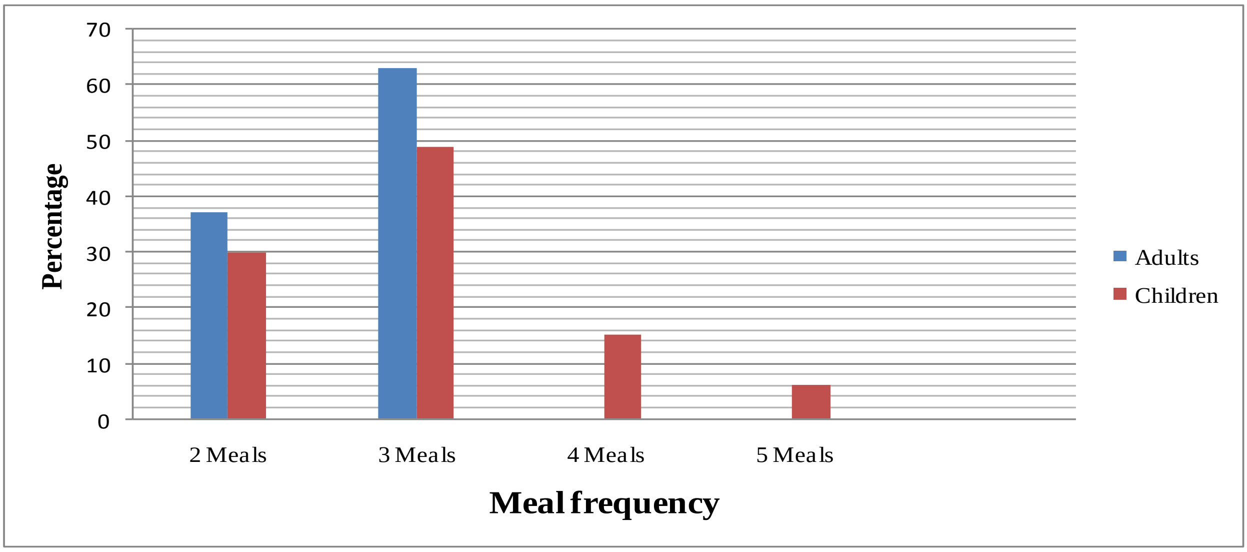


Figure 5.7: Number of Meals in a Regular Day

Adults had less than four meals daily while (30%) and (6%) of children had two and 5 meals daily respectively. A majority of the respondents at 77 % had to eat less due to having experienced food shortage. Twenty percent of the respondents had not experienced food shortage in the preceding year. Food shortage months are as indicated in Table 5.5. The months of want according to the respondents were December, November, October, September and August. The month of April experienced food shortage to a small extent with 5.5% of the respondents in affirmation.

Table 5.5: Months of Food Shortage

Months	Frequency	Percent
November	11	2.8
August	12	3.0
April	22	5.5
August and September	22	5.5
July, August and September	23	5.8
August, September, October	33	8.3
September, October, November and December	198	49.5
Non Response	79	19.8
Total	**400**	**100**

The farmers perception on food shortages were mainly ancored on climatic factors, as illustrated in figure 5.8 . A majority 95 % , stated drought as the main cause of food shortage.

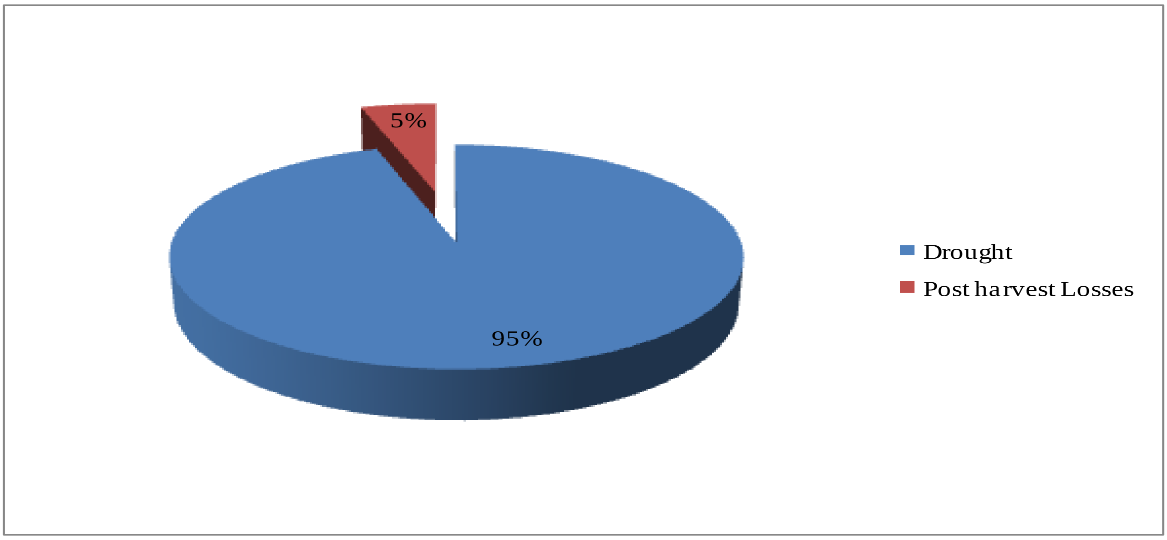


Figure 5.8: Causes of Food Shortage

Basing on the hazards experienced in the last ten years, a majority 82% were in affirmation. Table 5.6 shows the year and the type of hazard. From table 5.6, the majority of the respondents were affected by drought in the year 2015 at 23.7% and the year 2000 at 14.8%.

Table 5.6a: Farmers Perception on the Year of Drought Occurrence	
Year of Drought	**Proportion of the farmers perception on the recall of drought occurrences**
1972	3.6
1978	3.3
1982	3.0
1984	6.5
1992	5.9
1993	5.9
1996	6.5
1997	8.3
2000	14.8
2012	3.3
2014	9.5
2015	23.7
2016	5.9
N	**400**

The hazards that were experienced were drought (50.5%) followed by other drought related hazard such as livestock death (12%), emaciation of livestock (25.2%) and crop failure (30.6%).

Table 5.6b: Hazards Mentioned by Farmers	
Hazards mentioned by farmers	**Proportion of the farmers that mentioned the hazard**
Migration	6.6
Deforestation	7.2
Soil erosion	8.4
Death of livestock	12.0
Emaciation of Livestock	25.2
Crop Failure	30.6
Drought	50.5
N	**400**

5.5 Correlation Analysis

The summary of correlation analysis for adaptation to food security variables is shown in table 5.7. The first column has the independent variables while the second row shows the dependent variables. Each variable in the second row was correlated with the variables in the first column. The correlation is positive between the respondents' education level and the number of meals adults respondents regularly ate daily with a coefficient of 0.60.

Table 5.7: Correlations of Determinants of Food Security Status

Variables	**Food consumption which is not from own production**	**Food shortages**	**Average number of years food shortages was experienced**	**Average number of meals per day for adults**	**Average number of meals per day for children**
Level of Education	0.25	0.24	0.09	0.60	0.31
Land Size	0.66	0.17	-0.16	-0.11	-0.28
Gender/Sex	0.02	0.01	0.16	-0.11	-0.31
Children (Sons) Number	-0.03	-0.09	-0.33	-0.76	-0.32
Age/Year of Birth	-0.24	-0.34	-0.08	-0.11	0.08
Children (Daughters) Number	0.31	-0.49	-0.37	-0.35	-0.23
Income	0.16	-0.37	-0.73	-0.35	-0.30

One of the coping strategies to food security challenges is the number of daily meals uptake. The correlation between the adults' daily meals uptake by the respondents and their age/birth year were negative with a coefficient of -0.11. Also the relationship between numbers of children (sons) and average number of meals per day for adults was negative (-0.76). The number of children (daughters) and the number of meals adults ate on a regular day had negative correlation (-0.35). There was a negative correlation (-0.11) between number of meals eaten by adults on regular day and size of land held by the household. The total annual income for the household was negatively related to the number of years in the ten years that the household has experienced food shortage at coefficient level of -0.73.

5.6 Regression Analysis

The dependent variables for this study were the four pillars of food security. The net results of independent variables that are important in explaining the dependent variables are determined using multiple regressions as their estimates. Availability is defined in terms of food reserves, transportation and markets wild foods, production (number of kilograms per hectare as the proxy indicator). Access is defined by way of physical access, financial access and social access (purchasing power as the proxy indicator cost per kilogram). Utilization is defined in terms of food safety, storage, food preparation, food preferences, feeding practices and access to water (the proxy indicator is frequency of meals) whereas stability is well-defined with social, economic and political variables (Food availability in kilograms per household per year). To establish household food security status determinants, four models were run using the multivariate analysis.

Table 5.8 defines the dependent variable food availability which was run against the ten independent variables. Multiple regressions were calculated to estimate the net effect of the variables gender, number of children (sons and daughters) age, linkage to household head, household members, size of land and place of birth on the dependent variable, availability.

Table 5.8: Independent Variables		
S/no	**Independent variables**	**Definition of Independent variables**
1	Sex	2=Female 1= Male
2	Age	5=>65 4=56 to 65 3=46 to 55 2=36 to 45 1=<35
3	Marital status	6= Separated/Divorced 5= Widowed 4= Consensual union 3= Polygamous 2= Monogamous 1= Single
4	Relationship to the household head	4= Daughter 3= Son 2= Spouse 1= Household head
5	Number of children (Daughters)	3= 3 Daughters 2= 2 Daughters 1= 1 Daughter
6	Number of children (sons)	3= 3 Sons 2= 2 Sons 1= 1 Son
7	Education level	6= Vocational 5= Tertiary 4= Secondary 3= Primary 2= Literacy 1= None
8	Size of the land	5= >10acres 4= 7 to 10 acres 3= 4 to 6 acres 2= 1 to 3 acres 1= less than 1 acre
9	Place of birth	4= Abroad 3= Elsewhere in the County 2= Elsewhere in the region 1= This village

5.7 Multivariate Analysis

The net effect of the variables tested using multivariate analysis is introduced in this section. The basis of the analysis is the four pillars of food security (utilization, stability, availability and access); which comprise the explained variables.

5.7.1 Availability Pillar of Food Security

Availability of food was well-defined based on the idea of food stocks, domestic production, food aid and import capacity. Domestic production was the proxy indicator (Number of Kilogrammes per hectare). The overall multiple regression fit statistics and model summary are indicated in table 5.9. The adjusted R^2 of our models from table 5.9 for the significant variables are 0.10, 0.20 and 0.20 for the number of children (sons), the size of land cultivated and the marital status respectively. The R^2 for the significant variables are, 0.11, 0.20 and 0.21. The implication is that the important explanatory variables explain 20%, 11% and 21% of the change in the explained variable respectively. The Durbin-Watson is within the two limits ($1.5 < d < 2.5$) meaning that the assumption of absence of first order auto-correlation in the multiple regression data holds.

Table 5.9: Multiple Regression Model Summary

Model	Std. Error of the Estimate	R Square	R	Adjusted R Square	Durbin-Watson
3	.45	.21	.46[c]	.20	2.05
2	.45	.20	.44[b]	.19	
1	.48	.11	.33[a]	.10	

Table 5.10 show the results of F-test output. The null hypothesis for F-test multiple regression is that the model explains zero change in the dependent variable ($R^2 = 0$). It is observed that ($F(1,227) = 26.92$, $R^2 = 0.11$, $F(2, 226) = 27.49$, $R^2 = 0.20$ and $F(3, 225) = 20.10$, $R^2 = 0.21$).

Table 5.10: F Test Output (ANOVA) for Availability						
Model		Sig.	F	Mean Square	df	Sum of Squares
3	Residual			.20	225	45.15
	Regression	.00[d]	20.10	4.03	3	12.10
	Total				228	57.25
2	Residual			.20	226	46.05
	Regression	.00[c]	27.49	5.60	2	11.20
	Total				228	57.25
1	Residual			.23	227	51.18
	Regression	.00[b]	26.92	6.07	1	6.07
	Total				228	57.25

From table 5.11, the study predicted outcome of availability is equal to 1.94 - 0.18(land size cultivated). After introducing in the model the variable the number of children, the predicted outcome of availability is equal to 1.79 - 0.27(land size cultivated) + 0.13(number of children). When marital status is introduced in the model, the outcome of availability is equal to 1.63 – 0.29(land size cultivated) + 0.14(number of children) + 0.06(marital status). The Beta value in table 5.11 shows that the variable, 'number of children' had a bigger impact of 0.35 and 0.40 than the other two important variables. Table 5.11 additionally indicates the VIF values are all less than 10 meaning that there was no multicollinearity. The range of a VIF value should be $1<VIF<10$ to contravene multicollinearity.

Table 5.11: Model for Availability								
Model		Collinearity Statistics		Sig.	t	Standardized Coefficients	Unstandardized Coefficients	
		Tolerance	VIF			Beta	B	Std. Error
3	Constant			.00	13.48		1.63	.12
	Size of land cultivated this year	.71	1.41	.00	-7.59	.53	-.29	.04
	Children (Sons) Number	.66	1.51	.00	5.47	.40	.14	.03
	Marital Status	.88	1.13	.04	2.11	.13	.06	.03
2	Constant			.00	19.64		1.79	.09
	Size of land cultivated this year	.75	1.34	.00	-7.24	.50	-.27	.04
	Children (Sons) Number	.75	1.34	.00	5.02	.35	.13	.03
1	Constant			.00	21.32		1.94	.09
	Size of land cultivated this year	1.00	1.00	.00	-5.19	.33	-.18	.03

The multiple linear regression model overall fit statistics and summary is shown in table 5.12. The adjusted R^2 of the model are 0.32 and 0.34 for the size of land cultivated and the number of children (sons) respectively. The R^2 for the two significant variables are, 0.33 and 0.35. This means that the size of land cultivated and the number of children (sons) explain 33% and 35% of the change in the explained variable respectively. The Durbin-Watson is between the two limits of $1.5 < d < 2.5$. Thus, the assumption that there is no first order linear auto-correlation in the multiple linear regression data is ascertained.

Table 5.12: Multiple Linear Regression Model Summary - Alternative					
Model	Durbin-Watson	Std. Error of the Estimate	Adjusted R Square	R Square	R
2	1.81	.20	.34	.35	.59[b]
1		.20	.32	.33	.57[a]

F-test output is table 5.13. Multiple linear regression has the null hypothesis for F-test (R=0), that is no variance in the dependent variable is explained by the model. It can be seen that (F (1,171) = 82.68, R^2 = 0.33 and F(2, 170) = 45.40, R^2 = 0.35).

Table 5.13: F Test Output (ANOVA)-Alternative						
Model		Sig	F	Mean Square	Df	Sum of Squares
2	Residual			.04	170	6.71
	Regression	.00[c]	45.40	1.79	2	3.59
	Total				172	10.30
1	Residual			.04	171	6.94
	Regression	.00[b]	82.68	3.36	1	3.36
	Total				172	10.30

As indicated in table 5.14, respondents projected the outcome of availability to be equal to 0.72 + 0.13(land size cultivated). With the introduction of the number of children in the model, the projected outcome of availability is equal to 0.75 - 0.03(number of children) + 0.15(land size cultivated). Where land size cultivated was measured in acres and number of children was sons. The Beta values in table 5.14 are 0.18 and (0.57 and 0.66) for the variables, number of children (sons) and land size cultivated respectively. The implication is that land size cultivated variable had a bigger influence than the number of children (sons) variable. Since all values of VIF in table 5.14 are <10, it is indicative that there was no multicollinearity.

Table 5.14: Model Coefficients – Alternative								
Model		Sig.	t	Collinearity Statistics		Standardized Coefficients	Unstandardized Coefficients	
				Tolerance	VIF	Beta	B	Std. Error
2	Constant	17.42	.00				.75	.04
	Size of land cultivated this year?	9.11	.00	.73	1.38	.66	.15	.02
	Children (Sons) Number	-2.41	.02	.73	1.38	.18	-.03	.01
1	Constant	17.34	.00				.72	.04
	Size of land cultivated this year	9.09	.00	1.00	1.00	.57	.13	.01

5.7.2 Stability Pillar of Food Security

The proxy indicators that can be used to measure outcome of stability are price fluctuations, weather variability, economic and political. Numerous explanatory variables were regressed on the variables, ‘did you ask for money or food from other persons to deal with the hazard (drought) and weather variability. The multiple linear regression model overall fit statistic and model summary are shown in table 5.15. The adjusted R^2 of the models are 0.18, 0.10, , 0.29, 0.30 and 0.22 for relation to household head, land size, number of children (sons) respectively, number of children (daughters) and marital status. The R^2 for the variables are, 0.11, 0.18, 0.23, 0.30 and 0.32 for size of land, relation to household head, marital status, number of children (daughters) and number of children (sons) respectively. The implication of this is that the variables relation to household head, land size, marital status, number of children (sons) and number of children (daughters) explain 18%, 11%, 23% 32.1% and 30% of the variance in the explained variable respectively. The Durbin-Watson (d = 2.193) is between the applicable limits 2.5> d >1.5. Consequently, the assumption that there is no first order linear auto-correlation in our multiple regression data is confirmed.

Table 5.15: Multiple Linear Regression Model Summaries for Stability

Model	Durbin-Watson	Std. Error of the Estimate	Adjusted R Square	R Square	R
5	2.19	1.07	0.31	0.32	.57[e]
4		1.08	0.29	0.30	.55[d]
3		1.14	0.22	0.23	.48[c]
2		1.17	0.18	0.18	.43[b]
1		1.22	0.11	0.11	.33[a]

The F-test output or stability is table 5.16. The null hypothesis for multiple regression F-test is that the model explains zero change in the explained variable ($R^2 = 0$). Clearly table 5.16 indicates that ($F(1,251) = 31.02$, $R^2 = 0.11$, $F(2,250) = 28.11$, $R^2 = 0.18$, $F(3, 249) = 25.12$, $R^2 = 0.23$, $F(4,248) = 26.84$, $R^2 = 0.302$ and $F(5, 247) = 23.35$, $R^2 = 0.32$). This means that the F-tests are exceedingly important.

Table 5.16: F Test Output (ANOVA) for Stability						
Model		Sig.	F	Df	Sum of Squares	Mean Square
5	Residual			247	283.60	1.15
	Regression	.00[f]	23.35	5	134.07	26.82
	Total			252	417.68	
4	Residual			248	291.48	1.18
	Regression	.00[e]	26.84	4	126.20	31.55
	Total			252	417.68	
3	Residual			249	320.63	1.29
	Regression	.00[d]	25.12	3	97.04	32.35
	Total			252	417.68	
2	Residual			250	341	1.36
	Regression	.00[c]	28.11	2	76.68	38.34
	Total			252	417.68	
1	Residual			251	371.74	1.48
	Regression	.00[b]	31.02	1	45.94	45.94
	Total			252	417.68	

The predictions of outcome of stability are shown in table 5.17 in which the respondents projected outcome of stability is equal to 0.68 + 0.48(land size cultivated). On introduction to the model of the variable relation to household head, the projected outcome of stability is equal to 0.39 + 0.82(relation to household head) + 0.50(land size cultivated). The introduction of the third explanatory variable which is the marital status, the projected outcome of stability is equal to 0.37 - 0.28(marital status) + 0.74(relation to household head) + 0.52(land size). The introduction of the fourth independent variable, number of children-daughters, the projected outcome of stability is 1.11 - 0.36(marital status) – 0.24(number of children-daughter) + 0.66(relation to household head) + 0.6(size of land). The fifth independent variable introduction in the model gives a projected outcome of stability; 1.64 - 0.17(number of children (sons)) - 0.21(number of children-(daughter)) - 0.42(marital status) + 0.71(size of land) + 0.47(relation to household head).

Table 5.17: Model Coefficients for Stability								
Model		Sig.	t	Collinearity Statistics		Standardized Coefficients	Unstandardized Coefficients	
				Tolerance	VIF	Beta	B	Std. Error
5	Constant	0	3.88				1.64	0.42
	Land size	0	7.94	0.72	1.40	0.49	0.71	0.09
	Relationship to head of household	0.01	2.68	0.81	1.24	0.16	0.47	0.18
	Marital Status	0	-5.75	0.85	1.18	0.33	-0.41	0.07
	Children (Daughters) Number	0	-4.46	0.89	1.13	0.25	-0.21	0.05
	Children (Sons) Number	0.01	-2.62	0.57	1.77	0.18	-0.17	0.07
4	Constant	0	2.96				1.11	0.38
	Land size	0	7.6	0.96	1.05	0.41	0.60	0.08
	Relationship to head of household	0	4.06	0.97	1.03	0.22	0.66	0.16
	Marital Status	0	-5.13	0.94	1.07	0.28	-0.36	0.07
	Children (Daughters) Number	0	-4.98	0.92	1.09	0.28	-0.24	0.05
3	Constant	0.31	1.01				0.37	0.36
	Land size	0	6.43	0.99	1.01	0.36	0.52	0.08
	Relationship to head of household	0	4.36	0.98	1.02	0.24	0.74	0.17
	Marital Status	0	-3.98	0.98	1.02	0.22	-0.28	0.07
2	Constant	0.22	-1.23				-0.39	0.32
	Land size	0	6.06	1	1	0.35	0.50	0.08
	Relationship to head of household	0	4.75	1	1	0.27	0.82	0.17
1	Constant	0	2.98				0.68	0.23
	Land size	0	5.57	1	1	0.33	0.48	0.09

Clearly from table 5.17, the birth year/age, education level, marital status, place of birth, number of children (sons), number of children (daughters) were important independent variables in elucidating changes in the explained variable.

Table 5.18: Multiple Linear Regression Model Summaries for Stability-Alternative					
Model	Durbin-Watson	Std. Error of the Estimate	Adjusted R Square	R Square	R
6	1.650	1.02	.60	.60	.78[f]
5		1.03	.59	.59	.77[e]
4		1.06	.56	.56	.75[d]
3		1.10	.52	.53	.73[c]
2		1.19	.45	.45	.67[b]
1		1.27	.37	.37	.61[a]

The model overall fit statistics and summary for multiple linear regression is shown in table 5.18. The adjusted R^2 of the models are 0.60, 0.37, 0.56, 0.45, 0.59 and 0.52 for place of birth, number of children (sons), number of children (daughter), birth year/age, marital status and education level respectively. The R^2 for the variables are 0.45, 0.37, 0.56, 0.53, 0.60 and 0.59 for birth year/age, number of children (sons), number of children (daughter), education level, place of birth and marital status correspondingly. This means that the variables birth year/age, number of children (sons), number of children (daughter), education level, place of birth and marital status explain 45%, 37%, 56%, 53%, 60% and 59% of changes in the explained variable correspondingly. The Durbin-Watson ($d = 1.65$) is within the acceptable limits of $1.5 < d < 2.5$. Thus we the assumption that there is no first order linear auto-correlation in the regression data used.

Table 5.19: F Test Output for Stability, Alternative						
Model		Sig.	F	Mean Square	df	Sum of Square
6	Residual			1.03	242	249.99
	Regression	.00[g]	61.61	63.64	6	381.85
	Total				248	631.84
5	Residual			1.06	243	257.06
	Regression	.00[f]	70.86	74.96	5	374.78
	Total				248	631.84
4	Residual			1.131	244	276.04
	Regression	.00[e]	78.62	88.95	4	355.80
	Total				248	631.84
3	Residual			1.21	245	296.90
	Regression	.00[d]	92.13	111.65	3	334.94
	Total				248	631.84
2	Residual			1.40	246	345.46
	Regression	.00[c]	101.97	143.19	2	286.38
	Total				248	631.84
1	Residual			1.61	247	397.19
	Regression	.00[b]	145.92	234.65	1	234.65
	Total				248	631.84

Using the alternate explanatory variable, the F-test output table 5.19 is derived. The multiple linear regression F-test null hypothesis is; the model explains zero variance in the explained variable that is $R^2 = 0$. Therefore, ($F(1,247) = 145.92$, $R^2 = 0.37$, $F(2,246) = 101.97$, $R^2 = 0.45$, $F(3, 245) = 92.13$, $R^2 = 0.53$, $F(4,244) = 78.62$, $R^2 = 0.56$, $F(5, 243) = 70.86$, $R^2 = 0.59$) and $F(6, 242) = 61.61$, $R^2 = 0.60$).

Table 5.20: Model Coefficients for Stability, Alternative								
Model		Sig.	t	Collinearity Statistics		Standardized Coefficients	Unstandardized Coefficients	
				Tolerance	VIF	Beta	B	Std. Error
6	Constant	.00	-3.27				-1.64	.50
	Number of Children (sons)	.00	14.50	.81	1.24	.65	.61	.04
	Age/Year of Birth	.00	11.04	.62	1.60	.57	1.00	.09
	Level of Education	.00	7.21	.70	1.43	.35	.50	.07
	Children (Daughters) Number	.00	-5.56	.86	1.16	.24	-.27	.05
	Marital Status	.00	-4.19	.83	1.20	.19	-.29	.07
	Birth Place	.01	-2.62	.80	1.25	.12	-.32	.12
5	Constant	.00	-3.87				-1.92	.50
	Children (Sons) Number	.00	15.19	.85	1.18	.68	.63	.04
	Age/Year of Birth	.00	10.66	.70	1.43	.52	.92	.09
	Level of Education	.00	6.87	.71	1.42	.34	.48	.07
	Children (Daughters) Number	.00	-5.17	.88	1.14	.23	-.25	.05
	Marital Status	.00	-4.24	.83	1.20	.19	-.30	.07
4	Constant	.00	-6.09				-2.82	.46
	Children (Sons) Number	.00	16.23	.90	1.11	.72	.68	.04
	Age/Year of Birth	.00	9.79	.72	1.40	.49	.87	.09
	Level of Education	.00	7.14	.72	1.40	.36	.51	.07
	Children (Daughters) Number	.00	-4.29	.91	1.10	.19	-.21	.05
3	Constant	.00	-6.06				-2.90	.48
	Children (Sons) Number	.00	15.12	.97	1.04	.67	.63	.04
	Age/Year of Birth	.00	8.84	.74	1.35	.45	.79	.09
	Level of Education	.00	6.33	.73	1.36	.32	.46	.07
2	Constant	.10	-1.67				-.54	.32
	Children (Sons) Number	.00	13.21	1.0	1.00	.62	.58	.04
	Age/Year of Birth	.00	6.07	1.0	1.00	.29	.51	.08
1	Constant	.00	6.34				1.14	.18
	Children (Sons) Number	.00	12.08	1.00	1.00	.61	.57	.05

The projections of the outcome of stability from table 5.20 is; 1.14 + 0.57(number of children-sons). Introducing the birth year in the model, the projected outcome of stability is -0.54 + 0.51(year of birth) + 0.58(number of children (sons)). The introduction of the third explanatory variable gives the projected outcome of stability as -2.90 + 0.79(year of birth) + 0.63(number of children (sons)) + 0.46(level of education). The introduction of the fourth independent variable, number of children (daughters), the projected outcome of stability is -2.82 + 0.68(number of children (sons)) – 0.21(number of children (daughters)) + 0.51(education level) + 0.87(year of birth). Introducing the fifth important variable marital status, the projected outcome of stability is -1.92 – 0.25(number of children (daughters)) - 0.30(marital status) + 0.63(number of children (sons)) + 0.921(year of birth) + 0.48(education level). The sixth important variable introduction in the model gave the predicted outcome of stability as -1.64 - 0.29(marital status) + 0.61(number of children (sons)) – 0.27 (number of children (daughters)) + 1.00(year of birth) + 0.50(education level) – 0.32(place of birth).

In table 5.20, the Beta values are highest for independent variable age/year of birth and number of children (sons) implying that the explained variable was greatly impacted by the two more than the other explanatory variables. The VIF values in table 5.20 show non-existence of multicollinearity since they are <10.

5.7.3 Utilization Pillar of Food Security

The description of utilization might be by the usage of feeding and care practices, quality and safety of food, clean water, sanitation and health. In this study the frequency of eating meals was the proxy pointer. The significant variables under this section were, place of birth, land size cultivated, marital status, relation to household head and education level.

Table 5.21: Multiple Linear Regression Model Summaries for Utilization					
Model	Durbin-Watson	Std. Error of the Estimate	Adjusted R Square	R Square	R
5	1.88	.82	.16	.17	.41[e]
4		.81	.14	.15	.39[d]
3		.83	.12	.13	.36[c]
2		.84	.10	.11	.33[b]
1		.86	.06	.06	.25[a]

The linear regression model overall fit statistics and summary for utilization is indicated in table 5.21. The adjusted R^2 of the models are 0.10, 0.14, 0.06, 0.16 and 0.12, for place of birth, size of land cultivated, relation to household head, education level and marital status correspondingly. The R^2 for the variables are; 0.17, 0.06, 0.15, 0.11 and 0.13 for education level, relation to household head, size of land cultivated, place of birth and marital status correspondingly. The implication is that education level, relation to household head, size of land cultivated, place of birth and marital status explain 17%, 6%, 15%, 11% and 13% of change in the dependent variable correspondingly. The Durbin-Watson value d = 1.88 and being within the limits $1.5 < d < 2.5$, the assumption that there is no first order linear auto-correlation in the data is upheld.

Table 5.22: F Test Output for Utilization						
Model		Sig.	F	df	Sum of Squares	Mean Square
5	Residual			269	179.43	.67
	Regression	.00[f]	11.13	5	37.13	7.43
	Total			274	216.56	
4	Residual			270	183.71	.68
	Regression	.00[e]	12.07	4	32.85	8.21
	Total			274	216.56	
3	Residual			271	188.52	.70
	Regression	.00[d]	13.44	3	28.04	9.35
	Total			274	216.56	
2	Residual			272	193.31	.71
	Regression	.00[c]	16.36	2	23.25	11.63
	Total			274	216.56	
1	Residual			273	202.81	.74
	Regression	.00[b]	18.51	1	13.75	13.75
	Total			274	216.56	

The F-test output table for utilization is table 5.22. The null hypothesis for the multiple linear regression model is that the model does not explain any change in the explained variable meaning $R^2 = 0$. From table 5.22,($F(1,273) = 18.51$, $R^2 = 0.06$, $F(2,272) = 16.36$, $R^2 = 0.107$, $F(3, 271) = 13.44$, $R^2 = 0.13$, $F(4,270) = 12.07$, $R^2 = 0.15$ and $F(5, 269) = 11.13$, $R^2 = 0.17$).

Table 5.23: Model Coefficients for Utilization

Model		Sig.	T	Collinearity Statistics		Standardized Coefficients	Unstandardized Coefficients	
				Tolerance	VIF	Beta	B	Std. Error
5	Constant	.00	11.70	.96	1.05		3.93	.34
	Relationship to head of household	.00	-3.97	.88	1.14	.23	-.48	.12
	Birth Place	.00	-4.87	.90	1.11	.29	-.45	.09
	Marital Status	.00	3.36	.90	1.11	.20	.18	.05
	Size of land cultivated this year	.00	-2.96	.92	1.08	.17	-.17	.06
	Level of Education	.01	2.53			.15	.12	.05
4	Constant	.00	14.80	.98	1.02		4.35	.29
	Relationship to head of household	.00	-4.43	.88	1.14	.25	-.54	.12
	Birth Place	.00	-4.79	.94	1.07	.29	-.45	.09
	Marital Status	.00	2.88	.91	1.09	.17	.15	.05
	Size of land cultivated this year	.01	-2.66			.16	-.15	.06
3	Constant	.00	16.62	.99	1.01		3.87	.23
	Relationship to head of household	.00	-4.20	.96	1.05	.24	-.51	.12
	Birth Place	.00	-4.16	.95	1.06	.24	-.38	.09
	Marital Status	.01	2.62			.15	.14	.05
2	Constant	.00	20.44	1.00	1.00		4.17	.20
	Relationship to head of household	.00	-4.45	1.00	1.00	.26	-.55	.12
	Birth Place	.00	-3.66			.21	-.33	.09
1	Constant	.00	22.86	1.00	1.00		3.70	.16
	Relationship to head of household	.00	-4.30			.25	-.54	.13

The respondents as seen in table 5.23 projected that utilization outcome is 3.7 - 0.541(relation to household head). On introducing in the model the variable, place of birth, the projected utilization outcome is 4.17 - 0.33(place of birth) - 0.55(relation to household head). Introducing the variable marital status in the model, the projected utilization outcome is 3.87 + 0.14(marital status) - 0.38(place of birth) - 0.51(relation to household head). The predicted utilization outcome with the introduction of the variable size of land cultivated is 4.35 - 0.15(size of land cultivated) + 0.15(marital status) - 0.45(place of birth) - 0.54(relation to house hold head). Finally the predicted utilization outcome with the introduction of the variable education level is 3.93 + 0.12(education level) + 0.18(marital status) - 0.45(place of birth) - 0.48(relation to household head) - 0.17(size of land cultivated).

In table 5.23, all the Beta values are negative except the value for marital status. The implication is that marital status was the only independent variable that had a positive impact on the dependent variable. There was absence of multicollinearity since all values of VIF are <10.

5.7.4 Access Pillar of Food Security

The access outcome was elucidated using the level of household poverty, food distribution, purchasing power of the household and lastly infrastructure and transport. The variables that were significant in elucidating the change in the explained variable include marital status, education level, number of children (sons) and number of children (daughters). The multiple regression model overall fit statics and summary for access is shown in table 5.24. The adjusted R^2 of the models are 1.00, 0.79, 1.0 and 0.88 for marital status, education level, number of children (sons) and number of children (daughters) correspondingly. The R^2 for the variables are, 1.00, 0.79, 1.0 and 0.88 for marital status, education level, number of children (sons) and number of children (daughters) correspondingly. The implication is that marital status, education level, number of children (sons) and number of children (daughters) explain 100%, 79%, 100% and 88% correspondingly the change in the explained variable. The Durbin-Watson d = 2.00 and is within the limits values of $1.5 < d < 2.5$; allowing acceptance of the assumption that there is non-existence first order linear auto-correlation in the regression data.

Table 5.24: Multiple Linear Regression Model Summaries for Access					
Model	Durbin-Watson	Std. Error of the Estimate	Adjusted R Square	R Square	R
4	2.00	.00	1.00	1.00	1.00[d]
3		.10	1.00	1.00	1.00[c]
2		.57	.88	.88	.934[b]
1		.74	.79	.79	.89[a]

The F-test output for access is indicated in table 5.25. The null hypothesis for F-test in multiple linear regression is that the model does not explain variance in the dependent variable that is $R^2 = 0$. From table 5.25; ($F(1,64)=245.33$, $R^2 = 0.79$, $F(2,63) = 229.07$, $R^2 = 0.88$, $F(3, 62) = 6226.57$, $R^2 = 1.00$, $F(4,61) = 0$, $R^2 = 1.00$).

Table 5.25: F Test Output (ANOVA) for Access						
Model		Sig.	F	df	Sum of Squares	Mean Square
4	Residual			61	.00	.00
	Regression	.00[e]	0.00	4	168.67	42.17
	Total			65	168.67	
3	Residual			62	.56	.01
	Regression	.00[d]	6226.57	3	168.11	56.04
	Total			65	168.67	
2	Residual			63	20.39	.32
	Regression	.00[c]	229.07	2	148.28	74.14
	Total			65	168.67	
1	Residual			64	34.90	.55
	Regression	.00[b]	245.33	1	133.77	133.77
	Total			65	168.67	

The projected access outcome as shown in table 5.26 is 7.83 - 1.59 (education level). With the introduction in the model variable, number of children (daughters), the projected access outcome is 11.20 - 0.68 (number of children-daughters) - 2.29 (education level). The introduction of the third explanatory variable, number of children (sons), the projected access outcome is 9.70 + 0.73 (number of children (sons)) - 1.29 (number of children (daughters)) - 2.239 (education level). Introducing the last and fourth variable, marital status, the projected access outcome is 11.00 + 0.67 (number of children (sons)) - 1.33 (number of children (daughters)) - 2.33 (education level) - 0.33(marital status).

In table 5.26 all the Beta values are negative except Beta value for the variable number of children (sons). The implication is that this was the only variable that had a positive impact on the explained variable. Since all the VIF values in table 5.26 are less than ten, then there was no multicollinearity in the data used.

Table 5.26: Model Coefficients for Access

Model		Sig.	T	Collinearity Statistics		Standardized Coefficients	Unstandardized Coefficients	
				Tolerance	VIF	Beta	B	Std. Error
4	Constant	.00	56133104.52				11.00	.00
	Level of Education	.00	-91725619.90	.27	3.68	1.31	-2.33	.00
	Children (Daughters) Number	.00	-59300395.74	.21	4.76	.96	-1.33	.00
	Children (Sons) Number	.00	37062747.34	.28	3.62	.53	.67	.00
	Marital Status	.00	-7728117.04	.55	1.83	.08	-.33	.00
3	Constant	.00	99.21				9.70	.10
	Level of Education	.00	-102.18	.35	2.84	1.26	-2.24	.02
	Children (Daughters) Number	.00	-60.37	.22	4.46	.93	-1.29	.02
	Children (Sons) Number	.00	46.94	.35	2.82	.58	.73	.02
2	Constant	.00	20.21				11.20	.55
	Level of Education	.00	-17.47	.35	2.83	1.29	-2.29	.13
	Children (daughters) Number	.00	-6.70	.35	2.83	.49	-.68	.10
1	Constant	.00	26.01				7.83	.30
	Level of Education	.00	-15.66	1.00	1.00	.89	-1.59	.10

5.8 Summary of Regression Analysis

Food availability pillar demonstrated the significant independent variables were; the number of children (sons), the size of land cultivated and the marital status respectively at 19.6%, 10.6% and 21.1%. The pillar of food stability data showed that relation to household head, land size, marital status, number of children (sons) and number of children (daughters) explain 18.4%, 11.0%, 23.2%, 32.1% and 30.2% respectively. The utilization pillar illustrated education level, relation to household head, size of land cultivated, place of birth and marital status explained 17.1%, 6.4%, 15.2%, 10.7% and 12.9% of change in the dependent variable correspondingly while the access pillar marital status, education level, number of children (sons) and number of children (daughters) explained 100%, 79.3%, 99.7% and 87.9% correspondingly the change in the explained variable.

CHAPTER SIX: RESULTS AND DISCUSSION FOR ADAPTATION THROUGH CONSERVATIONAL AGRICULTURE

6.0 Introduction

The third objective of the study was to incorporate conservation agriculture practices to build resilience and lessen the impact of change to climate. The question the study sought to answer was; what ways can be used for adaptation to be promoted and be made more resilient at policy and community level with preference on conservational agriculture?

6.1 Results and Discussions

6.1.1 Rainfall Distribution in the Study Area

Rainfall distribution in the course of the study varied. The data showed that the highest rainfall was recorded during short rain season 2015 (457 mm) and the lowest was recorded during the long rains season of 2016 (336 mm). Total rainfall during the long rains was 376 mm in 2015. It was also established that the distribution of rainfall improved in 2015 than 2016 as demonstrated in figure 6.1 and figure 6.2.

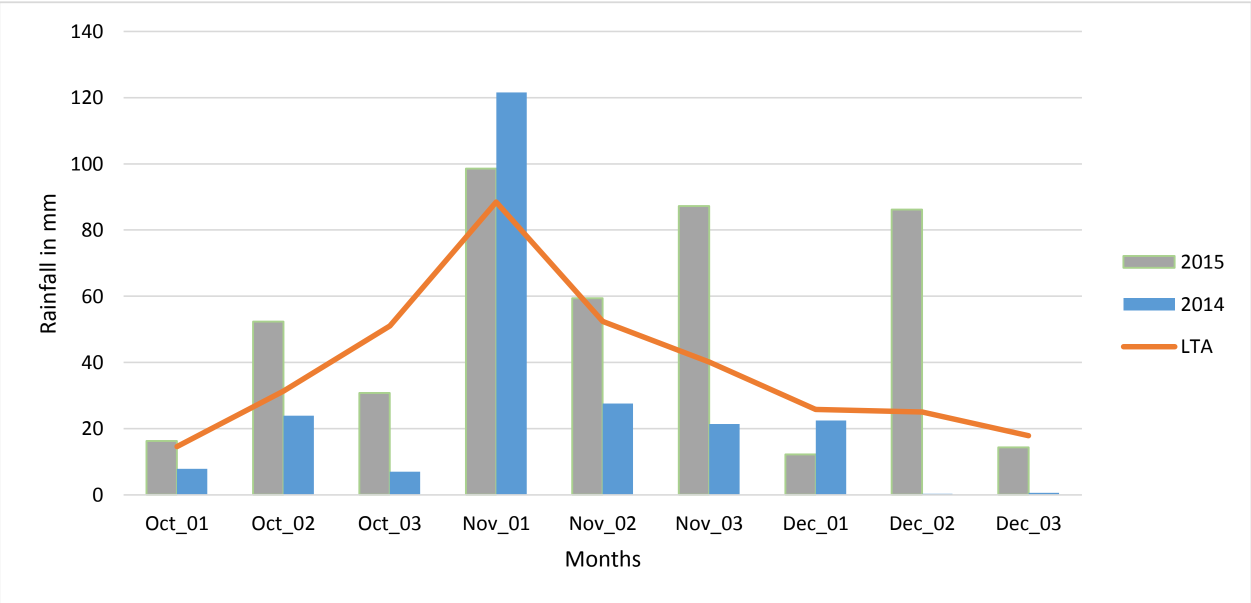


Figure 6.1: Short Rains Performance

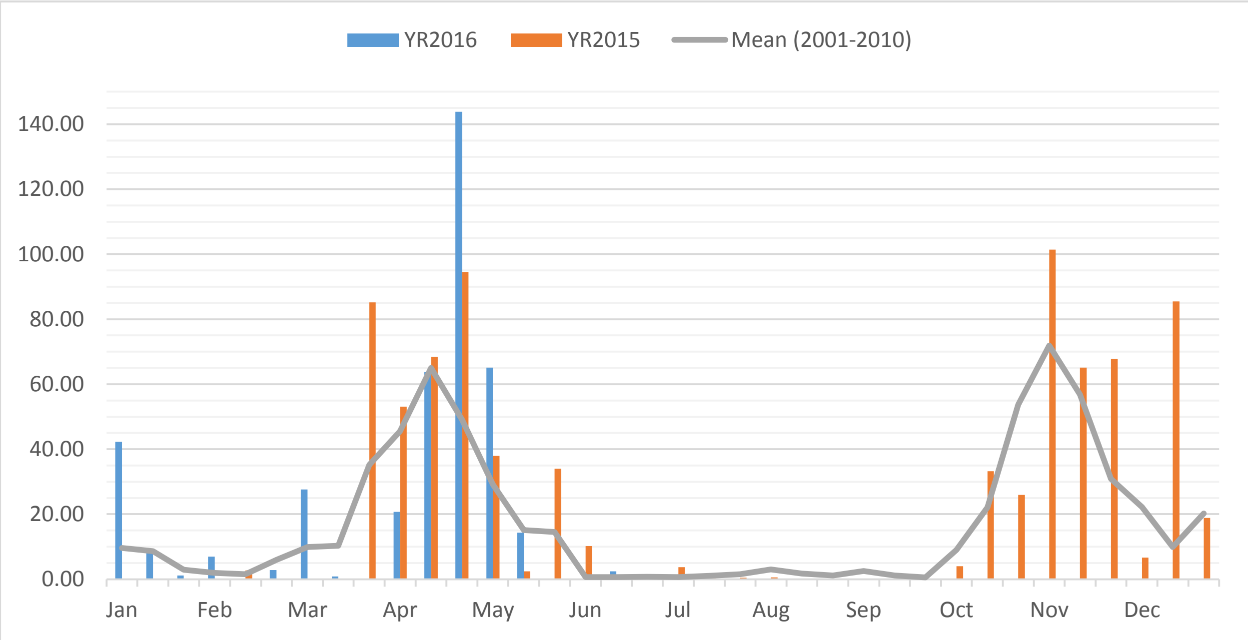


Figure 6.2: Long Rains Performance

The distinction between treatment values and conventional control (sorghum) was affirmed significant using the one sample test. The biophysical variables on crop yield were analysed by descriptive analysis. The demo plots indicated significance level of $p<0.05$ for one sample test as shown in table 6.1.

Table 6.1: One Sample Test on Trials

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Sorghum Under Conservation Agriculture	21.72879	4	2.65E-05	2320	2023.557	2616.443
Sorghum/ Cowpeas	25.0998	4	3.15E-05	2100	1867.706	2332.294
Sorghum/green grams	19.4155	4	4.15E-05	1980	1696.857	2263.143
Green grams	11.39227	4	0.000339	980	741.1612	1218.839
Cowpeas	11.49223	4	0.000327	860	652.2299	1067.77
Cowpeas Under Conservation Agriculture	14.16485	4	0.000144	1060	852.2299	1267.77

6.2 Duncan’s Multiple Range Test (DMRT)

Duncan’s Multiple Range Test (DMRT) is suitable for experiments requiring the comparison of all possible pairs of treatment means. All the treatment means were ranked in decreasing order thus it compares difference between means (see Table 6.2).

Table 6.2: Yield Ranked in Decreasing Order

Treatment		Long rains, 2015 Production (Kg/Hec)	Short rains, 2015 Production (Kg/Hec)	Long rains, 2016 Production (Kg/Hec)	Short rains, 2016 Production (Kg/Hec)	Average Production (Kg/Hec)	Rank	SD	Variance
T^1	Sorghum CA	2600	2500	2000	2200	2300	a	3	8
T^2	Sorghum/ Cowpeas	2300	2200	1800	2100	2100	b	2	5
T^3	Sorghum/green grams	2200	2100	1600	2000	2000	c	3	7
T^6	Conventional Control (Sorghum)	1000	1200	800	1200	1100	d	2	4
T^4	Green grams	900	1200	700	1100	1000	e	2	5
T^5	Cowpeas	800	1000	600	1000	900	f	2	4

In comparison with the conventional control, the summary in figure 6.3 shows the treatments subjected to conservational agriculture had a higher yield in comparison to the conventional method (sorghum crop).

Figure 6.3: Summary of Sorghum Grain Yield

Findings in Table 6.1 highlight the experiential crop (Sorghum) evaluation from the field experiment noted. The results also illustrate two cropping system of which conservation agriculture method demo plots illustrated a higher yield than the conventional method demo plot. There was higher yield in terms of harvested grain in the five trials under conservation agriculture among themselves with external nutrient replenishment of 60 Kilogrammes of CAN in addition to 60 Kilogrammes NPK. The results illustrate the aspects of cover crop and minimum soil tillage. Table 6.3 illustrates the analysis of variance findings, in terms of grain yield among the six conservational agriculture treatments ($p<0.05$).

Table 6.3: ANOVA Results

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Sorghum Under Conservation Agriculture	Between Groups	183000	3	61000	1.355556	0.546451
	Within Groups	45000	1	45000		
	Total	228000	4			
Sorghum and cowpeas Under Conservation Agriculture	Between Groups	135000	3	45000	9	0.23918
	Within Groups	5000	1	5000		
	Total	140000	4			
Sorghum and green grams Under Conservation Agriculture	Between Groups	203000	3	67666.67	13.53333	0.196614
	Within Groups	5000	1	5000		
	Total	208000	4			
Green grams Under Conservation Agriculture	Between Groups	143000	3	47666.67	9.533333	0.232702
	Within Groups	5000	1	5000		
	Total	148000	4			
Cowpeas Under Conservation Agriculture	Between Groups	112000	3	37333.33	.	.
	Within Groups	0	1	0		
	Total	112000	4			

Climate change observations were evident from meetings with groups of farmers and during discussions with the agricultural extension officers. Most community members participating in the field meetings reported that weather pattern had, over the last decade, become more erratic exemplified with irregular rainfall, late rains, erratic rains and prolonged periods of drought with variable temperatures and more incidences of crops diseases. Highest grain yield was in the range of 1.6 tonnes per hectare for the intercropped (sorghum) to 2.6 tonnes per hectare for the mono cropped for conservation agriculture trials (figure 6.3).

Generally, trials under conventional controls (Sorghum) had the lower yield at as 0.8 to 1.2 tonnes per hectare for the mono cropped. This was evident that conservation agriculture could contribute positively to increased crop yield hence ensuring food security among households in Tharaka community. This confirms the assertion that conservation agriculture aims to sustain and improve productivity, stimulate soil biological performance and decrease droughts impact (Famba *et al.,* 2011). Additional guidance was done to farmers on Land preparation, Farmyard manure utilization, Fertilizers use, Pests and disease control, weeding and crop rotation and on post-harvest technologies; Shelling, Grading, Packaging, Best storage practices and Best transport practices.

6.3 Retention Tillage and Cropping System Effects on Crop Residue Production

According to Palm, Blanco-Canqui *et al.,* (2014) crop residue on surface is a crucial element of CA and it is envisioned to escalate input of carbon and improve bionetworks benefits like improved relation of soil water and biological characteristics and soil fertility. However, the degree derived benefits is contingent on the volume of retained residue on the field alongside other ecological settings. The reported retained crop residue as surface mulch ranged between 2–6 Mg ha-1 to raise soil moisture, infiltration and eventually increase crop yields (Mupangwa *et al.,* 2007 and Mupangwa *et al.,* 2012). In this study residue production was extremely small applied at 0.2 - 0.5 tons per acre. It was also evident that greatest number of farmers did not utilize fertilizers when planting besides not controlling diseases and pests as evidenced in the conventional trial of sorghum. This was in agreement with other research findings which agree that in Sub-Saharan Africa, many small scale farmers do not use fertilizers in farming (Jama *et al.,* 1998).

The study established that low fertility status of the soils coupled with insufficient application of fertilizer resulted in production of low crop residue. Further, soils in Africa are severely poor in phosphorus and nitrogen. This results in little crop residues that are available for mulching occasioned by low production levels of biomass and massive removal of residue by livestock especially in the dry season which see increase in communal grazing. In CA, achieving enough soil cover might be tough for small scale farmers in Tharaka applying only in situ biomass production.

The use of enough mineral fertilizer is important in order to achieve the production of crop residue which permits appropriate residues to be regenerated in the fields and some to be removed for extra uses devoid of harmful impacts to the soil and consequent crop yields. Intercropping of agro forestry trees and planting of grain legumes like pigeon peas help farmers may also be able to compensate for low production biomass.

6.4 Tillage and Cropping Systems Effects on Crop Yields

The study recognized that there was an important variance between the Conservation practices and conventional practice with trial of conservation practice having higher absolute values. Where cross cropping was used, highest grain yield ranged from 1.6 tonnes per hectare for the intercropped (sorghum) while 2.6 tonnes per hectare for the mono cropped (sorghum) for conservation agriculture trials (figure 6.3). Trials under conventional controls (Sorghum) had the lower yield at as 0.8 tonnes while 1.2 tonnes per hectare for the mono cropped. This study agreed with previous studies where sorghum grain yields attained by farmers using their local conventional practices are quite low compared to conservational yield (Ogecha, 1995).Minimal tillage in the study implied instead of ploughing the farm before planting, the seed to be planted is deposited directly in the ground by a narrow opening.

6.5 Trans Disciplinary and Conservation Agriculture

With rise in population more suitable agricultural methods need to be adopted, initially land clearing in preparation for cultivation was used however that was suitable in low population density. The study established that most farmers are smallholders who practice different production systems. These smallholders are interested in adopting systems that cater for their interests and hence evading risk but ensuring food and money for the household. In this study therefore conservation agriculture called for a pool of 25 to 30 members per gathering who were trained by academicians and practitioners. Suitability concept was adopted for the teams, in turn it brought new knowledge in that many meeting of community participation are usually not followed and are taken as a formality but in this case the whole system was present and hence the trans-disciplinary in conservation agriculture was evident.

CHAPTER SEVEN: SYNTHESIS AND DISCUSSION OF RESULTS

7.0 Introduction

This chapter brings together all the key findings in the preceding chapters (those that relate to the specific objectives), makes connections across and between the specific objectives and derives a higher order discussion that leads the author to a clear demonstration of achievement of the overall objective.

7.1 Synthesis and Discussion on Climate Change Analysis

The first specific objective was to examine historical climate data and its implication on household food security in Tharaka Nithi County. This was to find out if climate change has really taken place and the implication on food productivity. The findings are key in explaining the current experienced food shortages and the increasing number of persons in need of food aid. According to the data on maximum temperature, there was an increasing trend for New DJF, JJA, MAM and SON as per the Mann-Kendall test. Except for JJA, the MK test for SON, DJF and MAM was statistically significant for temperature maximum, while for temperature minimum is statistically significant for SON, DJF and MAM except for JJA. In the period 1981-1990, the increase in annual average temperature in was about 0.4°C per decade.

The increase was 0.3°C and 0.25°C per decade in the period 1991-2000 and 2001-2010 respectively. This data was obtained from the Kenya meteorology data set. The observed temporal patterns and trends are comparable to the general global trends; which since 1850, it involved a raise in average temperature of about 0.8°C (IPCC, 2007). There was no similarity among seasons in the recorded statistic for temperature. The linear trend line indicates there was an increasing trend in temperature for all seasons, even though slopes were small in terms of magnitude. The general noted increase in temperature trend for all the seasons in 39 years period indicated indeed climate change has occurred.

Agriculture in Kenya is largely rain-fed and predominantly rainfall dependent. From the rainfall data. The MK test Statistic (S) test results were weak for DJF, MAM, JJA and SON hence we can accept the null hypothesis H_0. The implication is that for rainfall, no trend was seen. When the S statistic for the four seasons was further analysed, it was evident that conformity was observed in size of the statistic when a consideration of latitudinal factor is taken. For instance, for MAM the S statistic is -51, JJA -66 and SON -8 while the statistics were small in size, but to some extent they were similar. Further, when the linear trend line was fitted, the observation was that the trend was declining for all. The gradient of the trend line was not very big in size. Considering latitudinal factors, seasonal fall is similar in slope magnitude and it ranged between -66 and 98 (Table 4.1). It was of significant to discuss the economic, social and ecological impacts that could result if in future continued precipitation trends were decreasing in these seasons. The vulnerability to drought might further be increased owing to decrease in rainfall in the future. Thus, the two variables temperature and rainfall clearly illustrated climate change. Challinor *et al.*, (2010) stated that temperature and water were of relative importance and can be assessed using models.

The direction of change in some cases is determined by the direction of correlation. Thornton *et al.*, (2009b) found that the response of crop yield in dry lands of East Africa due to climate change does not respond to rainfall increases. This is because climates that are wetter are related to warmer temperatures, thus decrease yields. Rainfall shows more longitudinal variations than temperature. Temporal variance in the spatial mean of rainfall appears to reduce as the longitudinal domain broadens. This leads to the conclusion that rainfall is less important in broadly predicting crop yields (Lobell & Field, 2007). Predictable changes in rainfall from models in climate appear to be longitudinally variable than temperature. Thus, leads to enhanced importance of predicted temperatures as the longitudinal scale of analysis broadens (Lobell & Burke, 2008). The development of crop is affected by changes in climate and consequently yields a non-linear and linear reaction to weather variations; surpassing well-defined crop thresholds, predominantly, temperature (Porter & Semenov, 2005). The plant growth processes involve the falling of leaves under diverse temperature circumstance, several developments mechanisms outside as well as inside the soil surface. Many reactions and procedures affected directly by increasing temperature, weathering and decomposition may speed up in the soil provided there is an optimum soil moisture condition.

The fourth assessment report of IPCC, (2007) opines that the at the plot level, the overall impacts of greater temperatures on the response of crop, with changes in the frequency of extreme events not considered such as modest warming (i.e. as observed in the first half of 21^{st} century), may profit pasture and crop productivity in temperate regions. Conversely, it may decrease productivity in semi-arid and tropical zones. It has been modelled in studies to show an inconsequential valuable impact in temperature matches local average temperature raises of 1-3^{o}C with link to rainfall changes and an increase in CO_2. This has been contrasted with models in the topical zones that indicate there are negative impacts on the yield for major crops with modest increase in temperature (1-2^{o}C); however, a further warming is projected in all zones by the end of twenty-first century ensuing increased negative consequences (Tubiello *et al.,* 2008). Agricultural productivity according to Alexandrov and Hoogenboom, (2000) is directly affected by changes in climate in developing and developed world. Climatic changes highly influence yield levels through reducing or increasing global perspective from temperate to tropics.

7.2 Synthesis and Discussion on Determinants of Food Security at Household Level

On assessing and analysing household food security status and its determinants the findings indicated that households with household heads having secondary school and above education level are more expected to be food secure (Table 5.26). It was clearly depicted those household head had a pool of information on alternative livelihood sources, environmental management, ecosystems balance and protection of livelihood. This exposed the individual to the advantage of timely planting as per the metrological forecast, timely harvesting, minimal post-harvest management loses, value addition and hence a greater purchasing power for food or direct availability of food at household level. The study found that the association amongst household education level and food security was positive (Table 5.27).

According to the regression analysis food availability pillar demonstrated the important explanatory variables were; land size cultivated, the number of children (sons) and the marital status at 10.6%, 19.6% and 21.1% respectively explaining the change in the explained variable. The pillar of food stability data showed number of children (daughters), number of children (sons), size of land, marital status and relation to household head explained 30.2%, 32.1%, 11.0%, 23.2% and 18.4% of the change in the explained variable correspondingly. The utilization pillar illustrated that education level, relation to household head, size of land cultivated, place of birth and marital status explained 17.1%, 6.4%, 15.2%, 10.7% and 12.9% of change in the dependent variable correspondingly while the variables relation to household head, size of land, marital status, number of children (sons) and number of children (daughters) explained 18.4%, 11.0%, 23.2% 32.1% and 30.2% of the variance in the explained variable respectively. According to Norris (1987) advanced education was associated with a larger access to information and hence increase on productivity. Other studies have also established that the relationship between education level of the head of the household and food security was positive (Igoden *et al.,* 1990) and also are able to adapt faster to climatic changes (Madison, 2006). Farmers with higher education were predisposed to climate change adaptation.

Smaller household were more probable to be food secure (Table 5.26). The study found that the relationships between the size of the household and food security variables were negative. This implied that food insecurity is promoted by an increase in the number of household members (Table 5.26). The finding were contrary to a study by Croppernsted *et al*., (2003) where they argued that large family households had a better pool of casual labour hence had a higher probability of adapting to changes in climate and increases the frequency of on-farm activities attributed to plenty of labour opportunities at most needed seasons. From the regression analysis that was undertaken, the study found that there was a negative linear relationship between the income derived from farm, non-farm and food security (Table 5.27). This implied that an increase in income per se does not guarantee food security. Literature from (CIMMYT, 1993) indicates households with ability of high wage labour income have greater access on information for climate change in addition could simply afford a variety of climate change plans and activities.

Researchers have established that farmers sold their products at lower prices during the harvesting period driven by need for money. The same farmers then rely on buying food after a few months when the prices are high. It has also been established that there is a significant negative influence of food aid on food security. In times of economic-wide extreme crisis the international community response is mainly in food aid this is because most of this crisis pose an instant danger to livelihoods and lives both long run and in short term stability and development.

According to (Barrett & Maxwell, 2005) foodstuff relief protects basic human rights and contributes to economic development through filling severe food gap. Vulnerability is reduced by food aid since it plays a safety net role and hence guarding productive assets. However, foodstuff relief is also responsible for diminished government subsidy to agriculture in the long term thus triggering prices distortions in the local foodstuffs (Barrett *et al.,* 2005).

In this study, food security challenges facing households has been caused by adverse weather conditions and weakness of institutions in their effectiveness to sufficiently facilitate adaptation and mitigation. The availability of food is also inadequate due to insufficient production resources while access is destabilized by inadequate employment in non-farm activities (Nyariki *et al.*, 2002 and Muyanga, 2004). Interventions should incorporate plans that augment no-farm income and farm productivity. The focus of the intervention process should be on building capacity of households in the rural areas to diminish bureaucratic barriers and establish linkages with communal involvement, private market formation and public service to permit sustainability (Transdisciplinary research linkages). This study calls for more active participation of the different state actors at all levels which include all professionals, the community and the academicians. The documented requirements are better road network that enables urban-rural linkages, formal education, international trade and economic growth (Nzomoi *et al.,* 2007 and GoK, 2008).

7.3 Synthesis and Discussion on Conservation Agriculture

On the identification of ways in which adaptation can be promoted and made more resilient at policy and community level using conservational agriculture the study found that treatments of conservation agriculture in addition to soil amendment of 60 Kilogrammes of CAN (Calcium Ammonium Nitrate) in addition to 60 Kilogrammes NPK (Nitrogen, Phosphorus Potasssium) had the highest grain yield ranging from 2.0 tonnes per hectare for the intercropped to 2.3 tonnes per hectare for the mono cropped for the conservation agriculture demo plots (Table 6.2). Trials under conventional controls had the lower yield at as 1.0 tonnes per hectare for the mono cropped.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) compared yields from farmers practicing conservation agriculture and those farmers practising conventional farming. It was established that averagely CA harvests were 80% more than the yield from conventional techniques of farming. Introducing manure with micro-dosed nitrogen in CA farming, harvests improved by 340% as compared to the conventional farming yields. Compared to CA, conventional practices underperformed yearly excluding a year in the 30 years under consideration. In developing countries, smallholder farmers are exposed thus predisposed to the brunt of climate change effects. Therefore it is vital that any discussion concerning food security should identify the potential impact of climate change.

According to Thomas *et al.*, (2007), there has been a significant impact on food production by fluctuation in intensity and frequency of drought and in air temperature. In Africa, smallholder farmers are least prepared to handle the adverse effect of climate (FAO, 2007). Originally, CA was established to avert soil erosion because it has ecological benefits that cushion farmers from climatic change effects. Mulching with residues of crops; associated with better soil structure and increase in soil organic matter, lessen evaporation of water from the soil and thus improving infiltration of rainwater.

Soils with a higher ability to hold water enhances crop maturity by utilizing residual soil moisture even when rains stop before the physiological maturity of crops. To understand the sequestration value of CA, further research is required (Govaerts *et al.*, 2009). Soil disturbances during conventional agriculture lead to release of global warming gases. Reduction in tillage increases organic matter in the soil therefore rising the capability of the soil to get and store atmospheric carbon for conservation (Hobbs, 2007). Studies on minimal tillage systems indicate that under given circumstances, rates of denitrification may increase leading to emissions of powerful greenhouse gases such as CH4 and N2O (Govaerts *et al.*, 2009). Residue burning is discouraged by CA principles and through land management that is sustainable, new field from forest and bush clearing is discouraged because such activities releases CO2 to the atmosphere. According to Hobbs (2007) minimal tilling of soils reduce the carbon footprint of farming that require high farm input because of lower requirements for artificial fertilizer and fuel.

On the right the researcher takes a closer look at the progress of the trees in a nursery to supplement the protection of soil and increase livelihood sources for the community.

Plate 7: Diversification of Livelihood and Promoting Tree Planting in the Community

CHAPTER EIGHT: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.0 Introduction

This chapter summarizes the findings in the whole thesis. Generalizations inform of conclusions and recommendations for the solution of problem analysed by the study are addressed.

8.1 Summary

Four pillars have been used to define food security; food access, food utilization, Stability and food availability. The research findings of the first objective showed a general decrease in average rainfall and an increase in temperature. An upsurge in temperature has direct impact on food production at all levels which include, farm crop production, Livestock productivity is affected due to reduction in browse and pasture together with increase to distance covered to sources of water and also the low water levels which results to low livestock productivity.

Results for the second objective on food security indicates that there are various food security determinants among them are; size of land, size of family and level of education. In this study, by understanding the key food security determinants, direction is given on the variables directly linked to food production. Thus increase in education level has a positive direct significant relationship with food production. Since the climate is constantly changing, the community needs to build resilience. From the regression perspective, food availability pillar demonstrated the important explanatory variables were; marital status, size of land and the number of children (sons) the marital status at 21.1%, 10.6% and 19.6%, respectively explained the change in the dependent variable.

The pillar of food stability data showed that relation to household head, land size, marital status, number of children (sons) and number of children (daughters) explain 18.4%, 11.0%, 23.2%, 32.1% and 30.2% respectively. The utilization pillar illustrated education level, relation to household head, size of land cultivated, place of birth and marital status explained 17.1%, 6.4%, 15.2%, 10.7% and 12.9% of change in the dependent variable correspondingly while the access pillar marital status, education level, number of children (sons) and number of children (daughters) explained 100%, 79.3%, 99.7% and 87.9% correspondingly the change in the explained variable.

On the third objective conservation agriculture works on three principles that enhance moisture retention in the soil, reduce the cycle of diseases, enrich the soils and reduced runoff; crop rotation, minimum soil disturbance and use of cover crops, the three principles enhance moisture retention. Hence it benefits the community by increased on farm crop production. The community also benefited on the crop diversification and hence improved nutrition levels at households. The study was able to affirm the positive perception of conservation agriculture by the community due to increase in crop yield and livelihood diversification. The community can now manage to have food at all times and therefore these were lessons learnt and worth adapting.

8.2 Conclusion

Farming in Tharaka is characterized by low levels of technology use in agricultural, poor soil fertility and poor rainfall distribution. The study sought to investigate historical climate data and its implication to household food security in Tharaka community, examine household food security status and their determinants, evaluate conservation agriculture practices that build resilience and mitigate climate change effects. The study findings are of interest to development stakeholders, primarily government agencies (planning, policy, research and extension) and Non-Governmental Organizations (NGOs).

From the first objective, the analysis of statistical tests and graphs showed prolonged inconsistency in mean annual rainfall received in each climatic zone when they are partitioned into three (3). Variability was established in zonal rainfall received in Tharaka and also jumps in average zonal rainfall distribution. Global warming has caused changes in zonal rainfall received and also redistribution. Besides the socioeconomic importance of the prolonged inconsistency of mean annual rainfall, the impact on groundwater resources and hydrological sector is appreciated.

The study also concluded from the second objective that; creation of awareness of the determinants of household food security status influence adoption will allow development of strategies, policies and plans that take advantage of the main influences of adoption and sustainable use of conservation Agriculture. Sustainable farming together with adoption of conservation agriculture is critical towards adapting and making communities more resilient to climatic change impacts. They also suggest that a household head with some form of education with a higher number of people contributing to labour increased the chances of household food security.

It was established in the third objective that farmers with small farms could use CA techniques to produce significant surplus food. This was building on the truth of the assumptions made by agronomists on the influence of Conservational Agriculture on food security and livelihood in semi-arid areas. Conservation agriculture study area was not targeted for food aid according to the data from Kenya food security steering group 2015 due to the success of the study. It has also been established that farmers who in 2013/2014 were getting food aid are currently able to provide food aid instead. It is known that principles of Conservation agriculture are effortlessly learned and CA techniques can therefore be easily spread minus the necessity for costs of start-up to farmers in the neighbourhood due to imitation effort leading to increased food security, community-wide reduction in poverty and higher resilience to shocks. This enables an enhanced process of protecting natural resource base. When properly used, conservation agriculture can further perform a key role in permitting the elderly and weak members of the community to productively participate in farming activities.

8.3 Recommendations

From the conclusions of the study the researcher recommends that it is significant that small scale farmers be aided in the discovery of relevant and suitable agricultural solutions that meet their requirements in the midst of increased demand for land for production of food climate change and increased prices of farm input. Although there has been no one speedy solution in ending poverty and boosting food security, this study shows conservation agriculture promotion in Tharaka Nithi county is a way of improving agricultural productivity for farmers by stabilizing yields in marginal lands in poor climatic conditions thus alleviating the poverty and effects of drought especially in regions where labour is limited because of poor health, migration or old age. Enhanced pressure on the available land is due to population upsurge and as such CA also provides a means of intensifying production of crops without having issues on the environment frequently related with intensification. Consequently, investment in conservation agriculture is encouraged. In agro-ecological zones, this promotes food security.

The study established that crop yield from conservation agriculture farming exceeded yield from conventional farming methods in each season since the start of the study and it can therefore be concluded that CA gives insurance against extreme deviations in climate. Environmental and agronomic studies have indicated that besides increased yields, CA delivers community with goods in terms of environmental services. Compensating farmers for environmental services has been difficult in Kenya. Nevertheless, farmers have been compensated through enhanced yields thus making small scale farming profitable. This profitability is inclusive of farmers in low potential areas which have adopted conservation agriculture techniques. The study also recommended the use of evaluated climate data for planning and development in Agricultural and general socio-economic improvement.

8.4 Policy Brief

Based on this study, the key policy recommendations for the achievement of food security include: more investment in conservation agriculture in the semi-arid agro-ecological zones by the National and County governments as an operational and practical way of increasing smallholder farmers' profitability and productivity in a sustainable way besides buffering farmers against climatic change impacts. The buffering would be in terms of a concerted effort by the government to roll out a massive programme on conservational agriculture in semi-arid agro ecological areas. In addition, this could be supported by the private sector financial institutions in terms of developing insurance products for crops and livestock in semi-arid areas. Secondly the International funders especially donors should target smallholder farmers and the poor in their investment strategy in agriculture. This should begin with supporting the adoption of CA in agricultural zones that are semi-arid through funding arrangements, research and supportive policies. To encourage conservational agriculture, the government and private sector should consider a national award system for farmers who demonstrate excellence in utilization of conservational agriculture systems in production of food as a means of climate change adaptation.

Moreover, farmers should be educated through early warning information by utilization of satellite information to help them in proper planning in farming. Government should therefore invest in satellite information gathering on climate and weather patterns which can be used by farmers in planning their on farm activities. This will help in drought management by mitigating the adverse effects of change in climate at national, community and household level. This is in realization that effects of climate change do not only affect semiarid areas but also rain sufficient locations.

Data on water availability, utilization and quality is inadequate in Kenya. To close the gap, efforts should be put in place to annually collect the necessary data to inform policy on availability, utilization and quality for making decisions on farming and nutrition status in semiarid areas. Household should ensure they are water secure by adapting water harvesting techniques that are cost effective. This is an area that the County governments should focus on and direct enough financial and human resources.

It is no doubt that climate change has occurred. The government should mainstream climate change knowledge in the school curriculum from the formative stages in learning all the way to higher levels. This will instil a sense of care and concern by everyone in climate change adaptation especially in food security. Further to this, there should be involvement of women in issues of climate change given their central role in provision of food to their families.

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APPENDINCES

APPENDIX I: EARLY WARNING SYSTEM BULLETIN SUMMARY

November 2016 EW Phase

Drought Situation & EW Phase Classification

Biophysical Indicators

- The onset of rains for the current season was in the first week of November 2016 with the date's varying from 4th to 5th, which was late by three weeks. Temporal distribution was fair while spatial distribution was even for the month under review.
- Tharaka was in the severe vegetation deficit band at thresholds of 20. However, with the good rains received in the third week of November are expected to increase the VCI in December.
- The major source of water for livestock and domestic use were natural rivers, Pipelines, boreholes, roof catchments and traditional river wells, the recorded sources were normal at this time of the year

Socio Economic Indicators (Impact Indicators)

Production Indicators

- Pasture and browse quality was fair attributed to favourable weather characterized by onset of the short rains and low temperatures. The trend in pasture quality will be highly dependent on the stability of the prevailing rainfall.
- Pest control and major weeding was noted across all zones.

Access Indicators

- Milk production and consumption per household was 0.72 litres and 0.64 litres respectively compared to an average production of 1.5 litres and an average consumption of 1 litre.

Utilization Indicators

- Percentage of children at risk of malnourishment whose MUAC was below 135mm was 8.2 for the period under review

Early Warning Phase Classification

Livelihood Zone	EW PHASE	TRENDS
Mixed Farming	Normal	Stable
Marginal Mixed Farming	Normal	Stable
Rainfed cropping	Normal	Stable
County	Normal	Stable
Biophysical Indicators	**Value**	**Normal Range/Value**
VCI-3month (Tharaka)	20	>35
Water Sources	Fair	Fair
Production Indicators	**Value**	**Normal**
Livestock Body Conditions	Fair	Fair
Milk Production	0.72 Litres	>1.5 Litres
Livestock deaths (from drought)	No death	No death
Access Indicators	**Value**	**Normal**
Terms of Trade	72	>81
Milk Consumption	0.64 Litres	>1Litres
Water for Households	Fair	Fair
Utilization indicators	**Value**	**Range/Value**
Coping Strategy Index (CSI)	1.2	<0.93

Jan – Mar	Mar – Jun	Jul – Oct	Nov – Dec
Short rains harvests Short dry spell Reduced milk yields Increased HH Food Stocks Land preparation	Planting/Weeding Long rains High Calving Rate Milk Yields Increase	Long rains harvests A long dry spell Land preparation Increased HH Food Stocks Kidding (Sept)	Short rains Planting/weeding

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec

BIO-PHYSICAL INDICATORS

1.0 MEASURING DROUGHT HAZARD

1.1 METEOROLOGICAL DROUGHT

1.1.1 Actual Rainfall

- The onset of rains was in the first week of November with the date's varying from 4th to 5th of November 2016, which was late by three weeks.
- Rainfall across the county over the month of November was in falls of 50 - 100 mm across Rainfed, and Mixed Farming livelihood zones. The Marginal Mixed farming livelihood zone received 10 - 50 mm, primarily in the north.
- The recorded amount of rainfall received was 285 mm for an average of 10 rainy days from 4 recording stations.
- With reference to the Rainfall Estimate Images, rainfall performance was normal in comparison to a normal year though with a late onset.

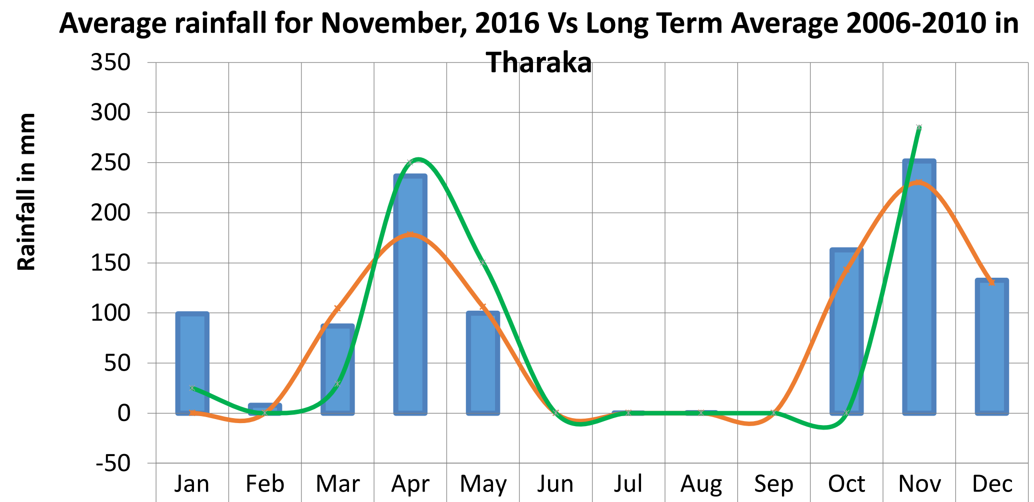
1.1.2 Spatial Distribution

- The spatial distribution of rains across the county was even, noted by an average of 10 rainy days from 4 recording stations though Rain-fed cropping and Mixed Farming zones received slightly higher amounts of rainfall in comparison to the Marginal Mixed Farming livelihood zone.

1.1.3 Temporal Distribution

- Temporal distribution was fair, Kathangachini recorded a total of 257 mm for 11 rainy days, Kanyuru a total of 259 mm for 10 rainy days while Thiiti recorded a total of 314 mm for 9 rainy days and Karocho recorded 310 mm for 10 rainy days
- The recorded average amount of rainfall was 285 mm for an average of 10 rainy days an indication of fair temporal distribution.

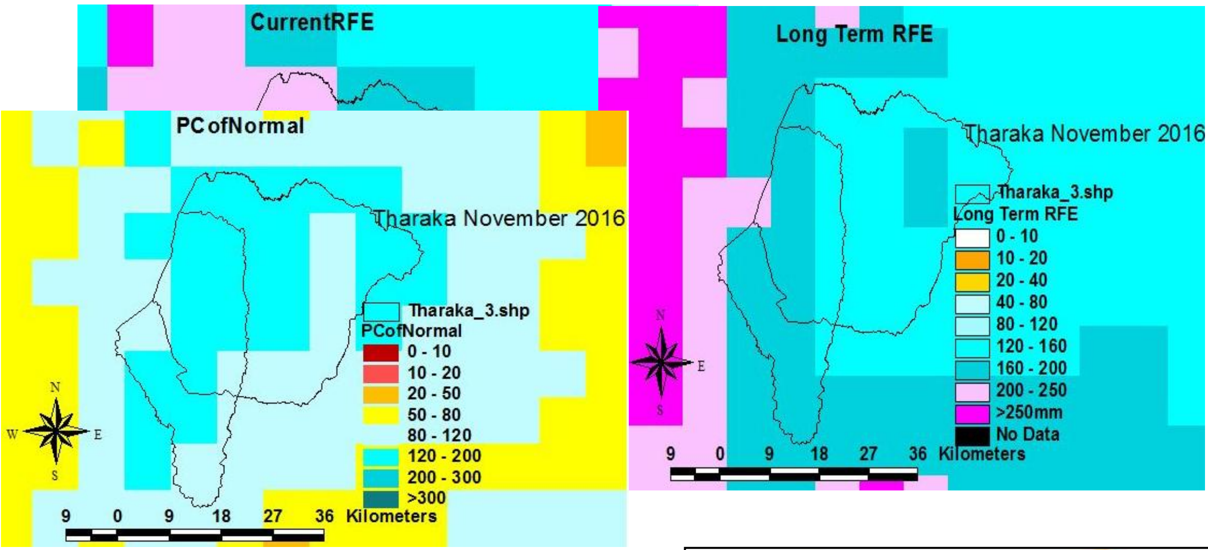
1.1.4 Rainfall Station Data



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average (2006-2010)	99	8	87	237	100	0	0	1	0	163	252	133
Average rainfall 2015	0	0	104	178	106	0	0	0	0	143	230	130
Average rainfall 2016	25	0	29	250	150	0	0	0	0	0	285	

1.1.4 RFE Analysis

Satellite RFE Imageries illustrating Current rainfall estimates, long-term rainfall estimates and percent of Normal estimates.



APPENDIX II: HOUSEHOLD QUESTIONNAIRE

Section1: Household Demographic, Vulnerability and Livelihood

1.1Respondent and household information

1. The Name:____
2. Date of Birth:___________Age__________
3. Gender:1= Male _____2=Female_____________
4. Linkage to the head of HH:1=Spouse,2=Household head,3=others________________________
5. Status of Marriage :1=Married,2=Single,3= Polygamous,4=Monogamous
6. No. of children: Daughters____________Sons_______________
7. Birth place:1=Village,2=Town,3=Other Town specify__________________
8. Level of Education:1= College/University ,2=Vocational/Technical ,3=Secondary ,4=Primary ,5= None
9. Tribe:_______________________
10. Religion:1=Christianity ,2=Muslim ,3=others Specify________________
11. Occupation:1= Livestock keeping ,2=Farming ,3=Casual Labour ,4=Employment ,Others Specify______________
12. Household Members in No:Adult men (18-65)__Adult Women(18-65)__Boys(<18)__Girls(<18)__Elderly men(<65)___Elderly Women___
13. Other Households members who provide food or income to Household?__________

1.2Farm and Land

14. How hectares of land were cultivated this year? In No._____________

15. Are you the land owner?1=yes ,2=no ,3=shared

(1) if the option is 2 or 3 how did you access the land? 1=Renting ,2= Community land ,3=Renting ,4=Leasing 5= Borrow ,6=others specify_____________ is land under irrigation: 1= yes , 2=no

(2) if yes how many in hectare?Number________

16: In order of priority which crop did you plant last year:1_______________2______________3_______________ __________4_______________5________________

17. Did you use traditional method or a tractor during land preparation?1=yes ,2= no If yes did you 1=own ,2=hire

3=borrow

18. Did you hire any casual laborers last year? 1=yes, 2=no if yes How many days___ and how many casuals _____

19. What is the main reason for your crop production? 1=Household consumption, 2=Sale, 3 others specify__________________________

20. Do you sale your crops after harvesting? How much 1=everything, 2=less than half, 3=half, 4=more than half, 5=nothing

21. How much income do you generate after selling the produce in the last 12month?_____________________

22. How is your crop production in the last 10 years? 1=increased, 2=decreased, 3=the same, 4=increased a little, 5=decreased a little

1.3 Economic and Livestock Trees

23. Do households own any livestock? 1=yes ,2=no how many in numbers 1=cows __,2=Goats and sheep__,3=Donkeys__,4=poultry __,5=Pigs__ others specify_________

(1) if yes what is the main reason for your livestock (choose one)? 1 = Sale, 2=Household use, 3=ploughing

24. How much income do you generate from livestock keeping in the last 12 month?____________

25. Did you or other members of the household engage in aquaculture? 1=yes, 2=no if yes, please specify :1=Fishing ,2=Fish keeping ,3=both

26. What is the main reason for aquaculture? Chose one 1=Sale 2=Household use 3=others, specify____________

27. How much income do you generate from Fishing in the last 12 months?_______________

28. Do you have any economic tree (fruit, timber etc)? 1=yes, 2=no if yes what is the main reason for economic tree (choose one)? 1=Households use ,2=Sale ,3=others, specify_______________

29. Please indicate the number of trees :(1) <10,(2) 10-50 ,(3) 50-100 ,(4)>100

30. In terms of economic income does the household hold any economic trees in the last 12 months_________

1.4 Other income generating activities

31. Is there any other income generating activities from non-farm activities? 1=yes, 2=no if yes how Many members are involved?____What activities are they involved in ?1= petty trading ,2=charcoal burning ,3=firewood selling ,4=crafts 6=others, specify_______

32. Can give a rough estimate of incomes from nonfarm activities in the last 12 months?_______________

33. Do you receive any remittances from any relative? 1=yes ,2=no if yes from who? 1=Son, 2=Daughter, 3=Brother, 4=Sister, 5=other, specify________

34. Where do they live? 11=within the county, 2=outside the county, 3=Abroad

35. What are the total remittances received in last 12 months________________

36. Any other item received which has value in the last 12 months______________

37. Do your household members engage in casual labour on other farms? 1=yes 2=no if yes how many?___

38. What is the total annual income earned through casual labour in the last 12 months_____

39.Is there any other source of income apart from the one mentioned above ? 1=yes ,2=no if yes please specify that source________________________________ and what is the total income derived from it in last 12 month__________

40. Plsease what is your budget at anytime in terms of Kenya shillings by the week________,month_______and year__________

41. According to other households in your village, how would you compare their monthly income budget (choose one option) 1=more than yours, 2=same as yours, 3=less than yours

1.5 Housing and other assets

42. Do you have the electricity in your house? 1=yes   , 2=no
43. What is main source of water in the household? 1=piped, 2=rivers, 3=Borehole, 4=wells, 5=others, specify___________
44. Do you have a latrine or toilet in your house or compound? 1=yes, 2=no
45. Which household assets do you own and how many: TV__ Mobile phone___ Fridge___ Car___ Motorbike___ Bicycle____ Computer____

1.6 Food Security

46. On a regular day how times does an adult have a meal?______________
47. On a regular day how times do children have a meal?________________
48. In last year which months did the household reduced the number of meals per day?(choose) 1=Jan-feb ,2= Mar-apr ,3=Apr-may ,4=Jun-jul ,5=Aug-Sep ,6=Oct-Nov ,7=Dec
49. Describe the cause(s) of this food shortage?
50. Has the household experienced any food shortage in the past 10 years? 1=yes , 2=no   if yes times within 10years ____
51. What is the main cause(s) of the shortage?
52. Please describe the food consumed by the household if is bought? What is bought is 1=Everything, 2=less than half, 3=More than half, 4=Average, 5=Hardly anything, 6= Nothing

2.0 Open questions

2.1 Coping strategy and impact of weather related extreme events

53. How many year have you lived in this county or sub county?_______________________
54. Describe the most severe or the most recent hazard that affected your household and mention the year and the events:
55. Describe how the hazard affected the crop and livestock production?
56. Did the situation of the hazard in extreme event have any other negative effects on your household? Explain
57. Did you dealt with the impact of the hazard, how it affected food, livestock or fish production? 1=yes, 2-no (skip the next two questions)   If yes what did you do?

If yes despite this measures your household still experienced negative effect from the hazard?1=no ,2=yes the measures were costly 3= yes the measures were not enough 3=yes others,specify____

58. If no? 1=lack of funds to mitigate the hazard 2=lack of knowledge/skills about the hazard 3=lack of awareness about the hazard 4=it was not my responsibility 5=it was a not a priority to us 6=any other reason, explain:

59.If no, what negative effect did the household experienced in terms of damage, cost and loss because no measures to mitigate the hazard were taken?.

2.2 Closed questions; impacts and coping strategy on extreme events

60. Have you ever been effected by a hazard?

1=no, 2=yes severely ,3=yes but not severely

If yes how did it affect the following?

Crops:1=no ,2=moderate ,3=severe ,4=NA if you choose 2or 3 what was the cost estimate______________

Livestock:1=no ,2=moderate ,3=severe ,4=NA if you choose 2or 3 what was the cost estimate______________

Economic trees:1=no ,2=moderate ,3=severe ,4=NA choosing 2or 3 what was the cost estimate______________

Trade or Business:1=no ,2=moderate ,3=severe ,4=NA choosing 2or 3 what was the cost estimate______________

Food prices:1=no ,2=moderate ,3=severe ,4=NA choosing 2or 3 what was the cost estimate______________

House or property:1=no ,2=moderate ,3=severe ,4=NA choosing 2or 3 what was the cost estimate______________

Any other explain:1=no ,2=moderate ,3=severe ,4=NA choosing 2or 3 what was the cost estimate______________

Questions about what people did to copw with the impacts of extreme events

61. Did you borrow money or food from other people to cope with the hazard? 1=no if yes from 2=relative, 3=Neighbor, 4=Friend, 5=other, specify_____________

62. Did receive any support from an NGO dealing with the hazard? 1=no if yes from 2=Government agency, which one____________ 3=NGO________________4=FBO____________________5=_____________________

63. Did the household members try to earn extra income to cope with the hazard? 1=no ,2=yes, engaged in new activities, specify____________________3=intensified the same activities, specify________________________

64. Did you migrate to deal with the hazard?1=no ,2=yes, whole HH, 3=HH head , 4=Other members of the HH Was the period: 1=short term (<6months) 2=long-term (>6months) and where to:1=Within the county___________2=outside the county_________________ was the migration destination 1= urban 2=rural

65. Did you sold HH assets to cope with the hazard? 1=no, 2=yes, land 3=TV, 4=Bicycle ,5=Motorbike ,5=furniture ,6=others____________________

66. Did you use less money to cope with the hazard? 1-no, 2=yes, on food items, 3=on school fees, 4=on healthcare, 5=on business, 6=others

67. Did change the food consumption pattern to deal with the hazard?1=no ,2=yes, reduced the portion, 3=relied on less preferred food ,4=reduced the no. of meals per day ,5=reduced the quantity of food consumed by adults to allow children to eat ,5=others_________________________

68. Did you take any other measure to with the hazard, extreme event 1=no 2=yes specify____________________

70. If you did take some measures to prevent the hazard do think the negative effects and the well being of your Households ? 1=no still severe negative effects 2=no still moderate negative effects 3=yes it allowed us to carry on 3=yes it improved the situation.

Also explain:

3. **Impacts and adaptation to slow onset climatic changes**

3.1 Open Questions

71. In last 30years what changes did you experienced in your village in terms of hazard frequency and intensity? Explain

72. Has the hazard extreme event affected the crop, livestock production and fishing activities, explain:

4.0 Vulnerability, gender and policy issues

73. Due to the impacts of the threat do you think your HH is more or less likely to suffer than other HHs in your community? 1=less 2=average 3=more and why?

74. Due to impact of climate change do you think men and women are affected differently, please explain?

75. What role should men and women play in issues dealing with climate threats, please explain?

76. What should the Government or other organization do to reduce the impacts of this climate threat?

APPENDIX III: CONSERVATION AGRICULTURE TRIAL DATA COLLECTION TOOL

1. Name of person conducting the study

   ………………………………………………………………..

2. Location Name………………………………………….
3. Longitude …………….. Latitude ………………Altitude………………
4. Earlier crop
5. Soil Type
6. Fertilizer applied

	Rate (Kg per Ha)	Applied date	Fertilizer type
Phosphorus			
Nitrogen			

7. Dates of farming activities………………… …………………………. Thinning……………………

   Weeding (First) ……….. Weeding (Second) ………………

Harvesting…………………….

8. Plot size
9. Row spacing (cm)……………… … Number of plants ……………………

Composition and Design

1. Conservation agricultural trial 2015/16 consists of 6 entries. Enough seed is provided for each entry to plant a plot of 10 rows with row spacing of spacing of 0.6 m. thin plants to 20 cm between plants in the row 2-3 weeks after emergence.

Data Recording

2. All observations should be taken from the entire plot

Leaf disease score

If the trial is infected with leaf disease please score these on a scale of 1-3 where

- 1 =(**LOW)** Less than 5% of plant populace attacked
- 2 =(**MEDIUM) 5-**10% of plant population attacked
- 3 = (**HIGH)**More than 10% of plant population attacked

Insects Pests

If trial is infected by insects, pest, score these on a scale as below

- 1= (**LOW)** Less than 5 pests per sample plant or no signs of pests attack
- 2 = (**MEDIUM)**5-10 pests per sample plant or onset of signs of attack
- 3 = (**HIGH)**More than 10 pests per sample plant or clear signs of pest damage

Agronomic Score

1. Score given for agronomic worth. Where

   - 1= Very good
   - 2= Good
   - 3= Average
   - 4= below average
   - 5= Poor

2. Plant populace at harvest: for the duration of maturity and prior to harvesting, count and document the figure of plants in the whole plot

3. Plot harvesting:

   - All panicles should be harvested from the plot
   - Dry the panicles
   - Thresh the completely dried panicles
   - Winnow the grain
   - Weigh and record the Kilogrammes of grain

MONITORING TOOL

	Sorghum under CA	Conventional Control	Green grams on CA	Cowpeas on CA	Sorghum-G.Grams Cover crop		Sorghum-Cowpeas Cover crop	
					Sorghum	G.Grams	Sorghum	Cowpeas
Number of days to germination								
Plant stand								
The weed populace								
Pest prevalence								
Disease ratings								
Pest or Insect harm score (1 to 3)								
Disease Score (1 to3)								
Height of the Plant								
sorghum Length of panicle								
Physiological maturity Days								
Agronomic score (1 to 5)								
Plant Populace at harvest								
Weight after threshing								

APPENDIX IV: PICTORIAL PRESENTATIONS OF VARIOUS TREATMENTS AT DIFFERENT STAGES

	Pictorial presentations of various treatments at different stages		
Mapping Layout and Planting			
Planted Blocks			
25th November, 2015	 Sorghum	 Sorghum and Cowpeas	 Sorghum and Green grams
25th November, 2015	 Green grams	 Cowpeas	 Conventional Method

Impacts of Climate change	 Pest and diseases	 Moisture deficit	 Pest and diseases
19th January, 2016	 Sorghum	 Sorghum and cowpeas	 Sorghum and green grams
19th January, 2015	 Green grams	 Cowpeas	 Conventional control
19th February, 2016 Threshing of the harvested sorghum.			

APPENDIX V: EVALUATION GUIDING TOOL

1. What change can you clearly state in the implementation of the project for the community?
2. What are the key lessons learnt and are worth adapting?
3. What impact was realized on food production?
4. Was acquisition of knowledge on the proper farming techniques by the beneficiaries?
5. Was there any unique practice that can be replicated at other level?
6. What other recommendations would you recommend to the government?

Part B

It consists of three research articles: three papers that have been published in peer-reviewed international Journals, and one submitted manuscript (policy brief) as abstracts appended and the originality test.

- Gioto Victoria Amwoliza, Increasing food production resilience through integrated agriculture under changing climate in Taita Taveta County, Kenya, Co Authored with Valerian Micheni http://www.jccs.kms.or.ke/index.php/23-increasing-food-production-resilience-through-integrated-agriculture-under-changing-climate-in-taita-taveta-county-kenya

- Gioto Victoria Amwoliza, Shem Wandiga, and Christopher Oludhe Climate Change Detection in Tharaka, Kenya, J. Meteorol. Related. Sci., 9:2:2 http://dx.doi.org/10.20987/jmrs.1.08.2016

- Gioto Victoria Amwoliza, Shem Wandiga, and Christopher Oludhe Conservation Agriculture for Climate Change Adaptation in Tharaka Nithi, *Journal of Climate Change and Sustainability (JCCS),*Volume 1, Issue 2 http://www.jccs.kms.or.ke/index.php/issues/9-journal-articles/26-conservation-

- Victoria Gioto, Shem Wandiga, and Christopher Oludhe agriculture-for-climate-change-adaptation-in-tharaka-nithi Determinants of Household Food Security Status and Challenges of Building Resilience to Climate Variability and Change Posed by Drought in Tharaka Nithi, Kenya https://link.springer.com/content/pdf

Increasing Food Production Resilience through Integrated Agriculture under Changing Climate in Taita-Taveta County, Kenya

Abstract

Increasing food production through sustainable food production coupled with integrated agriculture under a changing climate, by strengthening the capacities of farmers was one strategy to address food security. Climate change had been described as the most significant environmental threat of the 21st century and had the potential to damage irreversibly the natural resource base on which agriculture depends, with grave consequences for food security. Conversely, agriculture had the potential to the solution. There were approximately 60,000 food insecure people in Taita-Taveta based on the Long Rains Food Security Assessment analysis of 2015. This study assessed how climate change affected production of food security, to provide input to guide decision making for future resilience building programming and to engage local communities, increase understanding of climate change impacts and adaptation options through integrated farming practices. The research applied a two stage stratified cluster sampling with the clusters being selected using the probability proportional to population size (PPS) and thematic issues Cash for Assets, climate change adaptation, early warning, ending drought emergencies and disaster risk management. Data was collected using focused group discussion, observation and key in-depth interviews. The analysis was both qualitative and quantitative and adopted a trans-disciplinary perspective. From the findings, major factors affecting food security in Taita Taveta County were poor rainfall performance, human wildlife conflict, high food prices and poor soil fertility at 35 percent, 17 percent, 15 percent and 12 percent respectively. Other factors affecting food security were poor post-harvest handling practices, degraded land, unsubsidized farm inputs and poor infrastructure. Therefore, integrated agriculture would be considered as an alternative option towards increasing resilience on food security means and buffering the effects of climate change

Climate Change Detection across All Livelihood Zones in Tharaka Nithi County

Abstract

Kenyan agriculture is largely rain-fed and principally dependent on rainfall. According to FEWS NET report for Kenya in August 2010 based on historical data from 70 rainfall stations and 17 air temperature stations to interpolate the long-rains precipitation and temperature trends for all of Kenya from 1960 to 2009 (Funk et al, 2010). The FEWS NET report indicate that in Kenya long-rains traditionally occur between March and June and short rains in October to December. The authors report that Kenya has experienced trend of decreasing rainfall and rising temperatures as Sudan. In Central Kenya, one of the country's key agricultural regions, the area receiving adequate rainfall to support reliable rain-fed agriculture has declined by roughly 45 per cent since the mid-1970s (Funk et al, 2010). This study investigates change in temperature and rainfall pattern across all livelihood zones in Tharaka Nithi County. Data was collected for 39 years (1976 - 2015) period for the area of Study and in addition divisions were made to three non-overlapping climate period of 30 years (1982 - 1991, 1992 – 200 and 2002 - 2012). The data were subjected to Gaussian kernel analysis, moments, regression, and non-parametric approaches based on Mann-Kendal statistics to justify any change in the average monthly and annually rain fall and temperature trend. The results indicate common change points and transitions from wet to dry (upward shift). The test indicates rainfall variation over the study area is significant (p= 0.05).The study recommended on the use of the information for Agricultural development and general socio-economic improvement.

Conservation Agriculture for Climate Change Adaptation in Tharaka Nithi

Abstract

Rain-fed agricultural crop production has recently declined due to volatile and unreliable rainfall patterns in Tharaka community. The scarce understanding of seasonal rainfall variability in the cropping calendar by farmers has contributed to low crop yields. The study was designed to test the yields of sorghum, cowpeas and green grams using conservation agriculture in the semi-arid parts of the Tharaka Nithi County namely; Tharaka North and Tharaka South sub-counties (Tharaka Constituency). Two sites with four experimental plots were subjected to 6 treatments. Treatment one was Sorghum, treatment two was Sorghum/ Cowpeas, treatment three was Sorghum/green grams, treatment four Green grams, treatment five Cowpeas and finally treatment six Conventional Control, all treatments were under conservation agriculture with an exception of the treatment six. Sorghum was the main crop for the intercropping pattern. Using a randomized block design, the subjects were assessed and put in layout of six according to the study design. The four experimental plots (blocks) were then randomly assigned with a total of 3 times replication. The sorghum planting depth was 5 centimeter with spacing of 60 centimeter by 20 centimeter, cowpeas was at depth of 4 cm with spacing of 60 centimeter by 20 centimeter, while green grams was at depth of 4 cm with spacing of 45 centimeter by 15 centimeter. The treatments of conservation agriculture in addition to soil amendment of 60 Kilogrammes of CAN (Calcium Ammonium Nitrate) coupled with to 60 Kilogrammes NPK (Nitrogen, Phosphorus Potash) had the highest grain yield ranging from 2.0 tonnes per hectare for the intercropped to 2.3 tonnes per hectare for the mono cropped Conservation agriculture contributed positively in increased crop yield owing to more moisture retention in comparison to conventional control. Generally, trials under conventional controls had the lower yield at 1.0 tonnes per hectare for the mono cropped. Therefore, conservational agriculture could be considered as an alternative option towards increasing resilience on food security means and buffering the effects of climate change for Tharaka community attributed to the capability of more moisture retention.

Determinants of Household Food Security Status and Assesses the Challenges of Building Resilience to Climate Variability and Change Posed By Drought in Tharakanithi, Kenya

Abstract

Climate change and variability pose momentous severe threats to agricultural development and consequently to economic growth and increased poverty levels. In reference, this paper examines the determinants of household food security status and assesses the challenges of building resilience to climate variability and change posed by drought in TharakaNithi, Kenya. The study coverage is Tharaka North and Tharaka South sub-counties which are semiarid and cover an area of 1,569 square kilometers (km2) with a total population of 158,023 people; this is about 65% of Tharaka Nithi County (Kenya). The sub-counties have three main livelihood zones (LZs). These are marginal mixed farming at 52%, mixed farming at 38%, and rain-fed cropping at 10%. The area is exposed to climate change, aggravated by minimal adaptive capacity. Climate variability and climate change threaten food production leading to about 20–30% of the population being in poor and borderline food consumption score. The year 2017 describes one of the cyclical drought situations with low productivity and depleted range land conditions exposing approximately 30,000 persons in need of humanitarian assistance. This study reflects on challenges of building resilience to climate variability and change posed by drought using a transdisciplinary approach. The problems of the household food security status were poor rainfall performance, high temperatures, low livestock prices, high food prices, poor crop production, poor pasture and browse quality, and inadequate water for both domestic and livestock use. The solutions to the above-listed issues lie in the increased advocacy, rainwater harvesting structures, marketing linkages, timely early warning knowledge management, and eco-based farming practices. The study also found that there was a significant relationship between the household level of education, family size, household income, and household head age with food security. Findings of this study will form a platform for policy makers.

Turnitin Originality Report

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