INFLUENCE OF FOOD DISTRIBUTION SYSTEMS AND MARKET ACCESSIBILITY ON FOOD SECURITY IN THARAKA SUB COUNTY, KENYA

KIBETU DICKSON KINOTI

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been presented for a conferment of a degree in any other University or for any other award

Kibetu Dickson Kinoti
E300/2140P/13

Signature: …….. Date: ……

Declaration by the Supervisors

We confirm that the work reported in this thesis was carried out by the candidate under our supervision and has been submitted with our approval as university supervisors.

Prof. Julius M. Huho
Department of Arts and Social Sciences
School of Arts and Social Sciences
Garissa University

Signature: …….. Date: ……

Dr. Tom O. Ouna
Department of Humanities and Languages
School of Education and Social Sciences
Karatina University

Signature: …….. Date: ……

DEDICATION

This work and all thereof is dedicated to my dearest wife Joyce Muthoni and our lovely children; Prudencia, Claudia and Liam, for being the motivation to pursue this course of study and more so for standing in for me always when need arose. Thank you my wonderful kins. To parents from both sides and siblings who supported and believed in me throughout my study period, i sincerly salute you. To them all who in one way or another walked with me this journey, may God reward your efforts and repay you abundantly for the moral, spiritual and physical support.

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ABBREVIATIONS AND ACRONYMS

ACTESA:	Alliance for Commodity Trade in Eastern and Southern Africa
AOI:	Area of Interest
ASALs:	Arid and Semi-Arid Lands
COMESA:	Common Market for Eastern and Southern Africa.
DEM:	Digital Elevation Model
EC:	European Commission
FAO:	Food and Agricultural Organization.
FEWS NET:	Famine Early Warning System Network
GIS:	Geographic Information Systems
GoK:	Government of Kenya.
GoT:	Government of Tanzania.
ICDP:	Integrated County Development Plan
KALRO:	Kenya Agricultural and Livestock Research Organization
KFSSG:	Kenya Food Security Steering Group.
KMD:	Kenya Meteorological Department
KNBS:	Kenya National Bureau of Statistics.
LHZ:	Livelihood Zone
MF:	Mixed Farming
MMF:	Marginal Mixed Farming
MoA:	Ministry of Agriculture.
NDMA:	National Drought Management Authority.
NDVI:	Normalised Digital Vegetation Index
RC:	Rain fed Cropping
ReSAKSS:	Regional Strategic Analysis and Knowledge Support System.
USAID:	United States Agency for International Development

ABSTRACT

Food distribution and market accessibility impact food security and development of rural economies. About 30% of Kenya's population live in the country's food insecure rural arid and semi-arid lands. Semi-arid Tharaka sub county suffers from insufficient and inefficient food distribution due to problems of physical accessibility to food markets which constitute main source of food items (86.95%) consumed here. These have led to sporadic and acute food insecurity across the sub county. The purpose of this study was to examine influence of local food distribution systems and market accessibility on food security in Tharaka sub county. Maize (96.6%) and millet (54.1%) are important staple food crops widely consumed by households in the study area. The objectives of this research focused on identifying biophysical and climatic factors that determine optimal maize and millet production for the realisation of food security; to determine how marketing models for maize and millet influence distribution and retention of food stock by households in Tharaka sub county; to examine efficiency of physical accessibility to existing open air markets and its effect on food security in Tharaka sub county, and finally to examine spatial distribution and utilisation of open-air markets in Tharaka sub county and its influence on food security. It was hypothesized that no significant relationship existed between agro-climatic suitability and maize and millet production, marketing models and food stock retention, markets physical accessibility and food security and how open-air markets spatial distribution influenced utilisation of the markets. A sample of 395 households selected using cross-section survey and a multi-purposive cluster sampling technique from the 31,556 households in the studt area were considered. Primary data was collected through observation, semi-structured questionnaires and 5 key informants' interviews. GIS based modeling, Kendall's multiple correlation analysis and Tobit regression techniques were used to analyse the data. Results of GIS agro-climatic suitability analysis in Idris Selva software showed that 4,189.31 hectares of land were suitable for optimised production of maize and millet. Identified suitable areas felled within the rainfed cropping zone (RFC) and mixed farming (MF) livelihood zones. Kendall's multiple correlation analysis revealed that households living close to the markets (<5km) sold most of their food stocks retaining up to two bags for 3-4 weeks compared to those living away(>10km) who kept three to five bags for the same period or longer. Tobit regression analysis indicated education levels of household head and market price as important determinants in the choice of market models by a household. Lastly, ease of accessibility and service functional value influenced open-air markets preferential use by farmers and consumers alike. Conclusively, food security in Tharaka sub county is largely influenced by marketing models used by households to procure and sell foodstuffs, ease of physical accessibility to markets and the bio-physical and climatic conditions of the given livelihood cluster zone. In future, there is need to consider food distribution and market accessibility as determinant components of food security and nutrition improvement in the study area. Major recommendations from this study emphasize desire to promote food trade and market-based interventions to address food security. Furthermore, improving open-air markets' physical infrastructure and construction of missing-link roads connecting villages to markets would address the problem of low food markets utilisation.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Food security debate has dominated policy, society and the science worldwide. Issues of food production, processing, accessibility and distribution have become topics in many scientific journals. Food is an important ingredient for human life as a source of energy and nutrients. Therefore, production, distribution and marketing of food drive many of the modern world economies and forms basic fabric of human society. Ironically, the current world food system of agricultural production, food processing, distribution and sale of food does not adequately meet food needs of the increasing world's population. For instance, nearly one billion people suffer from chronic hunger in developing countries, further twenty-five million persons within transition societies and another nine million people in industrialized countries (FAO, 2011). FAO in its 2014 report notes that in sub Saharan Africa, more than a quarter of the population are chronically hungry and a large proportion of countries in this region are food insecure.

According to Pinstrup (2002), the 1996 World Food Summit pledged to reduce the food-insecure population by 400 million people by the year 2015. Leather and Foster (2009) observed that enough food is produced globally that can feed all the people in the world. It is now critical to look into ways of improving food distribution systems and accessibility strategies especially at local levels to help address challenges of food and nutrition security.

Strategies embraced by countries to tackle food insecurity and hunger majorly revolve around UN's Agenda 21 (1992); Millennium Development Goals (2010), Sustainable

Development Goals (2015) and the Maputo Declaration on Agriculture and Food Security (2003). National policies and programs have also been developed like the national food and nutrition security (2011), the Big Four Agenda (2017) and Kenya's vision 2030 social pillar on food security. Locally, the Integrated County Development Plan (ICDP) for Tharaka Nithi County (2017-2022) also highlight the importance of attaining food security across the county as a way of realizing ecological, social and economic growth for her people.

These initiatives though good, do not ensure guaranteed access to food by those in need or even help maintain stability in food commodity flow. The fact that such initiatives are macro-economic in nature makes them unsuitable for addressing local food security issues. Food marketing and distribution processes play an integral role in promoting world's food security since through intra-regional shipment, distribution of food commodities is achieved over a wide geographical area and across many markets (Getachew & Simon, 2007). Often, issues of feeding the hungry and access to food are dependent on policy frameworks, transport services and infrastructural facilities existing in any region (Eleonora, 2011; World Bank, 2009).

In Kenya, market barriers and poor infrastructure hinder access and distribution of local food commodities (Marcia, Maria & Steven, 2016; Omiti, Otieno, Nyanamba & Mcclough 2009). Significant factors contributing to the constant problem of erratic hunger, poor nutrition and food insecurity in the country are those related to distribution and market accessibility. Key components of any food distribution system are logistics planning, road networks and market accessibility which in turn are influenced by availability, affordability and access to food resources. Post-harvest loss

management, foods wastage reduction, agro based value addition and food distribution though an ignored component in many food security studies influences household nutritional status, agricultural productivity and development of rural economies.

Market accessibility influence consumption patterns of food commodities by dictating demand and supply at the market level. Distribution links farmers in the rural areas to consumers in urban centers by ensuring produce from the farms reach the markets. Therefore, improving distribution systems for food supplies and lowering the costs of accessing foodstuffs at local markets are important in the attainment of food security at the household level, promotion of rural economy and supporting agricultural development. Generally, food distribution systems reveal local commodity supply in relation to demand. On the other hand, market accessibility shows spatial relationship between location of supply and demand. The two components serve to connect food source regions (supply) to areas of need (demand). This seek to promote food security and more so rural development by strengthening farmer-consumer linkages while enhancing trade in agricultural products.

At the national level, agriculture is the main source of food and income for many households. Demand for cereals has in the last decade increased due to population growth and urbanisation (FEWS.NET, 2014). Most of the maize consumed in the country is imported from Common Market for East and South Africa (COMESA) countries to help bridge the increased national consumption demand which outweighs local production. About 70% of the Kenyan population comprises of net food buyers.

In rural areas, about 15% of the food comes directly from farms and in the urban areas over 70% of food consumed is purchased from local markets (KNBS, 2008).

As a result, dependence on market forms a significant source of food in the country. There is an increasing dietary energy requirement gap in the country according to the Kenya Integrated Household Budget survey report of 2005/2006 fiscal year (KIHBS, 2005/2006), with the daily average Dietary Energy Consumption (DEC) in the country standing at 1,800kcal/person. High levels of dietary energy consumption of up to 2,060kcal/person/day have been captured in urban areas as compared to 1,690kcal/person/day in rural areas (KNBS, 2008). The unmet problem of increasing dietary requirement has further been worsened by erratic drought resulting to food shortage and instability in food prices especially in arid and semi-arid lands. The low Dietary Energy Consumption in rural areas can be attributed to challenges of inefficient distribution systems and market inaccessibility.

Over 80% of Kenya's landmass falls within the most food insecure zones loosely referred to as ASALs. In the pastoral livelihood cluster for instance, market purchases account for over 65% of all food consumed while food aid and farmed crops accounting for 14% and 12% respectively (KFSSG, 2008; USAID-FEWS NET, 2010). Major challenges in pastoral livelihood zone are those of poor access to market related information, lack of suitable markets and undeveloped transport infrastructure. In the agro pastoral cluster zone, farm crop production accounts for over 30 percent of food needs while food purchases provide about 60 percent of total household food needs (GoK, 2012). The south eastern marginal mixed farming zone within which this study area falls is characterized by marginal agricultural production, labour migration and constant droughts. In this zone maize crop is the major food crop (Jayne, Mysers

& Nyoro, 2005). The main challenge is lack of proper storage facilities resulting to sale of cereals at low prices after harvesting when the supply is surplus in the local markets (Alila & Atieno, 2006). Nearly all households in this livelihood zone rely on market repurchases for their food needs mostly after the harvesting season, a period when there are shortages in the markets and prices of most food commodities have almost doubled (MoA, 2013). However, over 70 % of farmers in rural Tharaka sub county do not have access to formal markets (CIDP, 2013).

Urban livelihood cluster zone forms another important bioregion as far as food security issues especially those of distribution and market accessibility are concerned (Oxfam, 2012). In Kenya, urban population has grown tremendously to slightly over 30 % from about 8% in the year 2000. This has in the long run increased dependence on markets for food in the urban areas (GoK, 2013; MacAuslan & Schofield, 2011). Major challenges across urban livelihood zones revolve around food price volatility, poverty, low food consumption levels and inadequate market infrastructures. This often has failed to match the rising food demand given the growing population of urbanizing Kenyans. Over 75% of Kenya's population live in the medium to high potential mixed farming areas of Western, Eastern and Nyanza highlands. These are generally food secure areas with over 40% of all food needs coming from farms. In these regions, the share of food procured from markets is minimal compared to the same in other areas. Well-developed trade infrastructure, good market integration and close proximity to major urban centers help maintain food prices relatively low. Households in the high potential cereal and dairy livelihood zones are food secure. Maize is the predominant crop grown in these zones with over 70 % of all food needs met by on-farm production. Market purchases though not common usually account for

about 30% of food consumed especially for those not grown in these regions. This livelihood zones which is often referred as the food basket comprises the counties of Uasin-Gishu, Trans-Nzoia, Nandi, Kericho, Bungoma, Nakuru and Bomet.

Despite all these, lack of sufficient infrastructure such as paved roads, markets and storage facilities affects food distribution from producing regions to those in need (GoK, 2011; World Bank, 2013). It is estimated that 3.1 million people in the arid and semi-arid lands of Kenya are food insecure (USAID, 2016). According to Szmigiera (2021), 23% of Kenyans face malnutrition especially in the rural arid and semi-arid areas. The malnutrition rate in Tharaka-Nithi county stands at 30 percent which is relatively higher than the national prevalence (CIDP, 2013). Tharaka sub county which is found within Arid and Semi-Arid Lands has a short growing season and a recurrent drought problem. In rural Tharaka, maize and millet are grown as food as well as cash crops and widely traded as grains in local markets.

Maize and Millet are important staple crops widely cultivated by most households in Tharaka sub county (Alila & Atieno, 2006; FEWSNET, 2014). Maize and Millet crops account for over 26% of household income and are grown for food as well as cash crops (Alulu, Abay & Jensen, 2020; COMESA ACTESA, 2010). Historical analysis of climate data for the region shows a decline in rainfall and an increase in temperature since 1970s (Gioto, Wandiga & Oludhe, 2016; Recha, Makokha, Traore, Shisanya, Lodoun, & Sako, 2012).

The two crops form principal staple food accounting for about 26% of farmers' income. Although Tharaka Sub County lies in the southeastern marginal agricultural

area, it has three main livelihood zones as mixed farming (MF), marginal mixed farming (MMF), and rain fed cropping (RC). The marginal mixed farming comprises the main livelihood zone occupying over 75% of the sub county (FAO, 2014). A large population of the residents in this sub county rely on national relief food and local open-air markets for their food needs through purchases (Marangu, Audi, Mgonja & Mburu, 2014; KFSSG, 2008). According to the Kenya Integrated Household Budget Survey of 2005/2006 report by KNBS, 2008, at least 50 % of the population in Tharaka sub-county benefit from food relief and aid program. Even with all these interventions, food flow is often hampered by poorly integrated produce markets, road networks and ineffective food policies (KFSSG, 2009). This puts majority the region's population at risk of food shortage and malnutrition (European Commission, 2014; WFP, 2013).

Successive droughts lead to depletion of food stocks for many households with close to 16,300 people needing food aid at any time (KFSSG, 2014; CHF international, 2011). There exists no work as to how the fore said factors have impeded food flows in the study area. Most studies carried out in Tharaka region have focused on households coping strategies to challenges of drought and or climate Change (Smucker & Wisner, 2008). By using Livelihood zones as unit of spatial analysis unlike households as commonly used in other studies, this particular study will assess the influence of distribution systems and market accessibility on the region's food security. The findings are expected to inform current state of inter-regional food security situation and form a baseline to redraft context-specific food security policies for the sub county. To address these challenges, there is need to understand how food distribution systems and market accessibility have influenced food security at the

livelihood zone level. Livelihood system approach of analysing food security takes into consideration geographic areas of a country where people share common options for obtaining food and income and similar access to markets. This is important because it provides a framework to sample geographic areas for on-ground assessment of food security needs given that livelihood patterns will vary from one geographic area to another. Through analysis of market accessibility and food distribution field collected data, the study hopes to get new insights on how local distribution systems and physical accessibility to market problem influence food security across Rainfed cropping, Mixed Farming and Marginal Mixed Farming livelihood zones.

1.2 Statement of the Problem

Frequent failure of seasonal rains in Tharaka sub county lead to periodic droughts and low agricultural productivity. Most families result to purchasing food commodities from available markets (NDMA, 2014; Mclean, 2013). This coupled with high poverty levels (over 40% of population live on less than a dollar a day according to KNBS, 2010), limited access to financial resources and escalating food prices affects household's food self-sufficiency. While agricultural production in Tharaka sub county has a high potential for trade and sustainable household food security, food distribution systems and market accessibility remain the main causes of food insecurity in the region.

According to FEWS.NET (2018) and GoK (2011), inefficient distribution systems and market accessibility problems have contributed to food insecurity in Tharaka sub county a scenario fueled by poor transport networks and the lack of grain bulk storage

facilities. This make farmers sell their produce at lower than normal market prices specifically after harvesting reducing the volume of tradable foodstuff in local markets between planting and subsequent harvesting season. Improving local food distribution approaches and physical accessibility to markets is a probable solution to food insecurity in Tharaka sub county.

Currently, little if any, research has been done in Kenya especially in Tharaka sub county to investigate the influence of food distribution systems and market accessibility on food security at household level. Therefore, this study was conducted to understand influence of local food distribution systems and market accessibility on food security. In order to generate empirical knowledge to inform design of an appropriate food trade system to address local food needs and market-based food security interventions in the sub county, location and utilisation of open-air markets across the RC, MMF and MF livelihood zones was considered.

1.3 General Objective

The aim of this study was to assess the influence of food distribution systems and market accessibility on food security in Tharaka sub county.

1.3.1 Specific Objectives

i. To identify biophysical and climatic factors that determine optimal maize and millet production for the realisation of food security in Tharaka sub county.
ii. To investigate how marketing models for maize and millet influence distribution and retention of food stock by households in Tharaka sub county.

iii. To establish the efficiency of physical accessibility to existing open-air markets and its effect on food security in Tharaka sub county.

iv. To examine spatial distribution and utilisation of open-air markets in Tharaka sub county and its effects on food security.

1.4 Hypothesis

H_0 1: Biophysical and climatic factors do not determine optimal maize and millet production in Tharaka sub county.

H_0 2: Marketing models for maize and millet has no significant effect on quantity of food stocks retained by households in Tharaka sub county.

H_0 3: Physical accessibility to open-air markets does not affect food security in Tharaka sub county.

H_0 4: Spatial distribution of open-air markets has no effects on the utilisation of markets in Tharaka sub county.

1.5 Assumptions of the Study

i. That available data on maize and millet production at Tharaka sub county agricultural offices was current and updated regularly.

ii. That the County Government of Tharaka-Nithi maintained an electronic database on market prices for all foodstuff traded across the thirteen open-air food markets within Tharaka sub county.

iii. That respondents sampled were knowledgeable on food security, food distribution systems and market accessibility issues.

1.6 Justification of the Study

Many studies done on agriculture and rural development have focused on increasing agro-based production (IFAD, 2016; NEPAD, 2003). A few of these studies have looked at the influence of distribution systems or the contribution of market accessibility towards realisation of food security (Minten, 1999; Terpend & Kouyaté, 1997).

In Kenya, majority of the population comprise of net food buyers who depend on local markets and distribution channels (KFSSG, 2008; GoK, 2011, Oxfam, 2012). In Tharaka Sub County for instance, over 50 % of the population benefits from relief food distribution program (KNBS, 2009) yet this region has potential for self-food sufficiency.

Distribution systems facilitate movement of food commodities from farms to the markets where they are needed while market accessibility measures the ease of spatial interaction between food producers in the rural areas and consumers in urban areas (World Bank, 2011; Hooton & Omoore, 2007). Although efficient distribution networks and market accessibility play an important role in promoting food security and alleviation of poverty (Jayne *et al.*, 2010; World Bank, 2002), their contribution to the realisation of fore mentioned has not been adequately studied.

The study is therefore important for contextualizing policies to aid address food insecurity concerns for rural/urban households and small-scale farmers in the study area besides promoting the realisation of the universal right of access to food for all at all times. Consumers as well as food supply and distribution chain actors can

therefore benefit from this study in several ways. These include; strategies on how local farmers can raise the current market share participation, reduction of food transaction costs and reorganization of local food distribution systems to make them more efficient as discussed in the recommendations section of this work.

More so this research is valuable in the context of Kenya's Vision 2030 social pillar and the Big Four Agenda all on food security as well as the second SDG on; Zero Hunger by discussing approaches to aid the sub county achieve sustainable food security, improved nutrition and promote agriculture. Findings of this study will also inform strategies to assist raise productivity of dual-purpose maize and millet food crops and increase its commercialization in Tharaka sub county.

1.7 Scope of the Study

This study focused on maize and millet dual purpose crops grown by households across the Rain Fed Cropping, Marginal Farming and Mixed Marginal Farming livelihood zones of the semi-arid Tharaka Sub County. Analysis was limited to local food distribution systems and food retail market centers periodically accessed by households and farmers for their food needs. Donated or relief foods as well as imported maize and millet cereals brought into the sub county from other regions were not considered in the study.

The study covered the period of 2010 to 2020, a ten-year period of great national, political, economic and social transformations in Kenya which notably resulted to devolution, far-reaching agricultural reforms and accelerated transportation and communication infrastructural development in the country.

1.8 Definition of Operational Terms

Accessibility: In this study it means ability to reach an area easily due to limited distance, reduced traveling cost and short time taken to reach

Bioregion: In this study it means a zone that produces its own food and supplies it to other areas.

Distribution System: In this study it refers to road network and methods used to transport food from the farm or market or vice versa.

Food: In this study it entails crops grown or purchased from local markets and widely eaten by that community.

Geographic Information System (GIS): In this study it refers to a software used for analyzing data about location.

Household: In this study it refers to one family unit headed by a male or a female person

Market: In this study it means a designated area where grains and or livestock are sold or bought.

Remote Sensed Data: In this study, it refers to imageries of different resolutions gotten from satellites

Small holder Farmers: In this study it refers to individuals growing food in land less than 2.5 hectares.

Livelihood Zone: In this study it refers to a geographic area with similar food production systems and income generating activities

Agro Climatic Zone: In this study, it refers to an area with suitable moisture content and right temperature where specific crops are grown.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews studies related to food production, distribution and marketing. The aim of this review is to understand requirements for an effective local grains' distribution and market access framework that can be used in food insecure arid and semi-arid lands. Key variables reviewed are those of food production suitability mapping, common marketing models for food commodities, distribution networks and existing food policies. The chapter starts by examining approaches of mapping food production areas, conceptualizing food distribution channels, followed by a description of the various food supply chain markets initiatives and approaches. It then analyses the requirement for an efficient food distribution system.

2.2 Assessing Availability, Spatial Variations and Accessibility of Food

Many countries in sub Saharan Africa are embarking on strategies to address food insecurity through adoption of policies that emphasize on both food production and income generation (Dorward *et al*., 2004; Matshe, 2009). In Asia as well, improvement in productivity on small scale farms has been effective in reduction of poverty and hunger in rural areas (Rosegrant & Hazell, 2000). In Kenya most of the people derive their livelihood through farming with small scale farmers accounting for 42 percent of all irrigated land under crop production (ASDS, 2010). This shows the important role small scale agricultural production play in determining food security at both household and community levels.

The 2010 Kenyan Constitution states that all Kenyans should at all-time have access to safe food of sufficient quantity and quality to satisfy their nutritional needs for optimal health. Realisation of this aspiration will depend upon food being available when needed and households having enough resources to access it through purchase or own production. Tharaka Sub county lies within the southeastern marginal mixed farming zone and experiences failed rains (Funk, Dettinger, Michaelsen, Verdin, Brown & Barlow, 2008), reduced land area under crop cover (Jayne & Muyanga, 2012) and inconsistent crop production (Ngetich, Mucheru, Mugwe, Shisanya, Diels & Mugendi, 2014). Examining variations in availability and accessibility to food is important in understanding food security needs at local level. Therefore, developing a feasible food distribution strategy for Tharaka Sub County will majorly depend on the knowledge of temporal and spatial variations in food needs requirement. This is often driven by availability of update information disaggregated to specific geographic locations.

2.2.1 Food Availability

According to food security studies, availability addresses the supply side of food security. In this study food availability is considered in terms of domestic production, household food stock levels and food trade. It has been acknowledged in research and policy that due to the high population growth and rapid depletion of natural resources, food security in sub Saharan Africa can be realised through increased agricultural productivity (Lipton, 2012; Pedro, Sebastian, Michael & Alex., 2016). In particular, farm productivity has the potential to sustain food security as it offers an alternative source of food in situations where food needs cannot be addressed through trade or imports (UNDP, 2012).

As the demand for food increases in the region, it has created potential for increased agricultural production (OECD/PBL, 2012). This is needed to bridge food consumption gaps catalyzed by levels of increased food intake from the growing population. The increased food consumption gaps will be closed up if more food is produced through expansion of agricultural land and improvement in productivity (Hilderink, Brons, Ordoñez, Akinyoade, Leliveld & Lucas, 2012). Enhancing food trade through reduction of trade barriers and improving market efficiency will address issues of food demand and supply imbalances in markets (Abdulai, Diao & Johnson, 2005). For small scale farmers in sub Saharan Africa, farming has potential for increasing yields of food staples besides providing an opportunity to diversify production and consumption. Given a growing interest in local food production due to natural resource related agricultural production capacity, understanding location and scale of production can inform geographic variation in intra-region food availability. Assessing quantity of food produced in food insecure subsistence farming areas would help identify households in need of food as well as locate productive regions. Often, estimation of cultivated area is good measure of food production at local level given that large variation in subsistence crop production usually occur at the sub-national level.

Inconsistent production at this level therefore is attributed to lack of update data on the size of cropped land and location of farms. In the arid and semi-arid lands of Kenya, most of the markets are weakly integrated both amongst themselves and with the main markets (WFP, 2013). Access to affordable and nutritional food is often hampered by poor infrastructure and long physical distances to food markets due to

sparsely located domestic markets. The situation is no better also for small scale farmers in the high and medium potential areas due land subdivision where they own less than 0.5 hectares on average. This has reduced the capacity of the available land to sustain food production and cash crop farming. Due to this the rural households are now market dependent for their food needs with majority of them purchasing up to 76 % of their food (WFP, 2016).

Unavailability of such food could be determined by spatial variations of biophysical conditions among other socio-economic factors. This work assessed variations in production potential and suitability thresholds of the different livelihood zones and how these variations could influence food availability. Agro-climatic and pedological maps were important in identifying the areas with high maize and millet production. Food resources were mapped across the sub county to show their spatial variations and profiling food insecurity by LHZ as determined by their suitability thresholds. This is crucial in understanding demand and supply imbalances of maize and millet across the Tharaka region. Areas that were found suitable for maize and millet production were in mixed farming, marginal mixed farming and rainfed cropping livelihood zones.

Crop production in the sub county has been dropping over years due to land use intensification and poor rainfall patterns (NDMA, 2016; Smucker, 2003). High food prices, resource-based conflicts and inefficient market systems also interrupt crop production in the region (CHF, 2011; Ngare, 2014). Previous studies done in the same area have shown drought coping strategies and household livelihood strategies have

changed due to climate change and macro economy policies associated with Structural Adjusted Programs of 1990s (Thomas & Wisner, 2008).

In most rural areas across Kenya, access to affordable and nutritious food is often hampered by unavailability of quality food within reach distances. Due to diverse agro-ecological settings in this sub county, mapping of maize and millet production suitability areas will show demand and supply patterns of the two crops across mixed farming, marginal mixed farming and rain fed cropping livelihood zones. This geographic depiction is important for showing zones of potential productivity against those with deficits across the livelihood zones. Approach adopted is of identifying areas of suitable maize and millet production based on agro-climatic and pedological mapping. High risk areas will be deemed as those falling outside the suitability areas for maize and millet production. Mapping of food resource availability across the sub county will show a spatial variation in food insecurity by profiling LHZ based on suitability thresholds. This is crucial in understanding demand and supply imbalances of maize and millet across the region. Previous studies done in the same area have shown drought coping strategies and household livelihood strategies have changed due to climate change and macro economy policies associated with Structural Adjusted Programs of 1990s (Thomas & Wisner, 2008). Recent research has shown how it is possible to estimate small scale food crop production using remote sensing data (Marshall, Husak, Michaelsen, Funk, Pedreros & Adoum, 2011; Bauer, Hixson & Davis, 1978).

Other studies have used Normalized Difference Vegetation Index (NDVI) to estimate small-scale food production (De Beurs & Hereby, 2004; Funk & Budde, 2007). In

related studies, data on landscape characteristics, rainfall and vegetation cover has been used to estimate land area under cultivation (Husak, Marshall, Michaelsen, Pedreros, Funk & Galu, 2008; Rojas, 2007). A recent study by Grace, Greg and Seth, 2014 on estimation of agricultural production in marginal and food insecure areas in Kenya using very high resolution remotely sensed imagery showed that cultivated area and landscape characteristics were dependent on livelihood zone. This is why this study uses livelihood designation to understand and monitor variation in food production. Close review of studies done on estimation of cultivated areas using remotely sensed data have shown that such approaches require high resolution images to get information on what is growing at farm level. By mapping food availability at a sub-county level, this research seeks to make available empirical data useful to improve scientific understanding of small-scale agricultural production and related spatial food insecurity outcomes.

2.2.2 Food Accessibility Issues

Food may be available in one region and yet not reachable by those in need due to issue of food mobility from farms to markets. Generally, accessibility defines the ease with which people and regions have physical access to food. Often food markets play an important in ending hunger by linking food production areas with consumption zones. Therefore, well-functioning food markets enhance food security by spurring diversification of food systems (WFP, 2009). The contribution of market-based approach to addressing food insecurity has been advocated by scholars and institutions alike (KSSF, 2009; FSD, 2012). It has been argued in several circles that markets must be able to efficiently distribute food from surplus to deficit areas in structural food deficit countries (OXFAM, 2006; Matteis, 2010). However, this is not

the case in most instances due to issues to do with market related dynamics of food demand and supply and physical accessibility to food markets. For instance, existing literature on market-based food security interventions show that most of the markets in the arid and semi-arid lands are weakly integrated both amongst themselves and with main supply markets. This limits intra and inter- regional food flows through trade from the food rich areas to the food deficit regions.

In assessing variations in food accessibility, different methodologies and data have been used. For instance, Geospatial tools have been applied in food security studies to map spatial variations in food access and to identify areas underserved by food markets. A study by Wauchope and Ward, (2012) in the United States on how to map food insecurity and food sources in New Hampshire cities and towns, showed how accessing food in these urban areas was influenced by distance and socio-economic attributes of the residents. In this particular study, food insecurity risk mapping methodology based on poverty index data and population density data was used. The resultant maps showed that rural areas had more pockets of unmet food needs compared to the urbanised regions due to low population density and high poverty.

The same study found out that places most vulnerable to food insecurity also had shortage of food sources. Additionally, the study revealed how the quantity and quality of retail food sources and the availability of public food program sites declined with lower population density. Crucial factors identified as determinants of access to food were identified as traveling distance, availability of food, population density and poverty. Although the focus of this research was on towns and cities within Hampshire County in the United States, the study revealed that access to food

though a basic human right is also a challenge in the perceived urbanised societies. Major methodological gap with this study is that it did not explicitly calculate mean distances families had to travel to access food in towns from their homes or still attempt to explore strategies used by the disadvantaged families in overcoming challenges of access to food in those cities which had limited food options.

Another study by Marc Elgin and Frank in 2006 on spatial distribution of food outlet types and quality around schools in Atlanta, United States using GIS methodology measured variation in food accessibility using walking distance and income. The study found out that income influenced food availability more than the distance people walked to get that food. This research justifies income as a major determinant influencing food availability at household level. This is because it dictated what food was purchased for consumption and the quantity bought. While most research works reviewed this far have showed how access to food vary with distance, income, location and availability of vehicles, others have looked at constrains associated with access to food (Michele *et al*., 2012; Rose & Richards, 2004). A review of many studies did on application of GIS in mapping access to food at deferent scales of analysis and in different contexts have shown a consistent positive association between proximity and accessibility to food. This supports the idea that people will consume locally produced food because such food is found in most nearby markets and often is cheap compared to those brought from other regions.

Other studies in this domain have looked at factors influencing food access by individuals, households and community. For example, Shaw in 2006 identified disability as an important factor that influences food access by individuals with

disability. This was due to lack of basic infrastructures in markets like ramps that facilitate mobility within the market. Others have pointed out physical barriers, personal resources and government support as factors determining food accessibility (Borg, Larsson & Ostergren, 2011; Shannon, 2016).

Most of the reviewed studies in this domain have focused on comparative analysis of food availability and access. These studies have shown food security manifests itself in different forms across developed and developing countries. Identified gaps revolve around the approaches adopted in addressing food security challenges from a pragmatic and theoretical view point. This particular study will use dataset on climate, soil, market access and livelihood dynamics to analyse holistically food production variations and vulnerabilities. Through modeling of potential Maize and Millet production areas across the livelihood zones, this research aims to map staple food availability and vulnerability across the semi-arid rural Tharaka households. Collection and utilisation of livelihood and village level datasets in mapping maize and millet growth suitability areas will help profile spatially the availability of the two food crops across the sub county's wards.

2.2.3 Geographic Information Systems and Food Security

Geographic Information Systems is an information system integrating science and technology. It is used to gather, store, manipulate, analyse and visualize geo-referenced data (Burrough, 2001). GIS is also a decision support tool and can be used to identify areas that are suitable for different activities.

In the context of this study, GIS was used in measurement of physical accessibility and in identifying suitable areas for maize and millet production as determined by area environmental conditions. Suitability of land for agricultural production is determined by soil properties, climatic conditions and terrain characteristics. A study by Kalawa (2014) on developing suitability model for optimised production of ground nuts in Meru County found out that the suitability for the crop depended on weighting of all factors of production influencing groundnuts yields. This study though it shed more light on possible cropping patterns, it did not identify land suitability on the basis of agro climate zones. This modeling involved intensive data preparation and analysis such as criterion weighting which requires appropriate model building tools.

In this study besides moisture availability and temperature variables, soil properties and landform were considered because they largely influence crop productivity patterns in the area. On the other hand, the use of GIS in analysis of physical accessibility has been well established in the fields of health care and emergency planning (Guagliardo, 2004; Shuaib, 2007), transport and retail site analysis (Salonen, 2014). Locally, studies on the use of GIS in measuring geographical accessibility have widely focused on evaluation of physical accessibility to healthcare facilities at county and national levels (Ouko, Gachari, Sichangi & Alegana, 2019; Noor, Alegana, Gething & Snow, 2009). Geographic accessibility analysis for markets and its influence on utilisation of these facilities for food insecurity intervention has not received much attention both locally and internationally. This study will apply GIS based methodologies in examining spatial distribution and levels of utilisation of existing markets by households in rural semi-arid Tharaka Sub County.

2.3 Evaluation of Marketing and Food Distribution Channels

In any economy, distribution and marketing systems play an important role in addressing food insecurity. Farmers throughout the world raise crops for their own consumption but they largely depend on purchased food from local markets. This is because no farmer can produce all the food needed at any given one season. An analysis of studies from Latin America and Asia alone show majority of the small-scale farmers spends in between 68 and 76 percent of their family income on purchased food (Heinz, 2000). In East Africa, agricultural markets serve a large portion of households and are characterized by small volumes of marketed products as well as long transaction chains between farmers and consumers (FAO, 2011). Often local markets are inefficient and poorly integrated within selves and with other regional markets posing a challenge in addressing food security needs through market-based interventions. In Kenya, majority of the households' dependent on periodic food markets for most of food purchased. For instance, rural households purchase around 76 percent of their food for consumption (WFP, 2016). Usually market integration and food pricing to a large extent determine household food security in arid and semi-arid areas. This is because most of the food commodities traded in these areas are brought from other regions. Markets contribute to food availability, food access, food stability and food utilization by acting as centers where households can get diverse food supplies (KFSSG, 2008).

Globally, demand for local foods is on increase and farmers are striving to meet this consumption gap by expanding and diversifying their farming operations. This increase is attributed to the fact that local food commodities contribute to the growth of local economies (Kotler & Armstrong, 2006), enhance food security helps in the

preservation of local heritage (KFSSG, 2008) and are fresh. Buying food from local outlets contributes to the vitality of local areas through wealth creation and enhancing development of food trade businesses. This in turn promotes diversification of food items and stabilises prices of food commodities in the local markets (Du Puis & Goodman, 2005). Local food supply and distribution networks often mitigate food shortages by providing consumers with alternative food commodities and retail outlets.

Due to high level of competition, producers employ a variety of strategies in marketing their products. Most staple food commodities especially dry maize and beans have not found their way into supermarkets forcing consumers to visit farmer food markets. Open air markets where food items are periodically sold on certain days of the week form major food hubs in most urban areas. Small-scale farmers often use periodic retail markets and rural assembly markets to sell their produce mostly to consumers. Market places play an important role in supporting food distribution through convectional as well as formal market channels (Jayne *et al*., 2002). Given the different market structures in the country, design of efficient food marketing system has the potential to enhance income growth and raise productivity for small scale farmers (Jayne *et al*., 2002; Ngare, 2014).

In direct market channels, sale outlets are usually in form of farm stands, farmer's markets, and Community Supported Agriculture farms. These outlets form local food distribution system for they can be found in local open-air markets. In Kenya, farmers serve local consumers in periodic retail markets within rural areas (Dijkstra, Meulenberg & Tilburg, 2001). This approach ensures consumers have an opportunity

to connect and interact directly with farmers as they sell their produce (Kolodinsky & Pelch, 1997; Hinrichs, 2000). On the other hand, non-direct food marketing channels which include cereal stores, supermarkets, groceries and consumer cooperatives have major limitations in that they tend to physically separate farmers from consumers in the supply chain. From the consumer point of view, this reduces direct interaction and the inconveniences of searching for local foods by consumers themselves (Kotler & Armstrong, 2006). For the farmers the advantage with this market system is that time spent and money used for moving food items from the farm to the market is saved and could be used for other household supporting activities (World Bank, 2011).

2.3.1 Food Marketing Systems

Markets regardless of their size and type enhance access to food commodities. Through price stabilization and income generation for farmers, markets influence food production. In developing countries, food markets enhance food supply by ensuring food flows from production areas to needy regions (Barrett, 2008). In Kenya, markets and local food business networks bridge food deficits created by small volumes of production and lack of adequate food storage among small holder farmers.

Most harvested local food commodities are sold by the farmers in periodic retail rural markets. Convectional food marketing system is segmented into formal and informal. Formal marketing channels are characterised by large trade volumes involving international suppliers and large-scale commercial farmers, well specified standards, accessible market information and a legal framework to address contract disputes (Wambugu, 2005). On the other hand, informal marketing systems have low production of traded volumes serving mostly small-scale farmers (Jayne *et al.*, 2007).

These markets facilitate the movement of food commodities across food surplus and deficit regions (KFSSG, 2008). Profiling and delineation of local areas as spheres of land, people and businesses supplying a region with food is crucial in understanding the local food distribution and supply chain from the farmer to consumers . According to USAID 2013 report, close to 70 percent of Kenyans are market dependent and net buyers of most food consumed in their households. Due to drought and limited crop production in arid and semi-arid lands, households in these areas rely on markets and food assistance for all of their food needs (GoK, 2012).

Reviewed research done in Kenya on food market systems have dealt with maize cereal market liberalization strategies and market forces of demand and supply (Nyoro, Kiiru & Jayne, 1999; Karanja, 2002; Nzuma, 2007). Other studies have applied econometric modeling in analysing market efficiencies, integration and food commodity pricing across rural markets (Nzuma, 2007). Generally, food distribution channel will bridge the gap between production and consumption thereby creating time, place and possession utilities (Mwangi, Theuri, Kinyua & Muchiri, 2015).

A close look at channels of distribution show that food distribution and supply networks consist of downward and upward flows. In the downward flow, goods are moved from producers who own means of production to consumers who use these commodities. Upward flow involves transfer of marketing information and cash payments made to producers by consumers for goods bought. Depending on the type of channel and number of actors involved, food distribution channels can be short directly linking producers with consumers or long indirectly linking producers to consumers through middlemen. In a case of producer-consumer distribution, no

middlemen are involved and that farmers directly sell their produce to the consumers through salesmen, direct mail or own retail stores.

In the producer-retailer-consumer channel, farmers sell their products to retailers who later sell to the ultimate consumers. Such channels are suitable for commodities of high value and long shelf life such as electronics and hardware. Although this channel is not good for food commodities, it is widely used by small holder farmers in the region for they lack a collective action for produce market access. Another approach used in food distribution is the producer-wholesaler-retailer-consumer. In this channel the farmer sells produce to wholesalers who in turn will sell to retailers after which retailers ultimately sell to the consumers. This method is suitable for produce having a wide geographical market range of more than 400kms. Another distribution channel is the producer-agent-wholesaler-retailer-customer in which three middlemen are involved. Normally the agents distribute products among a few wholesalers who then distribute the same product among retailers to sell to the consumers. This channel is not suitable for food produce as such products do not require wider distribution and the long chain of market actors. Studies on food marketing in developing countries have showed that agricultural products are transported differently to the markets. For short distances, porters, carts and donkeys are used while buses and trucks are used for long distances.

The findings from these studies and other related works affirm that flow of food commodity, information and price transmission across markets is influenced by the volume of food produce, the type and number of middlemen in the supply chain. This study will analyse food marketing systems as food sheds which serve a wide range of local food distribution networks. To achieve this aim, variations across the rainfed

cropping, mixed marginal farming and marginal farming livelihood zones food production potential and food needs was assessed using geo-spatial, climatological and soil data.

2.3.2 Food Needs Assessment Approaches and Strategies

Community targeting is used in identifying vulnerable household and persons in need of food in rural areas of the ASALs. This approach promotes community participation and leadership in the distribution of food rations at local level (Katal & Lopez, 2001; GoT, 2001). By this, beneficiary communities identify and target the most vulnerable households in their communities and as such the locals manage food distribution process on their own. The approach proves an efficient form of food distribution strategy with most food reaching the target areas and population on time. The volume delivered is often documented using established forms in local language, offloaded, counted, stored in secured facility and then guarded within a centralized area before redistribution. The target community is then informed of beneficiary names, ration size entitlement, total quantity of food to be delivered, site of final distribution point, and date of distribution (JEFAP, 2003; WFP, 2002). This mechanism can be used to ensure an efficient food distribution in food insecure regions which depend mostly on national food supply program rather than the local food markets. The limitation with this approach is that it cannot serve a wide area and even population as food is channeled through ear marked and identified points of distribution. The fact that not all consumed food commodities can be produced within one area calls for the development of an appropriate context-specific food distribution channels.

2.4 Information Communication Technology (ICT) in Marketing and Production Systems

Development of ICT has facilitated the use of technology in agricultural production as well as provision of market information and knowledge (UNDP, 2012). Globally there is increased use of mobile phones, computers and wireless computing. The use of ICT has the potential to transform social, economic and political life (Thirumavalavan & Garforth, 2009; Muchena, 2008). ICT based extension services in Africa have enhanced commodity related information flow and connection of farmers with markets. In agricultural field, ICT has been used in accessing information on commodity prices, transport, storage facilities and other general advice related to agriculture (Gakuru, Winters & Stepman, 2009) In the case of Ethiopian Commodity Exchange (ECX) the use of ICT feeds famers with market data through text messaging, electronic display boards and telephone calls (World Bank, 2009). In Kenya, diverse sources of ICT based agricultural market information systems exists (Ogutu, Okello & Jakinda, 2012). Such include M-Farm and E-Farming (Situma, 2013) and Mobile phone services (Sandra, 2013; Okello, *et al*., 2010).

A study by Nyaga (2012) found out that information delivered to farmers by extension agents was not ICT supported. The study pointed out need to use information and communication technology (ICT) in identifying new markets and in dissemination of information to agricultural producers. Langat, Litondo and Ntale (2016) review of Information Communication Technologies and marketing decisions among small scale farmers in Kenya showed that ICT play a crucial role in local food distribution and making of informed marketing decisions among small scale farmers. The study further pointed out the need to enable small scale farmer's access

information through setting up of functional integrated information systems in rural and urban-poor communities. Small scale farmers' lack of access to information about agricultural production and markets limits their abilities to make profit and take risks (Gunga, 2008; Munyua & Stilwell, 2009). From the literature review the potential of ICT to support agricultural sector revolves around optimisation of production potential and access to markets through provision of information and networks. Most studies in this field have focused on impacts of integrating ICT tools in the livelihood of small-scale farmers (Kibet, Langat & Obare, 2011; Kizito, 2009).

Studies that have examined accessibility and utilisation of information systems have pointed out awareness of information existence as a key challenge to its utilisation in agricultural marketing (Ameru, 2019; Karani & Wanjohi, 2017).

Others have looked at the challenges hindering adoption of ICT in agriculture (Kalusopa, 2004). This in turn has increased opportunities of marketing ICT services in agriculture. Identified gaps in the reviewed ICT related studies show a need to focus on approaches of increasing uptake and use of ICT tools by small scale farmers across the value chain. This is because no studies have looked at strategies to increase consumption of ICT by farmers especially in the rural ASALs. This is an important action area with potential to address policy, geophysical and socio-cultural constraints hindering the attainment of food security through access to market and trade information via mobile phones by households.

2.5 Assessment of Business Models and their role in Food Distribution and Supply

Convectional food distribution systems often fail to meet basic food and health needs of many people because of their rigid framework. There is a need to build an innovative distribution solution based on the area's resources to improve access, quality and widespread distribution of good food. A close look at common business models used in the world reveals that different approaches are suited for different conditions. All models can be placed into three general categories as: a) those that focus on developing and supporting producer organisations; b) those that focus on specialised intermediaries; and, c) those that are driven by buyers.

2.5.1 Producer-Driven Model

These models improve negotiating skills and access to service provision as well as provide members with economic benefits such as access to dynamic markets. Such models play important roles from political lobbying to offering avenues for government subsidies (Huang & Reardon, 2008). However, it requires building a network of specialised actors to help achieve similar goals. In Africa many of the benefits achieved by relatively autonomous smallholder-owned and managed cooperatives can be captured if appropriate links are developed with other market actors (String, Coulter, Lucey, McKone & Hussain, 1997). In most cases the choice of either vertical integration or horizontal cooperation depends on cost.

The other Challenge with this model is on sustaining the inclusion of all members, the slow decision-making and limited entrepreneurial focus. A case study done of organisations owned by small-scale producers in the Philippines by Concepcion,

Digal and Uy (2006) revealed that producer organisations allow small scale farmers to collectively market their produce. The study however found out that such organisations may lead to conflicts of interest in cases where membership is heterogeneous. On a global scale, marketing cooperatives are few in number and as such they remain oriented towards the traditional commodity markets.

2.5.2 Buyer-Driven Model

The model allows for the inclusion of small-scale farmers into the agricultural food supply chain through contract framing. The rationale of this approach is to remove the middlemen from the supply chain by increasing direct relation with consumers, businesses and producers. With direct procurement, product assurance and improved quality as well as information exchange and flow are enhanced across the chain actors. An analysis of the various buyer-producer driven models in the world show that challenges of these models range from; lack of direct relations between producers and buyers who in most cases are the organised supermarkets supply chains (Lemeilleur & Tozanli, 2006; Tallontire & Vorley, 2005; Eaton & Shepherd, 2001) and lack of collective action by the producers which force businesses to organise their own supply base through contract farming with medium and large scale producers (Samaratunga, 2007; Reardon & Huang, 2008).

The advantage of this model is that contracting of farmers reduces the risks of periodic food shortage, price volatility and links small scale framers to the modern markets while enhancing commercialization of small-scale production (FAO, 2008; Eaton & Shepherd, 2001; Wiboonpongse, Sriboonchitta & Khuntonthong, 2007). The disadvantage of this model is that it affects small scale producers in respect to volume

and quality of produce especially if standards are applied. In most cases, the buyer invests in the supply network therefore preventing them from selling outside the network. More often it leads to exclusivity of small holder suppliers because the buyer is obliged to fulfill their contractual agreements for specified volume of supply to the customers (Berdegué, Biénabe & Peppelenbos, 2008). The advantage is that these models help identify consumer trends and provide incentives for market driven product and supply process upgrading.

2.6 Analysis of Food Distribution Networks and Supply Chains

In the Food supply chains, networks contribute to the regional development by ensuring sustainability of business activities and competitiveness of regions (Tarantilis & Kiranoudis, 2004; Rushton, Croucher & Baker, 2008; Beckeman & Skjöldebrand, 2007). Transportation of food by extension distribution is important in feeding densely populated places, catering of demand for out of season food as well as allowing regions to specialise in what they can best produce. By this, distribution networks bridge food consumption gaps by linking food abundant areas to food deficit places through movement of food supplies across regions.

Globally, there are concerns that transportation sector alone generates over 25% of the greenhouse gas emissions with road transport contributing over 75% of these emissions (IPCC, 2008; Määttä-Juntunen, 2010). Although this is not part of this study's objective, it shows a great proportion of emissions is from road transport through which a big volume of food stuffs is transported across in the country. In the wake of climate change mitigation debate, reduction of greenhouse gas emissions in transport sector could mean better methods of transportation and assurance of quality food in the long run. In the field of local food supply chains and distribution research,

there are few detailed studies on logistics related activities within the agricultural sector. In Tharaka sub county most of the local food produced is consumed at the household level. Open air food markets supply most of locally consumed foodstuffs especially off season within a road distances of about 15 to 20 km between markets.

A review of the local food market reports shows that the demand for locally produced food is rising and therefore promoting accessibility to local food markets is essential. As pointed out by Bosona and Gebresenbet (2011), uncoordinated and non-optimum food transport systems are some of the major problems affecting local food systems. This is true given that poor transport networks will tend to increase the cost of trading and selling of surplus production by farmers in the markets. However, the need for innovation in food supply and distribution network field has resulted to adoption of new approaches of food distribution as well as scoping. All these initiatives are geared towards efficient logistic management and food marketing strategies. Several studies have put forward suggestions on how to improve food transportation in the local food supply chains through development of new systems of food delivery (Beckeman & Skjöldebrand, 2007), introduction and use of energy efficient vehicles as well as full capacity utilisation of vehicles used in moving food (Wallgren, 2006; Techane, Ingrid, Girma & David, 2013) to those for planning of optimum routes for food distribution (Gebresenbet & Ljungberg, 2001).

GIS based techniques have been widely applied in optimization, suitability and location studies such as optimisation of collection routes (Tavares, Zsigraiova, Semiao & Carvalho, 2009), finding of best location for retail sites (Suárez-vega, Santos-Peñate & Dorta-González, 2012) and simulation modeling of food supply

chain (Van der. Vorst, Tromp & Van der Zee, 2009). A review of studies on analysis of food distribution reveal that GIS based techniques have not been widely used in local food supply chains analysis especially distribution center optimal sites and vehicle routing problem for the rural areas. A study on GIS-based analysis of integrated food distribution network in Borlänge community, Sweden revealed that integrated food distribution networks improve logistic efficiency, food quality and environmental sustainability (Techane *et al*., 2013). A study by Marie-Eve Ran court, *et al* (2013) on tactical network planning for food Aid distribution in Kenya applied a GIS based location model using data on road network, population and needs assessment to determine a set of food Aid distribution centers for the region of Garissa. In this particular study, analysis of existing networks will inform development of optimal routes for food distribution to improve on the local level food supply. The study will apply GIS based modeling of vehicle routing problem, location analysis and needs assessment to identify underserved regions in order to expand food distribution to unmet regions.

2.7 Food and Agricultural Policies and their Implications on Food Security

Kenya is a food insecure country due production, storage and marketing constraints. A look at the national food security situation indicate that the per capita food availability has declined by more than 10% over the last three decades (World Bank, 2011), while per capita consumption of maize has increased by 3% per annum owing to increasing population growth rate of 2.44 per annum (Alila & Atieno, 2006; IFAD, 2013). This shows the need to increase food access through production, local food marketisation and imports. Several efforts have been made to address food insecurity through enactment of various policies (Gitau, Kimenju, Kibaara, Nyoro, Bruntrup &

Zimmerman, 2008). Agricultural policies can be looked at as those supporting consumers, producers, trade and investment. A review of such policies indicates they are short term interventions intended towards attaining food self-efficiency. These approaches however cannot address food security issues in the long term. Through measures such as social safety net and food assistance program, effects of food shortage have been mitigated amongst the vulnerable population without sustained gains. Policies geared towards importation of staple food products has been blamed for reduced trade flows. Others such as price stabilization and producer support though noble policies failed to benefit the target poor producers due to failed implementation of the bills (Jayne *et al.*, 2008). Evaluation of previous national food policy frameworks has shown gaps due to failure in effective implementation of such policies. The National Food Policy Sessional paper 4 of 1981 sought to maintain self-sufficiency in major foodstuffs through equitable distribution of food.

This however did not achieve much because it did not provide for how food distribution would be done besides the government intervention. The second National Food Policy Sessional paper 2 of 1994 adopted a broad approach by seeking to address food security through market intervention approaches. This framework achieved little due to lack of implementation and coordination guidelines. Due to the shortfalls in the initial two food policies, the new Food and Nutritional Security policy (FNSP) was formulated in 2011 as a multi-sectoral approach to all food security issues. One of the objectives of the policy is to increase the quantity and quality of food available, accessible and affordable to all Kenyans at all times. County governments have the responsibilities of formulating and reviewing policies agricultural sector in line with national policy especially those to address food

security (Constitution of Kenya, 2010). A study on review of food and agricultural policies in Kenya (MAFAP, 2013) highlighted the need to assess investments and policy changes from a holistic point to understand the causes of past failures in policy. The study further emphasized the importance of consultative coordination amongst all actors. To achieve collective engagement, information is crucial in formulation and review of policies relevant to counties as per sectorial context needs. Development of programs to address food security and Agricultural/farmer advisory services often a time is through amendment of existing national policies to suit each county. This study will review marketing and local food distribution mechanisms in Tharaka Sub County to assess policy gaps to inform development of appropriate food /agricultural policies at a livelihood zone level.

2.8 Utilisation of Markets and their Geographic Accessibility

Utilisation patterns of markets for food needs define the status of food security at local level as it indicates how such facilities are put into use. The number and types of markets available in any area is greatly influenced by government and local factors especially the crops grown in the said areas, socio-economic status of the population and urbanization levels. Availability of markets influences demand for as well as supply of services by immediate population and therefore patterns of market utilisation is indicative of preferences by target population. Often patronage of open-air markets is determined by the socio-economic status of the population which could translate to the buying power of the people. Theories on utilisation of markets are not well developed as seen from other service delivery accessibility studies (Mazzilli & Davis, 2008; Manzoor, Hashmi & Mukhtar, 2009). When it comes to accessibility,

distance plays an important factor influencing utilisation of service provision facilities (Buor, 2003; Castella, Pham Hung, Suan Pheng, Villano & Tronche, 2005).

Access to services is influenced by financial resources as well as knowledge of the existence of these services in the first place. Physical accessibility determines utilisation of markets because it defines ease of reaching markets by users especially the farmers and consumers. Geographic accessibility can be computed in terms of travel time costs or distance from the user to the market location. Often physical accessibility is calculated using Euclidean distance, road network analysis or travel time (Marc Elgin & Frank, 2011; Gabrysch, Cousens, Cox & Campbell, 2010). Generally, physical accessibility to markets influences their utilisation by intra and inter-region's communities and this enhances market integration. At the center of physical accessibility and utilisation of market services is location. Location theory is a well-developed theory and has been applied widely in the field of industrialisation. Today this theory has found application in other areas like health (Bhatti, 2005; Gage & Guirlène Calixte, 2006) and rural service center accessibility analysis (Mallick & Routray, 2001).

Generally physical accessibility to markets influence utilisation of these facilities by intra and inter region communities enhancing market integration. At the center of physical accessibility and utilisation of market services is location especially distribution of these markets. However, literature on location theory is well developed and applied in the field of industrialisation but of late has started gaining ground in the area of health care. Since utilisation and market accessibility are key factors to understanding food security spatial variability, this study will assess how spatial

distribution of open-air markets influence utilisation of such facilities given their functional and geographical location disparities.

2.7 Theoretical Framework

Theoretical framework guides research with a formal theory which is constructed using an established, coherent explanation of certain phenomena and relationships (Eisenhart, 1991). Therefore, it is the foundation from which knowledge is constructed for a research study. On this note, this study will be guided by the theory on determinants of access to food resources (Shakey, 2011); theory on entitlement (Sen, 1981) and livelihood approach (Ellis, 2000). All the three theories emphasize access to resources as a determinant in the realization of sustainable food security in rural livelihoods.

2.8.1 Theory on Determinants of Access to Food Resources

This theory was developed by Dean and Sharkey (2011) to conceptualize food insecurity and the likely determinants of access to food resources. The model aims to explain factors that determine access to food security and how these factors affect food security at household level. According to Sharkey, access to food is influenced by personal characteristics, location of residence and a myriad of intervening variables especially those relating to access on food programs and economies of distribution. In this study accessibility to food markets and economies of distribution for food commodities locally determine households' food security. The theory on determinants of access to food resources is useful to this study because it gives an insight on the role of access to household food security.

2.8.2 Theory on Entitlement

Developed by Amartya Sen (1981), his research showed how famine could occur amidst plenty and how the normal functioning of markets could also cause famine. That the ability of individuals to access available food is important in determining if or not they become food insecure. According to Sen, an entitlement approach concentrates on the ability of people to command food through the use of production possibilities, trade opportunities, entitlements vis-a-vis the state and other methods of acquiring food. The entitlement theory has four components: trade-based-entitlement, production-based- entitlement, own-labor-entitlement and then transfer entitlement. Trade-based-entitlements occur when during trading one party transfer what they one with another willing party. Production-based-entitlements happen when a party using own or hired resources obtain own production. Own-labor-entitlements are obtained when one is entitled to his/her own labor power. Transfer entitlements occur whereby one is entitled to own what is given willingly by another who legitimately owns it. Based on this synthesis, food shortages arise due to decline in exchange entitlements owing under developed infrastructure and limited income. It is possible that famine can exist in the midst of food availability as long as a group of people have limited access to available food or they suffer food exchange failure. Therefore, this theory is a good tool for analysing differential access to food and explains why households starve while others have enough food.

2.8.3 The Rural Livelihood Approach

Postulated by Frank Ellis (2000) where livelihood comprised of assets, activities and access to them determine the living gained by households. Assets include land, infrastructure, education and membership to social groups. In the rural areas,

livelihood is dictated by physical and human environments which are subject to constant change. Similarly, rural livelihood is diversified by a portfolio of activities that improve survival and the standard of living of households or individuals in the face of adverse shocks. Assets that households own enable members of those households to undertake production, engage in labor markets or even participate in exchanges with other households. Translation of assets into livelihood strategies by a household is determined by economic, social and policy considerations. Social groups like farmer organization provide avenues for small scale farmers to access the market promoting households' food security. On the other hand, policies determine the economic, social and political context in which livelihood decisions are made by the state. Since this research identifies livelihood diversification as key in the attainment of food security, rural livelihood approach theory is used to understand how location of the target population, the assets at their disposal and the opportunities available influence food security.

Although the three theories as used in the study provide a framework to understand how livelihood sustainability and food entitlement impact household and individual food security, these theories have failed to show how the interaction between market accessibility and local food distribution systems influence food security. In this study, physical accessibility to market and organized food distribution systems is conceptualised as central to food security in ASALs. This is because they play a crucial role in ensuring food commodity flows across regions especially from surplus to areas of deficit.

2.9 Conceptual Model

Food security in Tharaka sub county can be achieved if agro-climatic suitability of current maize and millet growing areas is well mapped and analysed. Understanding marketing models used by households to sell and buy food and why such channels are chosen will inform strategies to increase food availability through market interventions. Food distribution systems determine how food flow between households and the market influence amount of food supplied and price set in the local markets. Utilisation of open-air markets for household food needs is dictated by the functionality of that market and its physical accessibility. Nevertheless, local food distribution systems, market accessibility and food security are majorly influenced by stipulated policies and the information communication technology (ICT) types available.

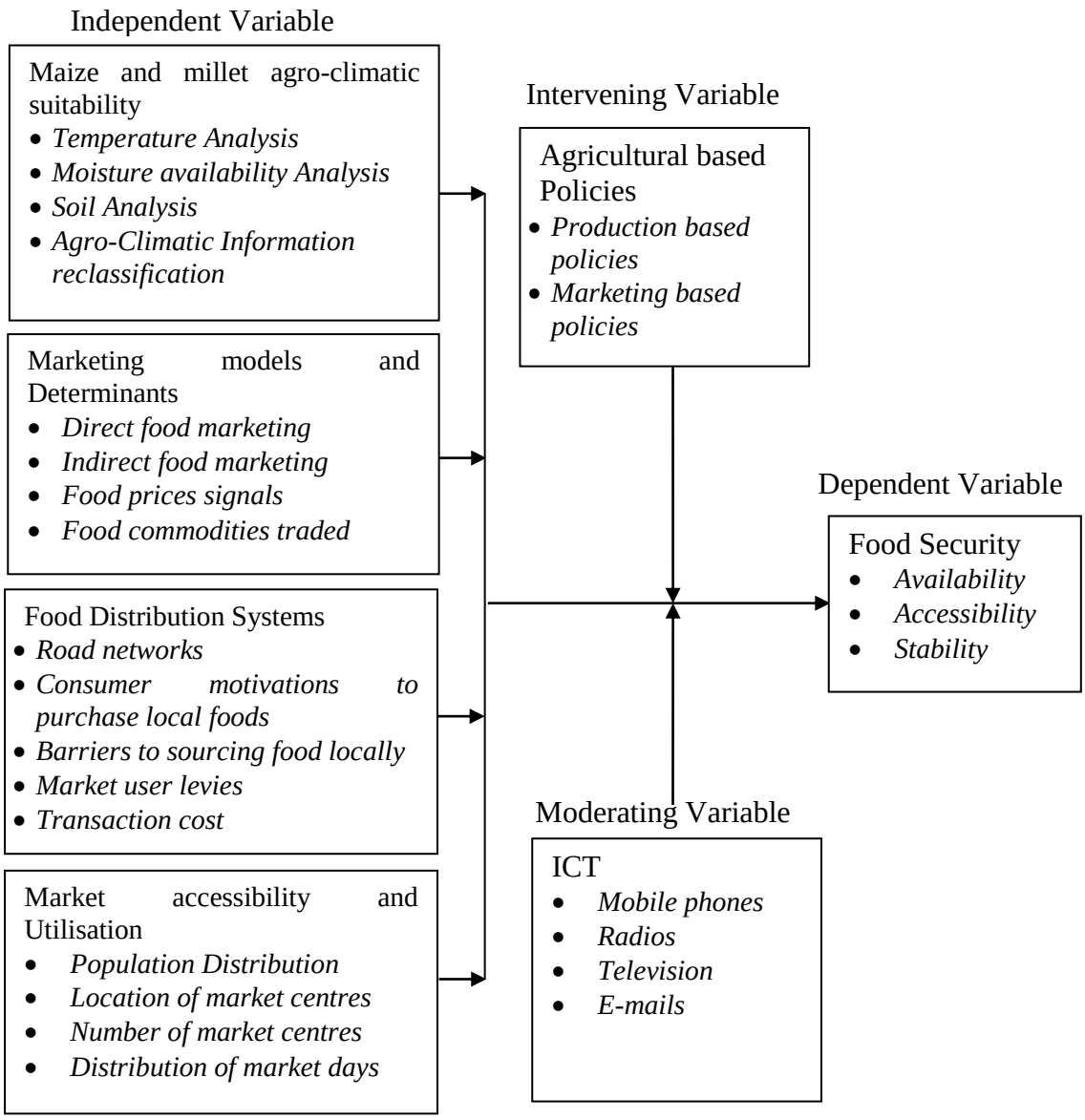


Figure 1: Conceptual model for an enhanced local level food security framework

The schema in the model (Figure 1) describes how food security could be improved through increased food productivity and optimized production of principal staple crops at village level. Through biophysical suitability and crop production mapping; analyses of marketing models; assessment of local food distribution systems and measurement of physical accessibility to markets, problems of food availability and accessibility can be managed at community and household level in the food deficient arid and semi-arid areas.

In the model, moisture availability, rainfall and temperature are considered as the most important agro-climatic factors influencing maize and millet production. It also examines direct and indirect marketing models used by traders and farmers selling or buying from existing remote food markets. Marketing models used are often influenced by commodity pricing in local markets and volume of food stuff available for trade. In the model also, market accessibility is analysed in terms of road network suitability, transportation methods used to move food from farms to the markets and the market levies charged on users. It further examines different constrains faced by households in food production and marketing, as well as analyses of existing policies that govern food security.

2.10 Knowledge and Methodological Gaps identified in the Studies Reviewed

Despite several studies having been carried out on food security in Kenya, few of existing studies are content specific in terms of analysing food availability and food access (WFP, 2013). Considerable gaps in knowledge exist in the literature relating to food insecurity. Most of the available literature has focused on examining indicators and determinants of food insecurity (Riely, Mock, Cogill, Bailey & Kenefick, 1999; Negin, Remans, Karuti & Fanzo, 2009); Land, resources and food security (Rockson, Bennett & Groenendijk, 2013; Ibrahim & Bello, 2009) as well as analysing link between food security and malnutrition (Maitra, 2018; Reis, 2012). Others have examined consumer behaviour (Govindasamy, DeCongelio & Bhuyan, 2006; Carpio & Isengildina-Massa, 2009), food marketing (Argenti, 1999) and staple food value chain (USAID, 2010). Few of existing studies have looked at market in the context of food security (FSD, 2012; Ariga, Jayne & Njukia, 2010). Literature available on food security does not look at food distribution requirements, local food supply chain

dynamics, market accessibility problem and spatio-temporal variation in food security.

At the center of a strong food security is a reliable and efficient distribution system which is determined by market accessibility among other factors. Some studies have analysed the challenges of the current models of distributing local foods and marketing within a spatial and temporal context. Critical reviews of existing research in this field focus mostly on conventional food distribution systems, which are designed to meet certain distribution criteria. For instance, some studies have focused on; management strategies of convectional food distribution systems (Kotler & Armstrong, 2006; Lyson & Raymer, 2000), transportation costs associated with food distribution (Pretty, Ball, Lang & Morison, 2005; Bloom & Hinrichs, 2010) while others have looked at the marketing strategies (Belcher, German & Schmutz, 2007; Onozaka, Nurse & Thilmany McFadden, 2010; Matson & Sullins, 2011).

In Kenya studies carried in this field have dealt majorly with food price crisis and interventions (ReSAKSS, 2009; Nyoro, 2007), food markets efficiency and price transmissions (Jayne *et al*., 2000; Omamo & Mose, 2001). These studies allude that local markets play an important role in food distribution and supply. However, high food prices often discourage consumption due to in affordability by many households mostly those in rural areas and the urban poor. Studies done in Tharaka district have focused majorly on climate variability (Recha, 2013) and Household drought coping strategies (Icheria, 2012; Smucker & Bisner, 2008). A review of studies related to grain marketing in Tharaka area indicates that social networking through farmer groups is not sufficient in facilitating access to better markets (Wambua, 2017).

Another study on increasing food production has shown that conservation agriculture could increase productivity of peasant farmers in Tharaka North and South Sub Counties (Gioto, 2018).

Although the studies are important towards understanding food production and marketing structures amongst small scale farmers in Tharaka region, they do not explore the influence of food production, distribution and marketing on food availability especially access by the rural households across the three livelihood cluster zones. Unlike reviewed studies which adopted a descriptive research design, this study will integrate statistical analysis and geospatial modeling to explore how food distribution and market accessibility can be harnessed and even scaled up as an important policy intervention to address food insecurity in Tharaka region.

This is anticipated to promote growth of small grain production and micro businesses in this semi-arid region, enhance development of local economies and help mitigate erratic food shortages and localised hunger.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This section discusses research design adopted for this study as well as its justification, description of the study area, sampling techniques used and sample size selection formula. Also, sources and methods of data collection as well as various techniques of data analysis are discussed in details in this chapter.

3.2 Study Area

3.2.1 Geographic Location

The hereby referred to as Tharaka Sub County in this study comprises of the two Tharaka North and Tharaka south sub counties. It borders Meru South sub county to the west, Maara to the south west, Kitui county to the east and Meru county to the north. The study area is located on latitude $0^0$07' and $0^0$26' South and on longitude $37^0$19' and $37^0$46' East (Figure 2). The area lies on an elevation ranging between 610 m to 1220 m a.s.l. It is found within a transitional zone between sub-humid highlands to the west and the arid and semi-arid plains to the south and east covering an area of 1569Km^2 (Smucker, 2003).

3.2.2 Population and Administrative Units

This region is occupied by the Tharaka people, a sub tribe of the Meru community. Tharaka sub county has five wards namely Chiakariga, Marimanti, Nkondi, Mukothima and Gatunga (IEBC, 2012). Administratively the region has 21 locations headed by Chiefs and 44 sub-locations under the governance of Sub-chiefs. The area

has a total population of 130,098 persons and 27493 households with population distribution varying across the five wards. Notably, Chiakariga ward has a population of 34,679; Marimanti ward has 32,609, Gatunga ward with 21,421 while Nkondi with 15,574 and finally Mukothima ward has approximately 28,555 persons (KNBS, 2009).

3.2.3 Climate

The region receives bi-modal rainfall pattern which ranges between 500mm in the lowlands to 1000mm in the upper transition zones. Long rains fall through the months of March to May (MAM) while short rains occur in the months of October to December (OND). Short rains are more reliable and therefore used for planting crops than MAM long rains. Tharaka is considered semi-arid with temperature ranging between 22^0C to 40^0C (NDMA, 2014). Major Agro Ecological Zones in this area are Lower Midland Zone (LM4, LM5) and Inner Low Land Zone (IL5, IL6) (Jaetzold & Schmidt, 1983).

3.2.4 Socio-economic activities and livelihood

Agriculture is the main livelihood of the Tharaka sub tribe with at least 92% of the households engaged in agricultural activities (Integrated Smart Survey, 2016). Communities living in this area practice mixed farming and the dominant staple crops grown are maize, bulrush millet, sorghum and legumes (Smucker & Binsey, 2008). The area comprises of low, hilly, stony and sandy lowlands. Major economic activities are crop farming and livestock keeping. The region is classified into three major livelihood zones; marginal mixed farming (MMF), rain-fed cropping (RFC) zone and the mixed farming (MF) zone (WFP/VAM, 2006). Due to erratic drought

and recurring famine in the study area, a lot of food security intervention programs have been rolled out. Programs by the Kenyan Government, Christian Organisations, Plan International and World Food Program support livelihood sustenance in the area. Interventions to food security and livelihood enhancement include strengthening marketing of local produce, support for smallholder irrigation schemes, relief food distribution, school feeding programs and constant relay of early famine warning alerts.

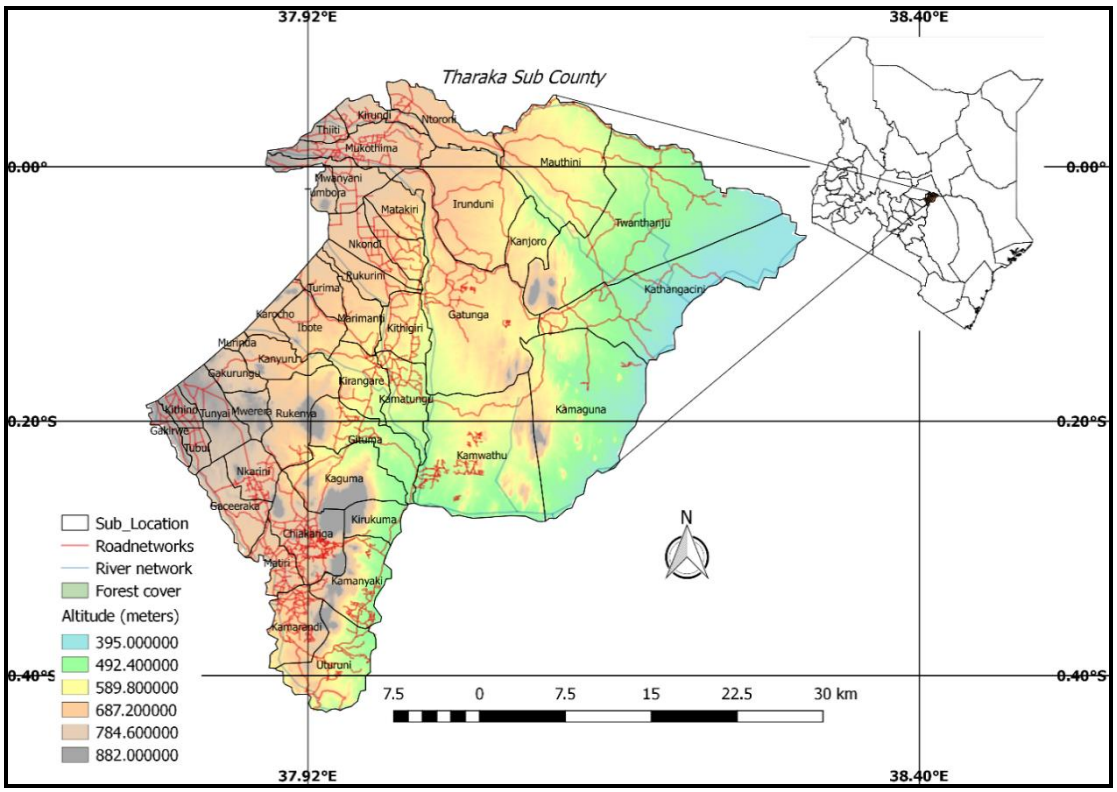


Figure 2: Physiographic map of study area showing 5th level administrative units

3.3 Research and Sampling Design

This research used a cross section survey design to gather context-specific information useful in understanding influence of food distribution systems and market accessibility on food security amongst households in the rural semi-arid Tharaka region. Cross-section survey focuses on studying and drawing inferences from

existing differences rather than change, this design is effective for collecting descriptive and quantitative data on the study problem. Since the study aimed at assessing the influence of market accessibility and food distribution systems, qualitative as well as quantitative data was collected. This study design provided an appropriate analytical framework to study the problem systematically and in details. A multi-stage cluster sampling method was used in this work. The study area was stratified and randomly sampled to get variety of food distribution systems and market accessibility scenarios. Sub locations in the study area were purposively selected in the first stage of this work on the basis of road network and agro-ecological as well as livelihood zones. In the second stage, probability sampling technique was used to select villages proportionate to household size as determined by probability sampling technique.

3.4 Target Population and Sample Size

Study population comprised of all households within the 48 sub-locations and spread across the 883 villages in Tharaka North and South Sub Counties. The projected 2018 Kenya National Bureau of Statistics household Population data for Tharaka District shown the region had 31,556 households. Households form the basic unit of social group at the village level and that the unit comprised of special interest groups of farmers, cereal business owners and target implementers of food security programs within the sub county.

In Tharaka Sub County, household socio-economic activities were used to define livelihood clusters zone which determined opportunities for farming and non-farming for the local population. Since it is the households that are engaged in local food

production systems, consumption and marketization, households' decisions largely influence food security dynamics in the study area. It was therefore important to consider households as target population due to their knowledge base on production and consumption systems. Livelihood cluster zone formed the spatial unit of analysis because it is also used by National Drought Management Authority in the study area to assess and classify drought and early famine warning alerts.

Tharaka being a semi-arid region, early famine warning alerts have direct implication on household's socio-economic wellbeing, agro-pastoral production as well as in the access and utilisation of resources. A total of 31,566 households from 883 villages in 48 sub locations of Tharaka constituency were considered. They were sampled randomly from the three livelihood zones (Table 1) of Marginal Mixed Farming (MMF), Rain Fed cropping (RFC) and Mixed Farming (MM). A sample size of 395 households distributed proportionately across the three livelihood zones were again selected to be interviewed using questionnaires.

Probability to Population Sampling works well for sampling units with heterogeneous population as is the case of households in the study area which have different socio-demographic composition. The 395-sample size was calculated based on a formula by (Yamane), (1967) as;

$n = N / 1 + N(e)^2$

Where,

N= 31,556 Households

e = margin of acceptable error (0.05)

n = $31{,}556 / 1 + 31{,}556(0.05)^2$

n = 395 Households

The 395 households were randomly sampled from selected villages across the three livelihood zones clusters. The number of households in each livelihood cluster zone was then computed proportionately using:

$$n = \frac{n \times Ni}{N}$$

Where,

n = total sample size;

Ni = population in strata;

N= total population

Table 1: Proportionate distribution of projected household population by livelihood zone

Strata	Livelihood Zone	Household Population	Sample Size (Households)
1.	Marginal Mixed Farming (MMF)	16,942	395*16942/31556 = 212
2.	Mixed Farming (MF)	4,148	395*4148/31556 =52
3.	Rain Fed Cropping (RFC)	10,466	395*10466/31556 = 131

3.5 Data Collection method

3.5.1 Reconnaissance Survey

A reconnaissance study was conducted before the actual field data collection exercise in order to acquaint with the area administrative units and physiography, gain local knowledge on household size and distribution as well as understand the most appropriate method of selecting participating households. Similarly, the pre-field survey was important in planning logistics for data collection and testing suitability of field data collection tools. From reconnaissance survey, it was discovered that out of the five wards in the study area, Gatunga ward which is within marginal mixed farming livelihood zone has the highest number of villages although it was not densely populated compared to Marimanti, Mukothima, Nkondi and Chiakariga wards.

3.5.2 Data Types

Data on maize and millet growing areas, local grain marketing methods, food distribution approaches, market utilisation, existing agricultural policies and ICT usage in agricultural marketing were collected. For purposes of data processing all the datasets were placed into three categories. The first category of collected data was; geospatial data which included: level 5 national administrative boundaries corresponding to sub location, location coordinates of open-air markets, road networks, Hydrographic network, Digital Elevation Model (DEM), soil data and land use/cover data. This data was collected from field surveys, bought from the county KERRA offices and others downloaded from the Kenyan digital soil database website (www.kenyasoil.or.ke) as well as Kenya Open Data portal(www.Kenyaopendata.or.ke).

The second category comprised of statistical data encompassing population data disaggregated to sub location level and household survey data. This particular category of data was purchased from the County Census Bureau at Chuka town. Finally, the last category of data collected was the normative data on road category classification and maximum acceptable speed for each road category which was acquired from the Kenya Roads Board. This data was important in modelling geographic accessibility to food and livestock markets by households from their villages. All the datasets were used in analysing different "what if" scenarios assessed in the study.

3.5.3 Sources and Methods of Data collection

Primary data was collected using questionnaires, key informant interviews, GPS, cameras and direct observation. During primary data collection, a total of 395 households, 9 local cereal traders and 5 key informants were interviewed. Data from household survey was collected using structured questionnaires while that from other local cereals traders was collected using semi-structured questionnaires.

Household surveys were conducted in 30 villages selected proportionate to population size from 28 sub locations across the rainfed cropping zone, marginal mixed farming and mixed farming livelihood zones. 395 households were selected using systematic random sampling and interviewed. Household survey questionnaire focused at demographic characteristics of the households, maize and millet production potentials, storage methods and the marketing channels used by the farmers. Key informant interview was done using an interview guide which focused on the general

food security situation in the region, agricultural production and food storage, market accessibility issues, community livelihood dynamics in the context of devolution and the role of ICT in food distribution and supply systems. The interviewed key informants included; Tharaka South and North sub county agricultural officers, Plan International-Tharaka program officer, cereal trader's association leader and the in-charge county open air markets operations.

Geospatial data was also used in this study and it was collected from different data hubs with login authorization rights granted by the site hosts. These data included; a 30m digital elevation model (DEM) which was obtained from National Aeronautics and Space Administration Shuttle Radar Topography Mission (NASA/SRTM) website (http://www.usg.gov). Population data for the region was obtained from Tharaka Nithi County office for the Kenya National Bureau of Statistics situated in Chuka town. Road network data was acquired from the County Kenya rural roads authority (KERRA) regional office at Chuka town while hydrographic data was downloaded from the World Resources Institute website (http//www.wri.org).Soil data was downloaded as a shapefile from the soil and terrain database for Kenya (http://data.isric.org/).Existing literature and related secondary data were gotten from the review of published and unpublished documents as well as online platforms.

3.6 Data Analysis

Mixed analysis including statistical and GIS based techniques were used. Data quality was maintained throughout the process by carrying out questionnaire checks, data standardization and pre-testing of research instruments before usage in the field. Training of research assistants was also done to provide them with sufficient skills on

field data collection. Participating research assistants were trained basically on how to conduct data collection using household questionnaires, key informant interview guides and on how to use GPS receivers to capture geographic coordinates of open-air markets.

3.6.1 Statistical Analysis

Statistical analysis was done in STATA software version 16 while data processing was done in Microsoft Excel version 2010. Non-parametric Kendall's and spearman's correlation analysis were employed to test formulated hypothesis. By assessing the nature and strength of relationship between explanatory and outcome variables, it was possible to determine if association existed between the variables.

In particular, the association between distance to the market, quantity harvested and food stock stored was tested using Kendall's correlation to understand determinants of households' decision to sell their food stock. Influence of temperature, moisture, slope and soil depth on optimization of maize and millet production was tested using spearman's correlation analysis. Censored Tobit regression was used to analyse the influence of market accessibility, distribution systems and availability of local food crops, marketing information as well as household characteristics on the choice of a marketing channel used by households to sell and buy food stuffs.

Frequency analysis on responses collected from the questionnaires was done while content analysis was carried out on oral market key interviews. Objective two data about quantity of maize and millet sold and price variation across all the fourteen

open air markets was analysed descriptively by computing the coefficient of variation of responses collected from the questionnaires.

3.6.2 GIS based Analysis

Various geospatial softwares were used to collect, transform, integrate and model datasets. These softwares include; QGIS version 2.14. ©, SIGEpi©, Arc Pad 10.2 ©, Idrisi Kilimanjaro© and MS Excel 2010©. QGIS© is open source GIS software that supports spatial analysis and data display. SIGEpi© is a geographic information system in epidemiology and public health analysis developed by Pan American Health Organisation to support health analysis. Arc pad is mobile GIS program developed by ESRI and usually installed into Trimble© GPS receivers to collect field data and support data management while in the field. Idrisi Kilimanjaro is raster GIS and image processing software developed by Clarks labs to support digital satellite image analysis.

Spatial analysis and modeling were carried out in QGIS© version 2.14 and SIGEPI© both vector-based GIS software. Before geo processing, all datasets were harmonized and reprojected to local datum of Arc 1960, UTM zone 37 South to ensure data compatibility. Data on objectives one, three and four were analysed geo-spatially through overlay analysis, cross tabulation, database query and network analysis. For the first objective whose aim was to determine biophysical and climatic suitability of livelihood zones for optimized maize and millet production, data on soil depth and PH, moisture availability, rainfall, evapotranspiration rate and temperature was analysed through building and running a geo-processing model in Idrisi Kilimanjaro software©.

Objective three aimed to examine spatial distribution and levels of utilisation of open-air markets by people in the study area was analysed using point to polygon overlay analysis. For this particular objective, geographic location of markets was overlaid on the study area's boundary polygon shape file to obtain point patterns of markets spatial distribution. To get levels of market utilisation, potential market users were calculated from population within market catchment and compared against the respective sub-location population.

Objective four on how to measure physical accessibility to existing open air markets and its effects on food security involved collection of market locations using Trimble Juno 3D GPS receiver and the calculation of Euclidean distance between market centers and village centroids. Then geographic accessibility was computed using distance to the nearest hub tool and travel time estimation geo-algorithms found in QGIS™ 2.14 version. The calculation of market catchment areas and the computation of critical accessibility index were all done in SIGEPI™. Generally, four categories of GIS analysis mostly used in this study were reclassification, topological overlay, neighborhood operations and connectivity functions especially network analysis.

Table 2: Summary of Data Analysis Methods and Variables Measured per Objective

Objective	Variables tested	Statistical methods
1. To identify biophysical and climatic factors that determine optimal maize and millet production for the realisation of food security in Tharaka sub county	Temperature Moisture content Soil type, depth and drainage Slope	Spearman's correlation, cross tabulation, GIS modelling

2. To investigate how marketing models for maize and millet influence distribution and retention of food stock by households in Tharaka sub county	Education Land cultivated Quantity harvested Transport cost Market price Distance to market Household size ICT utilisation	Censored Tobit regression model, Two-way classification Chi-square
3. To establish the efficiency of physical accessibility to existing open air markets and its effect on food security in Tharaka sub county	Population distribution Location of markets Transport modes used Travel time Distance covered	Inverse Distance Weight Interpolation, Kendall's rank correlation
4. To examine spatial distribution and utilisation of open-air markets in Tharaka sub county and its effects on food security	Distance between markets Population of users Market functional value	Distance Matrix Technique, Nearest Neighbour Analysis

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.1 Introduction

This chapter discusses findings based on data collected and analysed as per the study objectives. Specific objectives were to; (i) identify biophysical and climatic factors that determine optimal maize and millet production for the realisation of food security in Tharaka sub county, (ii) investigate how marketing models for maize and millet influence distribution and retention of food stock by households in Tharaka sub

county, (iii) establish the efficiency of physical accessibility to existing open-air markets and its effect on food security in Tharaka sub county, (iv) examine spatial distribution and utilisation of open-air markets in Tharaka sub county and its effects on food security. Also, data preparation and analysis procedures used are described, presentation of results done and formulated hypothesis tested as well as interpretations thereof. Finally, a summary of major findings is given at the end of each objective.

4.2 Biophysical and climatic suitability for optimized maize and millet production

This objective identifies biophysical and climatic factors that determine optimal maize and millet production for the realisation of food security in Tharaka sub county

4.2.1 Demographic Characteristics of Respondents

The respondents interviewed were females at 53.4% while males comprised of 46.6%. This could be attributed to fact that data collection was done at day time and therefore more women were available at home tending to household chores compared to men who were in the markets and away from home. In terms of age, majority of the respondents were within the age bracket of 30 up to and above 58 years and had different education backgrounds. Nkondi and Mukothima wards had the highest proportion of respondents with post-secondary education while Gatunga, Chiakariga and Marimanti wards had more of respondents with primary education. The survey also revealed that majority of the sampled and interviewed households had on average 4 to 6 and up to 7 family members. These findings agree with those of 2019 Kenya

National Population and Housing Census report which puts the female population in Tharaka sub county higher at 51.7% compared to males at 48.3%.

Table 3: Demographic Characteristics of Households

Demographic variable	Most prevalent in the survey (Percent)	Less prevalent in the survey (Percent)
gender	Females (53.4%)	Males (46.6%)
Age	30 up to and above 58 years (74.2%)	30 years and below (25.8%)
Education	Formal education (77.7%)	Non-formal education (22.3%)
Household members	4 upto7 individuals (75.2%)	1 up to 4 individuals (24.8%)

4.2.2 Biophysical Characteristics and Maize and Millet Production

Besides landform, slope and soil properties especially soil drainage and soil depth suitability were considered to have significant impact on crop establishment in the study area. In order to assess the relationship between soil and climatic suitability, composite soil map clipped to the study area geometry was overlaid on the area's agro climatic zone map. Soil composite map used in the study was downloaded from the International Livestock Research Institute (ILRI) website. Since it was in a different spatial reference system, it was reprojected to the common spatial reference properties of other used datasets in order to ensure compatibility during geo processing. Soil properties considered in this study were soil depth, soil texture, soil drainage and soil PH. These properties influence crop suitability and production potential based on agro climates.

4.2.2.1 Soil type and PH Spatial Distribution

From the overlay analysis, it was observed that soils in the study area varied from clayey, very clayey, loamy and sandy (Figure.3). Based on the Kenya Soil Survey database, Tharaka region has Luvisols, Phaeozem, Ferralsols, Lithosols and Arenosols classes of soils (MoA, 1980). Mapped soils type in the study area were related to the Kenya soil survey database classification. As shown in the derived soil map for the study area in figure three below, Luvisols are the very clayey soils (Pink code), Phaeozem are sandy soils (Purple code), Ferralsols are clayey soils (Yellow code), Lithosols are loamy soils (Green Code) and Arenosols are also sandy soils (Purple code) and thus similar to Phaeozem.

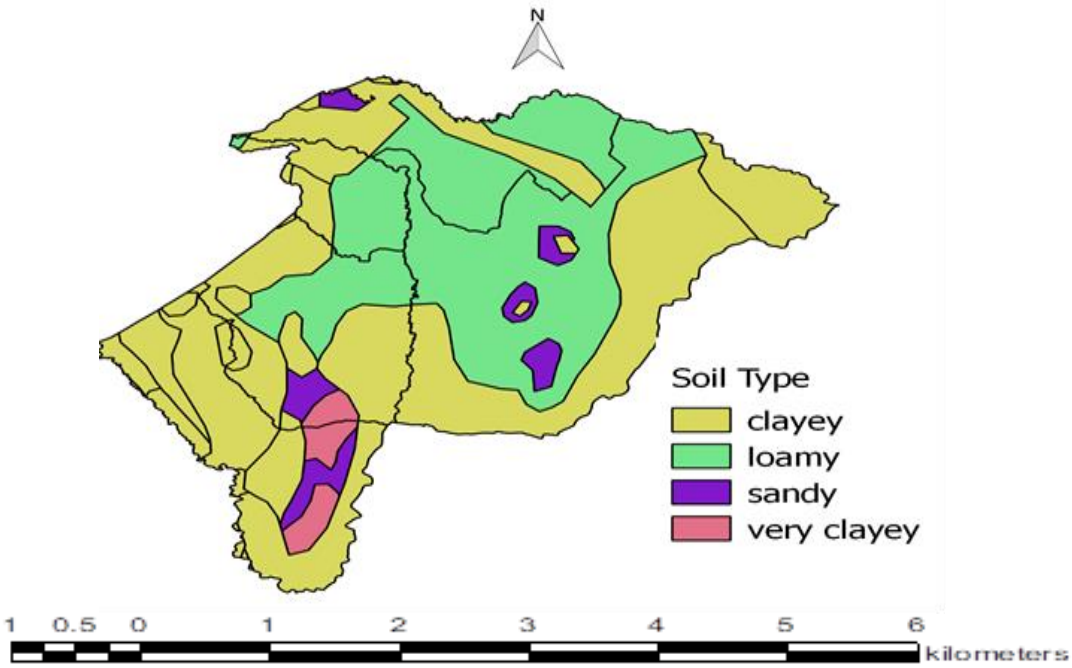


Figure 3: Spatial Distribution of Soil Types in the Study Area (Source: ILRI portal modified by Author)

Luvisols, Phaeozem, Ferralsols, Lithosols and Arenosols are spatially distributed across foot slopes, hills, plateaus, plains and uplands notable landforms in the study area as indicated in Table 2. Soil PH values in the area range from 5.64 to 8.35 (FAO, 1974; MoA, 2014).

Given this soil PH range, the soils can suitably support production of millet and maize dual-purpose food crops in the area having recommended PH of 5.0 to 6.4 for the two crops lie within the region's PH range of 5.64-8.35.

Table 4: Soil Classes and Associated Landforms

Soil Code	Landforms found	Soil Classification	Soil type
F	Foot slopes	Ferralsols	Clayey
H	Hill	Phaeozem	Sandy
L	Plateaus	Luvisols	Very Clayey
P	Plains	Arenosols	Sandy
U	Uplands	Lithosols	Loamy

4.2.2.2 Soil Drainage

It is an important factor influencing crops grown in a given area. Excessive water in the soil due to poor drainage can lead to suffocation of plant roots and eventually death of plants. Ability of soil to hold water influence maturity period of crops as well

as evapotranspiration. Ferralsols and lithosols common soil type in Tharaka sub county was spread across the Rain Fed cropping zone and the Mixed Farming zones. Areas with these soil types were well drained and comprised of loamy or clayey soils occurring on slope of less than 16%. Similarly, these soils were along landforms of foot slopes and uplands. These areas occurring on the western, central and the northeastern parts of sub county were considered suitable area for the production of maize and millet (Figure 4) while areas dominated by phaeozems, luvisols and arenosols were not conducive for the establishment of maize crops and partly millet due to the very poorly draining nature of these soils.

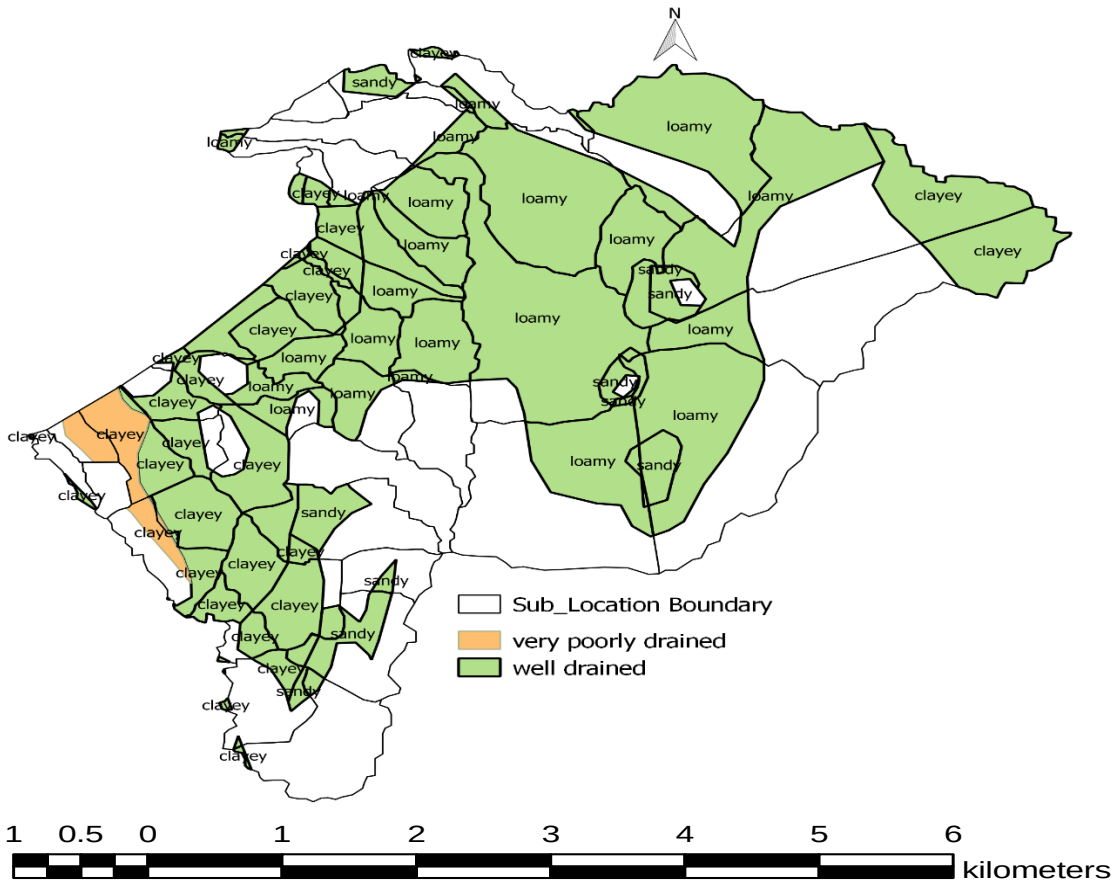


Figure 4: Soil Types and Drainage Properties

(Source: ILRI Portal but modified by Author)

4.2.2.3 Soil Depth

Spatial distribution of soil depth varied considerably across the three livelihood zones as; very deep (120-180cm), deep (80-120cm), moderately deep (50-80cm). Soil depth map showed variation in soil thickness as a parameter from the Kenya soil digital database. From the overlay analysis done on soil drainage capacity and soil depth, rainfed cropping zone (RFC) had very deep to moderately deep soils while mixed farming (MF) had mostly moderately deep soils. Marginal mixed farming (MMF)livelihood zone had deep soils to slowly draining moderate deep clayey soils. These soil depths were found adequate for the growth of maize and millet and other alternative crops since they could retain soil moisture more (Figure 5).

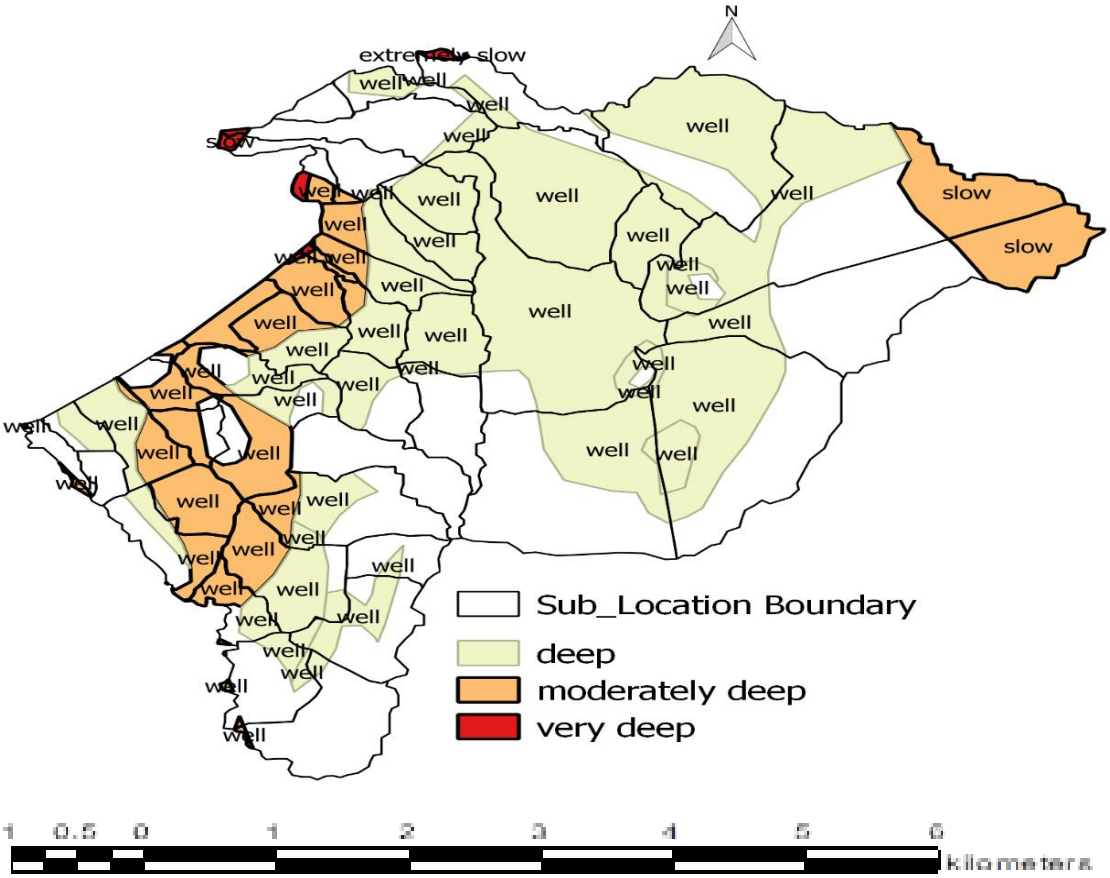


Figure 5: Spatial Distribution of Soil Depth Categories and Drainage Capacity

(Source: ILRI data portal, modified by Author).

4.2.2.4 Slope

It is an important morphometric variable influencing infiltration rate of surface water and by extension the soil moisture. Calculated slope from digital elevation model of the area indicated that the slope ranged from 0.6% to 10% which was classified as Flat, 10% to 18% classified as gently sloping areas and 18% to 26% considered as very steep land. Large proportion of the region's landscape is relatively flat (Figure 6) and comprised of Lithosols and Ferralsols soils. Areas with slope of less than 12% were considered suitable for maize and millet production for they comprised flat and undulating areas (Tashayo, Honarbakhsh, Akbari & Eftekhari, 2020).

Similarly, suitable areas for maize and millet were identified in agro-climate zones 3,5 and 9(ACZ3, ACZ5 and ACZ9).

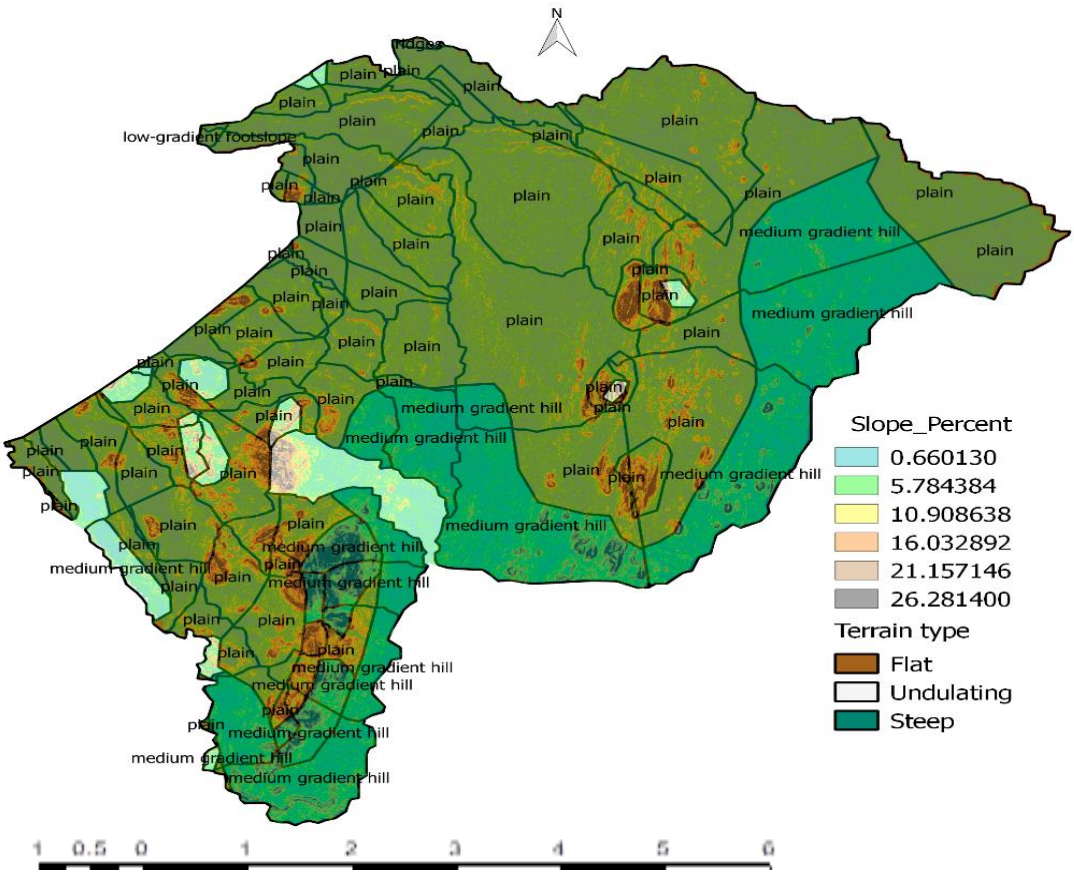


Figure 6: Landforms of the Study Area and Associated Slope Characteristics

4.2.3 Climatic Suitability for Maize and Millet Production

4.2.3.1 Datasets Used

Datasets used in this study were collected from multiple sources. Since the acquired datasets were in different spatial scales, they were all reprojected into Universal Transverse Mercator (UTM) coordinate metric system and datasets resolution harmonized to ensure compatibility during geo processing analysis. All the GIS datasets were referenced to UTM 37 South and projected to Arc 1960 local Datum. Datasets used for this particular objective were soil properties data which was obtained from the Kenya Agricultural and Livestock Research Organisation (KALRO), rainfall and temperature data for the area were acquired from the Kenya Meteorological Department(KMD), Relief data was downloaded as 30m Digital Elevation Model (DEM) from the National Aeronautics and Space Administration(NASA) Shuttle Radar Topography Mission while administrative boundary shape files for the study area were gotten from the Survey of Kenya (SoK) (Table. 3).

Table 5: Datasets used and Sources

Data	Source	Use
Soil	Ministry of Agriculture_ KALRO	Soil Classification
DEM	NASA-Shuttle Radar Topography Mission	Regression
Climate	Ministry of Environment_ KMD	Agro-climatic Mapping
Administrative boundary	Survey of Kenya	Clipping datasets to AOI

4.2.3.2 Data Analysis Done

Data conversion and reclassification was done on relief, temperature and rainfall datasets. All vector datasets were imported into Idrisi Kilimanjaro Software and rasterized through raster/vector conversion module. This was done because raster data unlike vector data allow the assignment of values for each cell in the dataset, enabling a cell-by-cell analysis through map algebra. Since cartographic modeling was used to produce an agro-climatic zoning for suitability analysis of maize and millet growth, temperature and moisture availability were considered important climatic variables for optimised production of maize and millet crops. Temperature and moisture availability images were derived from elevation.

4.2.3.2.1 Temperature Spatial Distribution

Temperature is an important climatological variable influencing cropping especially the duration of crop growth and maturity. Available temperature data from four weather stations in the study area which include Tunyai, Marimanti, Gatunga and Chiakariga was not adequate and updated with recorded data being 86% complete. Because of its incompleteness and inconsistency, it was supplemented with related satellite data for the same period of 2010 to 2020 from NOAA (http//www.noaa.gov). Temperature values were in (^{0}C) degrees Celsius while metric Digital Elevation Model (DEM) values were converted into feet (Ft). To derive a raster temperature map of the entire study area, a regression of DEM against temperature data was done using regression equation (1)

$$\text{TEMPERATURE } (^0\text{C}) = 25.5334 - 0.0011 * \text{ ELEVATION} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In this case, the relationship of elevation as independent variable and temperature as dependent variable was used because in the area as is the case in the country, usually temperature is dependent on altitude. From the analysis, seven temperature zones as T1, T2, T3, T4, T5, T6 and T7 were derived as seen in Table 4.

Table 6: Derived Temperature Clusters for Tharaka based on Altitude

Temperature Cluster	Annual Mean Temp (^{0}C)	Classification	Livelihood Cluster Zone	Altitude(m)
T1	20.0 – 21.6	Very Low	Rain Fed Cropping	943 m a.s.l
T2	21.6 – 22.0	Low to Medium	Rain Fed Cropping	882 m a.s.l
T3	22.0 – 22.6	Low	Mixed Farming	784 m a.s.l
T4	22.6 – 23.0	Medium	Rain Fed Cropping	687 m a.s.l
T5	23.0 – 23.6	Medium to High	Mixed Farming	589 m a.s.l
T6	23.6 – 24.0	High	Marginal Mixed Farming	492 m a.s.l
T7	24.0 – 24.6	Very High	Marginal Mixed Farming	395 m a.s.l

From overlay analysis, it was found that sub locations of Thiiti, Tunyai, Kithino, Gakirwe, Gakurungu, Mwanyani, Kirundi, Turima, Kathuura, Karocho, Ibote, Kanyuru, Rukurini, Nkondi, Mukothima, Ntoroni, Matakiri, Kereria, Gaceeraka, Nkarini and Chiakariga lie within zones that experience moderate to low temperatures of between 22^{0}C to 23^{0}C. Most of these areas support rain fed mixed farming.

Rukenya, Kirangare, Gituma, Kithigiri, Marimanti, Irunduni, Kanjoro, Mauthini, Kaguma, Gatunga, Uturini, Kamanyaki, Kirukuma, Kamwathu, Kamaguna, Kathangacini and Twanthanju sub locations are found in zones with high to very high temperatures range of between 23^{0}C and 24^{0}C. These areas lie in marginal mixed farming where mostly livestock keeping is practiced.

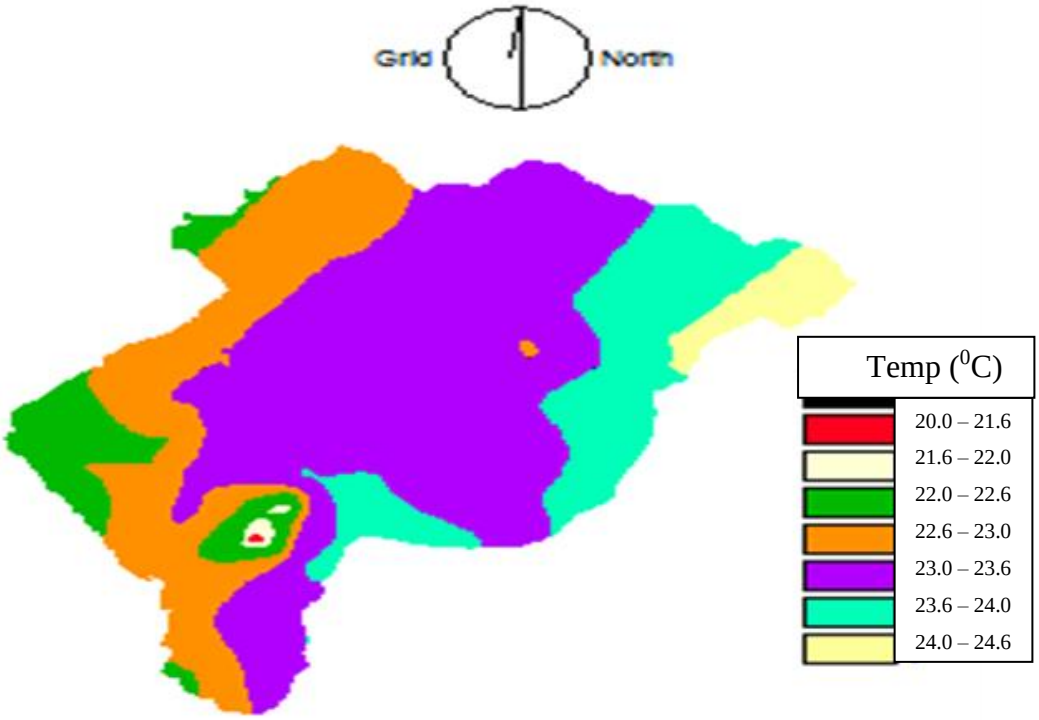


Figure 7: Temperature Cluster Map for the Study Area

From Equation (1) produced temperature image values ranged from 20.0^{0}C to 24.6^{0}C. From the map in figure 7 above, lowest temperatures of between 20^{0}C to 21.6^{0}C were observed within Kijege hill with surrounding areas experiencing temperatures of about 21.6^{0}C to 22.0^{0}C. These low temperatures are attributed to the high elevation (880m) of this volcanic hill which extensively influences climatic regime of the surrounding Chiakariga, Gituma and Kirukuma sub locations. Moderate temperatures of about 22.6^{0}C to 23.3^{0}C were found across the Rainfed Cropping Zones and Mixed Farming Livelihood Zones. This can be explained by fact that these zones lie within a transition area whose elevation is rising towards Nyambene hills to the North West and the mount. Kenya volcanic cone to the West. As the terrain drop towards the low-lying landscapes of Marimanti and Gatue locations relatively high temperatures of between 23.5^{0}C to 24.8^{0}C were noted.

4.2.3.2.2 Potential Evaporation

Evaporation image was needed as a variable in generating moisture availability map for the region. To achieve this, derived relationship between elevation and potential evapotranspiration (PET) for Kenya by Dagg, Woodhead and Rijks (1970) was used as seen in equation (2). Potential evaporation was measured in millimeters (mm) while DEM values was converted from meters to feet through multiplication by 3.28084.

POTENTIAL EVAPORATION (mm) = 2422 - 0.109*ELEVATION ……..(2)

Generated evaporation transpiration rate for the region ranged from 3760.2 mm to 6014.1 mm (Fig.8). These high PET values in the area are attributed to the region's low elevation coupled with high temperatures due to fact that it lies along the equator therefore receives maximum insolation. This spatial variation in PET values shows that rainfall and temperature are correlated with elevation.

Evaporation map for the study area was created using regression equation 2 above. High elevation areas of Mwanyani, Tunyai and Thiiti sub locations experienced similarly high evaporation rate of above 4700mm compared to the low lying Kathangacini and some parts of Kamaguna sub locations with an average of 3833mm. This shows that rainfed cropping zones which lie in humid areas have high evaporation explaining the high rainfall in these areas. This explains the rainfed nature of farming highly practiced in this zone. Generally, values of potential evapotranspiration derived for Tharaka region when compared to those by Dagg *et al.*, 1970 for East Africa confirm that in deed evaporation rates in the study area exceeds rainfall. This explains the semi-arid nature of Tharaka Sub County

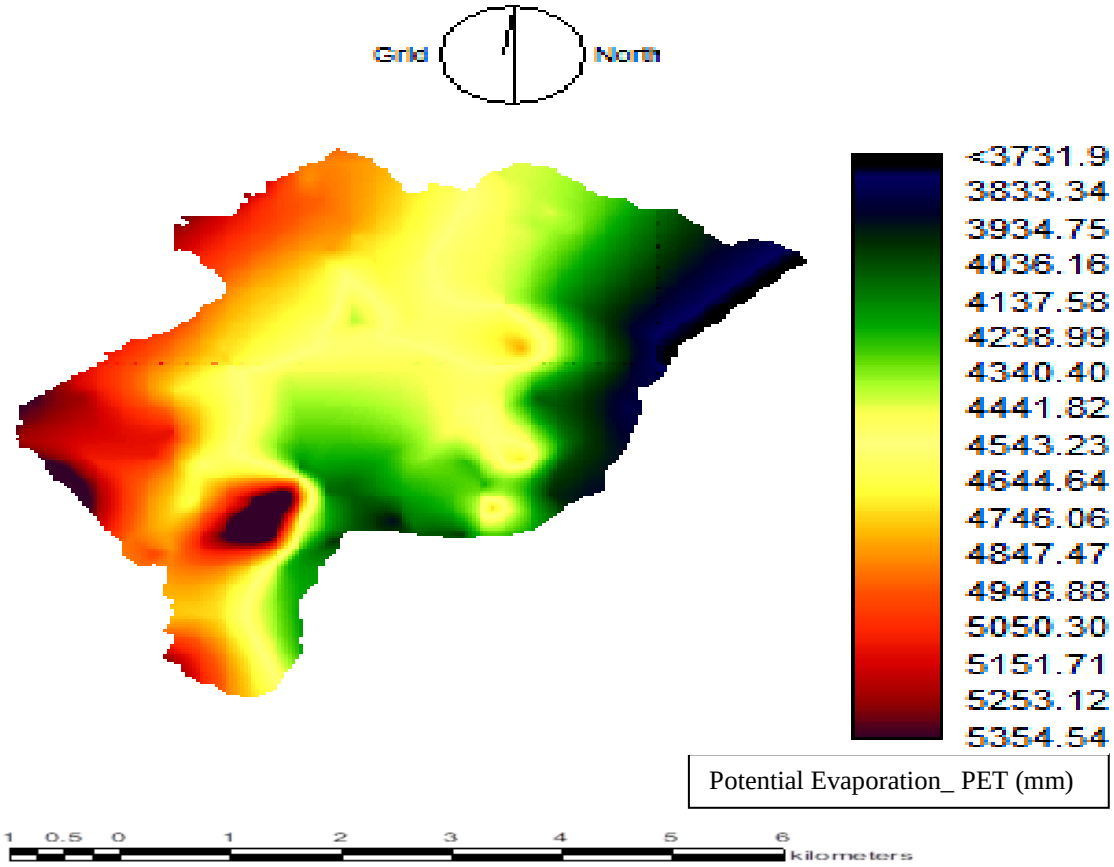


Figure 8: Derived Potential Evapo Transpiration map for Tharaka Sub County

4.2.3.3 Moisture Availability

Derived moisture index values for Tharaka Sub County ranged from 3.0 to 5.5. These values were used to generate moisture map through reclassification in Idrisi Kilimanjaro Image processing software. Aridity index as a measure of the balance between rainfall and evaporation was derived by dividing the annual average rainfall map with annual potential evaporation map. Rainfall map and evaporation map were combined using Zero option ratio operation, a special type of overlay analysis for it supports operations giving unit less results of variables. Four moisture zones were identified for the study area as indicated in the map below (Fig.9).

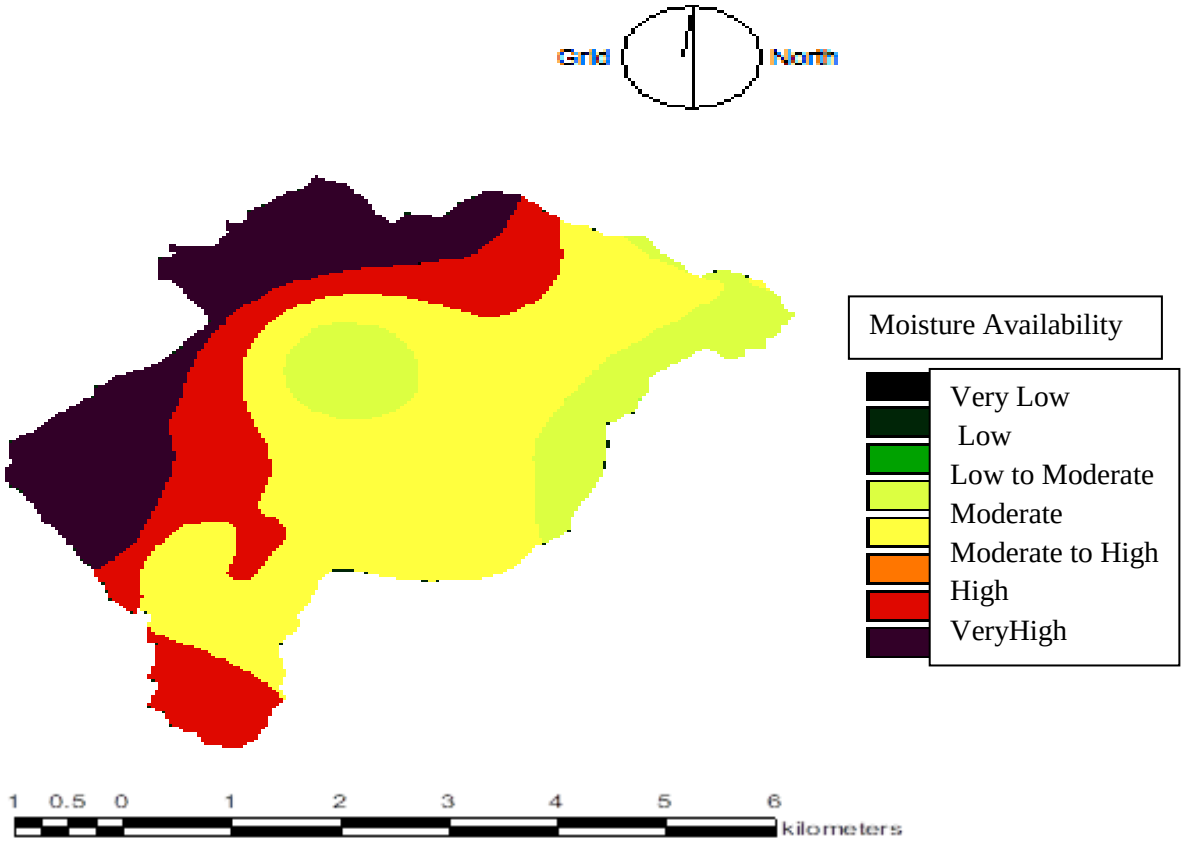


Figure 9: Moisture Availability Map Showing Various Moisture Zones

The seven moisture zones tabulated as M1, M2, M3, M4, M5, M6 and M7 indicates the different humidity levels decipherable from the study area (Table.5). M1and M2 represented areas with very low to low humidity's of 0.30 to 0.36. M3, M4 and M5 had moisture levels of the range 0.36 to 0.45. These areas had low to moderate and moderate to high humidity. Lastly, areas with moisture values of 0.45 to 0.55 were classified as high to very high humidity zones. Mukothima, Thiiti, Nkarini, Mwanyani, Kithino, Nkondi and Tunyai sub locations lie in high to very high humidity zones. Turima, Kibung'a, Karocho, Ibote, Twanthanju, Gaceeraka, Rukenya, Ntugi and Kaguma sub locations are found in low moderate to moderate high humidity areas. Kamanyaki, Kamaguna, Kamwathu, Chiakariga, Uturini and Kamarandi sub locations lie in very low to low humidity areas. These represent the

most moisture deficient areas in the sub county characterised by constant crop failure and minimal farming.

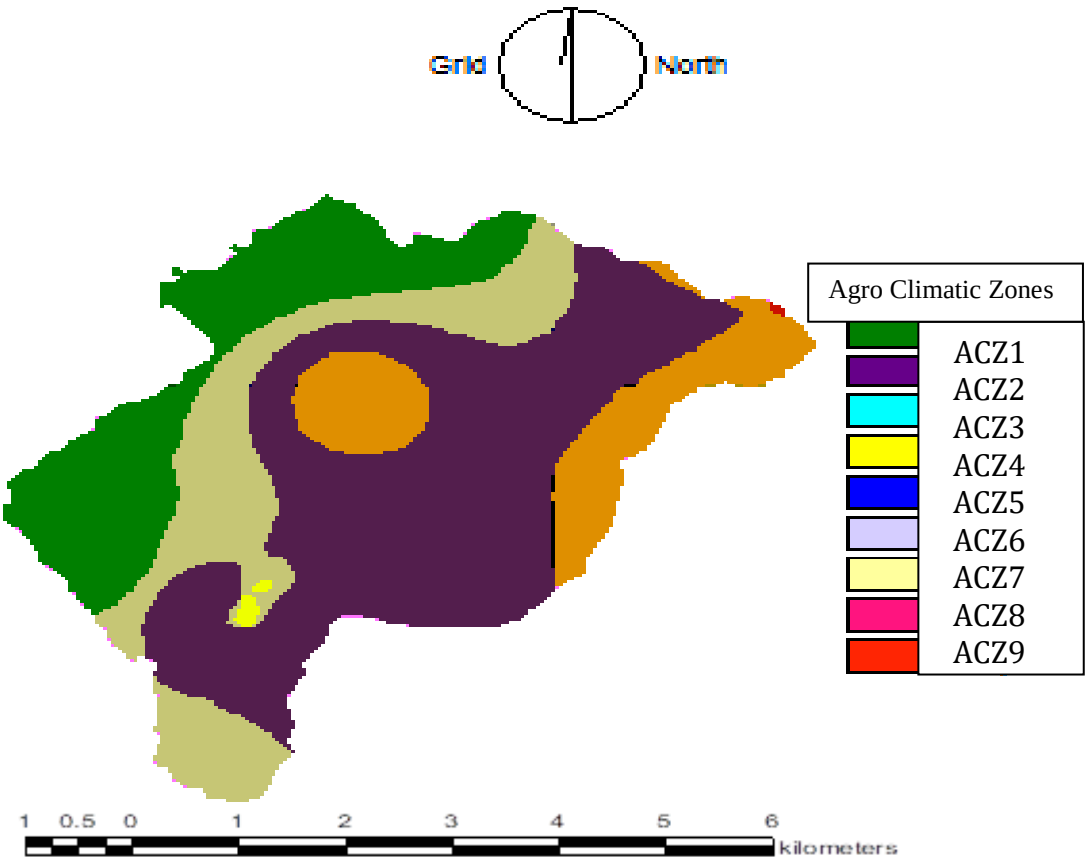
Table 7: Moisture Availability Zone Classification by Moisture Index

Moisture Zone	Moisture Values	Classification	Livelihood Zone
M1	0.30 - 0.33	Very low Humidity	Rain Fed Cropping
M2	0.33 - 0.36	Low Humidity	Rain Fed Cropping
M3	0.36 - 0.39	Low to Moderate Humidity	Mixed Farming
M4	0.39 - 0.42	Moderate Humidity	Rain Fed Cropping
M5	0.42 - 0.45	Moderate to High Humidity	Mixed Farming
M6	0.45 - 0.48	High Humidity	Marginal Mixed Farming
M7	0.48 - 0.55	Very Humidity	Marginal Mixed Farming

4.2.3.4 Agro-climatic Zones (ACZs) Derived

In order to assess climatic suitability of Tharaka Sub County for optimised production of maize and millet crops, agro climatic zones were generated through combining temperature cluster (Figure 7) and moisture zones (Figure 9) using cross tabulation to derive nine agro climatic zones as shown in figure.10 below. Cross tabulation is an enhanced type of multiple overlay analysis which may use either qualitative or quantitative variable to generate a composite output. In particular, full cross tabulation of temperature and moisture zones was done to generate the area's Agro Climatic Zone (ACZs) map as seen in figure 10 below. From the map of derived agro-climatic

zones, Tharaka Sub County has six major agro-climatic zones labeled as ACZ1, ACZ2, ACZ4, ACZ7, ACZ8 and ACZ9. The six agro-climatic zones cut across the three livelihood zones of rainfed cropping, mixed farming and marginal mixed farming livelihood zones. Ntoroni, Thiiti, Tunyai, Mwanyani, Mukothima, Kirundi, Irunduni, Turima, Kathuura, Karocho, Kanyuru, Rukurini, Nkondi, Matakiri, Nkarini and Gaceeraka sub locations lie within the maize and millet producing ACZ1 and ACZ2 areas. It was also observed that Rukenya, Kirangare, Gituma, Kithigiri, Marimanti, Mauthini, Kaguma, Gatunga, Kamanyaki, Kirukuma, Chiakariga and Twanthanju Sub locations occur within ACZ4 and ACZ8 which supports livestock keeping and mixed farming. Only Kamwathu, Kamaguna and Kathangacini sub



locations occur in purely pastoral areas.

Figure 10: Agroclimatic Zones Derived from Temperature and Moisture Variables.

From the cross tabulation, it was deciphered that the region could be classified into nine Agro Climatic Zones as indicated in Table 6 below. ACZ1 and ACZ2 comprised of areas with a temperature of between 21.6^{0}C to 22^{0}C and lie within aridity index of 0.30 to 0.45. These zones accounted for about 20,868.19 hectares of land. ACZ3, ACZ4 and ACZ5 lie in areas with temperatures of 22^{0}C to 22.6^{0}C and had aridity index of 0.30 to 0.55. These agro climatic zones covered about 68,906.27 hectares of land. ACZ6 and ACZ7 were found in areas with temperatures of 22.6^{0}C to 23^{0}C and aridity index of 0.35 to 0.45. The two agro climatic zones accounted for 30,901.92 hectares of land. ACZ8 and ACZ9 were agro climatic zones which lie in areas with high temperatures of 2.3^{0}C to 2.4^{0}C and aridity index of 0.35 to 0.45 accounting for close to 26,638.22 hectares of land.

Table 8: Agro Climatic Zones and their Land Size in Hectares

Agro Climatic Zone	Temperature(^{0}C)	Moisture Index	Land size (Ha)
ACZ 1	21.6 – 22.0	0.30 – 0.35	5380.57
ACZ 2	21.6 – 22.0	0.35 – 0.45	15487.62
ACZ 3	22.0 – 22.6	0.30 – 0.35	78.40
ACZ 4	22.0 – 22.6	0.35 – 0.45	68718.11
ACZ 5	22.0 – 22.6	0.45 – 0.55	109.76
ACZ 6	22.6 – 23.0	0.35 – 0.45	30456.53
ACZ 7	22.6 – 23.0	0.35 – 0.45	445.39
ACZ 8	23.0 – 23.6	0.35 – 0.45	22637.07
ACZ 9	23.6 – 24.0	0.35 – 0.45	4001.15

4.2.4 Evaluation of Areas Suitable For Maize And Millet Production

The nine agro climatic zones derived for Tharaka Sub County were evaluated against crop adaptability principles (FAO, 1993) and the agro-climate zone map of Kenya to obtain areas suitable for maize and millet cropping. Derived agro-climate zones

ACZ1, ACZ2, ACZ3 and ACZ5 were found suitable for maize crop production. These areas had temperature range of between 21^0C to 23^0C and moisture availability of 0.3-0.55 respectively with a total land size of about 21,056.35Ha. Millet on the other hand was found to do well in ACZ3, ACZ4, ACZ5, ACZ6, ACZ7, ACZ8 and ACZ9 agro-climate zones with temperatures in the range of 22^0C to 24^0C and moisture content range of 0.35-0.55. These areas accounted for 126,446.41 hectares of land. To obtain ACZ suitable for Maize and Millet production, derived agro climate zones for maize and millet were overlaid and areas of intersection taken to be zones suitable for the production of maize and millet. Agro climate zones ACZ3, ACZ5 and ACZ9 were found suitable for production of maize and millet. Derived agro climate zones three, five and nine land size by area covered about 4,189.31 hectares of land. However, ACZ1 was the only most suitable zone for the production of maize only with its land size covering 5,380.57 hectares. This particular agro climate zone had an aridity index of 0.3 to 0.35 and temperature range of between 20^0C to 21.6^0C.

Generally local maize varieties especially *Kimeru* and *Mbeu* are widely grown because they are cheaply available in local open-air cereal markets. Katumani composite (KB1) an improved maize variety from KALRO is intended for arid and semi-arid lands. This variety is also majorly grown for it is an early maturing variety and has high harvest index. Despite, KB1 being a short cycle variety doing well in both low and average elevation areas of 700 to 900 meters above sea level, it is susceptible to lodging and for this reason not a popular maize variety as such (Musembi, 2010). In Tharaka region, Katumani composite maize variety is intercropped with beans and other legumes especially cowpeas and pigeon pea as shown in Plate 1.

Plate 1: KB1 Maize Variety Intercropped with Cowpeas in the Rain Fed Cropping Zone

(Source: Field Survey)

From the analysis done for the data collected on the study area, maize does well in areas with temperature of 20-22^{0}C and with rainfall of about 750-1000mm per annum. It was observed that besides Katumani, other maize varieties like Duma 43, Pioneer, H513, DHO4, Pioneer, Pannar and DK8031 were also grown by households in the study area. DK 8031, Pannar and Pioneer are late maturing varieties taking relatively longer time to flower and mature (Muraya, Omolo & Ndirangu, 2006). Households growing the fore mentioned varieties experienced relatively lower yields compared to those who planted Duma 43 and DHO4 varieties respectively. For optimised production of maize in agro-climatic zone1, early maturing dryland hybrid maize varieties DHO1 and DHO2 can be adopted for cultivation alongside the commonly grown DHO 4 and Duma 43 maize varieties. Identified maize producing ACZ1

regions corresponds to the rainfed cropping and mixed farming livelihood zones of Thiiti, Mukothima, Mwanyani, Tunyai, Gakurungu, Karocho, Nkondi, Ntoroni, Kereria, Nkarini, Kirundi, Kithino and Irunduni sub locations.

Bulrush millet is also an important food crop grown for subsistence and income by households in the both mixed farming and rainfed cropping zones. Results revealed that within the mixed farming livelihood zone, about 45 per cent of interviewed households grew millet and maize for cash income while 31 per cent of the sampled households in the rainfed cropping livelihood zone traded in maize and millet as a main source of income for their families.

Within the marginal mixed farming, 24 per cent of interviewed households grew millet and maize for food although these crops were also traded for cash income in the local markets. However, in terms of cropped acreage, more millet was planted compared to maize crop. This could be explained by fact that millet being a drought resistant crop does well in moisture stressed zones. Tharaka has mostly semi-arid characteristics which support the growth of millet, sorghum and other grass family crops. The marginal mixed farming livelihood zone with high temperatures of 24^0C to 30^0C, low moisture content of 0.25 to 0.40 and poorly drained shallow sandy, loamy and clayey soils (50-80cm) is suitable for the production of millet.

Across the sub county, the common millet variety grown by the community is locally known as "*Kiraka"* as shown in Plate.2 below. This is a Katumani Pearl bulrush Millet-2(KAT/PM-2) variety widely cultivated in the region. Its tolerance to rust and leaf bright makes this variety preferred than Katumani Pearl Millet-1(KAT/PM-1)

variety. In terms of most planted millet variety, households in the marginal mixed farming zone grew more of KAT/PM-1 millet variety than households in the mixed farming zones. This translating to 54 % of sampled households who grew KAT/PM-1 millet variety in the MMF, 25% of households within MF zone and 21% were found in the RFC zone. The reason for this spatial variation was due to its bird-scaring trait thus saving farmers time spend on chasing weaver birds from their farms which devour millets in this zone.

Plate 2: "Kiraka" Millet Variety Growing in a farm Located within Mixed Farming Livelihood Zone

(Source: Field survey)

Resultant agro climate zones were overlaid on soil drainage and depth map layer to identify characteristics of these areas. It was found that areas suitable for the growth of millet and maize had temperature ranges between 20-24^{0}C; Moisture index of 0.35-0.55; deep to moderately deep loamy and clayey soils (50-120cm) and on undulating

land with slope less than 12%. Suitable areas found were spread across Rainfed Cropping LHZ, Mixed Farming LHZ and Marginal Mixed Farming LHZ as shown in Table 9.

Table 9: Suitability of Livelihood Zones for Maize and Millet Cropping

Livelihood Zone (LHZ)	Temp^{0}C	Moisture	Agro climatic Zone	Soil Depth	Texture	Crop
Rain Fed Cropping	22-24^0 C	0.25-0.65	ACZ1, ACZ3 ACZ6, ACZ7 ACZ8, ACZ9	180-120cm 80-120cm	Loamy, Clayey	Maize only Maize &Millet
Mixed Farming	22-24 ^{0}C	0.40-0.50	ACZ1, ACZ3	50-80cm 80-120cm	Clayey	Maize only; Maize &Millet
Marginal Mixed Farming	21-30 ^{0}C	0.25-0.40	ACZ5, ACZ6, ACZ7 ACZ8,	50-80cm	Sandy, Loamy, very clayey	Maize & Millet

ACZ9

(Source: Field Survey, 2018 and the National Atlas of Kenya)

Hypothesis postulated for objective one was tested for its statistical significance using spearman's correlation.

4.2.5 Biophysical and Climatic Factors do not Determine Optimization of Maize and Millet Production in the Study Area

For this particular hypothesis, the aim was to test influence of temperature, moisture, slope and soil depth on optimization of maize and millet production across the MMF, RFC and MF livelihood cluster zones in the study area. Non-parametric spearman's correlation in STATA 14.2 software was used to compute rank order association between the four biophysical and climatological variables identified above (Table 8). Spearman's Correlation was used because examined variables of temperature, moisture, slope and soil depth were measured on a continuous scale and when plotted on scatter gram they showed a monotonic relation.

Table 10: Spearman's Correlation Coefficients for Temperature, Moisture, Slope and Soil Depth

	Temperature	Moisture	Slope	Soil Depth
Temperature	1.000			
Moisture	0.2964*	1.000		
	(p=0.000)			
Slope	0.2916	0.5643**	1.000	

		(p=0.0086)		
Soil Depth	0.0811	0.4725	-0.1383*	1.000
			(p=0.012)	

*Correlation statistically significant at 5%, (2 tailed); **Correlation statistically significant at 1 %, (2 tailed).

From the tabulated correlation coefficients, the spearman's rho of moisture and temperature is 0.2964 and has a positive sign indicating that there exists a monotonic relationship between moisture availability and temperature. The correlation coefficient is statistically significant because the p = 0.000 is less than p<0.05 statistical significance level used. This means that medium to high temperatures in the study area are also associated positively with medium to high humidity. This translate to hot and humidity weather conditions typical in the study area which impacts growth rate and maturation of maize and millet. The findings indicate that temperature has a greater impact on production of maize and millet in the study area. These results confirm the findings by Kabubo-Mariara and Karanja (2007) and Bilham (2011) that temperature is a more important contributing factor for Kenyan crop yields.

According to the results above, although slope has a positive correlation coefficient value when compared to temperature, there is no statistically significant correlation to associate slope with temperature variation in the study area. Unlike the case of slope and moisture where the correlation coefficient is positive and significantly different from 0 because the p=0.0086 is less than 0.01 level of significance. Relationship between soil depth and temperature was positive but not significant statistically.

Similarly soil depth and moisture showed a positive relation but the correlation was not significant. The findings show that soil depth does not influence temperature or moisture as far as maize and millet production is concerned.

However, the correlation coefficient between soil depth and slope has a negative coefficient of 0.1383 at $p<0.05$. The association is one where soil depth decreases as the slope increases. Therefore, areas with slope gradient above 16% are considered steep and have shallow soils due to incidences of soil erosion. The findings corroborate with those of a study by Muthui, (2020) which established that soil properties of depth and texture have been influenced by the slope position in Mua hills, Machakos County. Similarly, Mohammad, (2008) in a study in southern west bank, Palestine found out that slope aspect in the arid and semi-arid region have an effect on spatial heterogeneity and distribution of moisture and nutrients resources.

This has serious adverse effects on crop production as thin soils do not harbor enough organic matter and suffer from limited soil fertility. Based on the results above, moisture and temperature, slope and moisture as well as soil depth and slope have a positive association with maize and millet production optimization in the study area. Therefore, the null hypothesis is rejected and alternative hypothesis that biophysical and climatic factors determine optimization of Maize and Millet production in the study area is accepted. Usually temperature influences atmospheric moisture content by affecting the rate of evapotranspiration. In semi-arid areas, slight temperature rise would translate to high humidity as water moisture is lost from soils, vegetation and open water bodies.

From the results of this analysis, it was found that rainfed cropping LHZ besides being the most suitable zone for production of maize, it can support growth of both maize and millet. The zone can support the growth of alternative crops like cassava, cotton, cowpeas, groundnuts, mango, Pigeon peas, beans, sorghum and sisal. The warm and semi humid nature of this zone as well as deep drained loamy and clayey soils is favorably suitable for rainfed crop development. The mixed farming livelihood zone as indicated by the analysis results in Table 7 above, show the area's moderate drained clayey soils and its warm, semi humid to semi-arid characteristics makes it suitable for beans, cowpeas, groundnuts, sisal, pigeon peas, cassava, sorghum as well as sisal. Lastly the marginal mixed farming zone which is fairly hot and semi-arid area with moderate deep clayey, sandy and loamy soil seems to favour growth of pigeon peas, cassava, sorghum, green grams and sisal.

Generally, RFC, MF and MMF have geophysical and pedological characteristics suitable for the production of millet and maize. However, for optimised production of maize RFC and MF livelihood zones should be considered for expanding the acreage under this crop.

The most preferable maize varieties which have the potential to raise the current production are DHO1 and DHO2. For millet besides the currently planted varieties, Katumani pearl millet-3 variety should be grown especially in the MMF zones for it is well suited for moisture stressed areas.

4.2.6. Summary

This objective has looked at how biophysical and climatic factors influence agricultural production across the rainfed cropping, mixed farming and marginal mixed farming livelihood zones of Tharaka Sub County. Important climatological factors identified as essential for optimal production of maize and millet in the study area were moisture availability and temperature. These results corroborate with those of (Thomas*et,* Hoon & Dougill, 2011), temperature is a crucial factor that plays an essential role in agriculture on dry land agriculture. Physiologically, temperature affects the transpiration rate, water, and nutrients' absorption rate, photosynthesis, and respiration.

From the analysis the researcher was able to confirm the significance of studied biophysical factors in influencing the transformation of local food production. Slope, elevation and soil characteristics were found extremely significant in the optimized production of maize and millet crops which is consistent with the conclusions of studies from other regions (Olah, Boltižiar & Petrovič, 2006; Geist & McConell, 2010, Opršal, Kladivo & Machar, 2016)

Agroclimatic zones derived contained suitable areas across rainfed cropping, mixed farming and marginal mixed farming which supported the growth of maize and millet. For example, ACZ1, ACZ3, ACZ5, ACZ6, ACZ7, ACZ8 and ACZ9 identified across rainfed cropping, mixed farming and marginal mixed were suitable for establishment of maize and millet crop. In particular, ACZ1 and ACZ3 extensively found in the mixed farming LHZ and partly in the upper rainfed zone were purely suitable for maize production. Therefore, these particular areas could be targeted for large scale maize production for Tharaka region.

These agro-climate zones spread across Thiiti, Mukothima, Mwanyani, Tunyai, Karocho, Kithino and Gakurungu sub locations have high elevation and well drained loamy and clayey soils. However, key areas within mixed farming livelihood zone that could be considered as maize producing spots are in Karocho, Kithino and Tunyai sub-locations.

As for millet crop, it was discovered that ACZ5, ACZ6, ACZ7, ACZ8 and ACZ9 spread across rainfed cropping zone and marginal mixed farming livelihood zones were favourable for the growth of Katumani pearl millet 1, 2 and 3 millet varieties besides its suitability for maize production. Particular areas mapped as suitable within marginal mixed farming and rainfed cropping livelihood zones were Gakirwe, Mwerera, Turima, Irunduni, Ntoroni, Kithigiri, Kirangare, Kanyuru, Nkarini, Gaceeraka, Tubui, Rukenya, Gituma, Kaguma and Rukurini sublocations. These zones have well drained deep soils, moderate humidity and temperature as well as appropriate PH for establishment of the two staple crops.

It was discovered that although maize selectively does well in certain areas, millet can grow in almost all agro-climate zones across the livelihood zones. Reduced moisture content and high temperature makes this sub-region suitable for dryland hybrid maize varieties and Katumani pearl millet varieties respectively. These particular varieties should be extensively grown in areas identified here above if optimal production of maize and millet crops at household and sub-regional levels is to be achieved. The next objective looks at marketing models currently used for maize and millet distribution.

4.3 Marketing models and their influence on household's food stock retention

This objective highlights various models used by households to market as well as procure maize and millet staples grown locally in the area. Close examination of factors influencing choice of a given marketing channel and issues associated with participation of small holder farmers in marketisation within the study area will be discussed. All presentations in this section are based on responses obtained from household survey and related literature reviewed.

4.3.1 Households' Organisational Attribute

In analysing characteristics of households and how it dictated choice and use of marketing models, data retrieved from questionnaire responses was used. From the questionnaires; gender, age, education and family membership composition information were collected as explanatory factors. Organisation of households was believed to inform food security measures adopted by families more so those relating to how food crops harvested were sold. In most cases, household composition is known to significantly influence local food production, distribution and marketisation. Decisions about where to sell, what to buy and how to move the produce from farm to the market are solely made by household headship.

4.3.1.1 Gender of the Respondents

One of the items in the questionnaire was to establish gender of the respondents interviewed. Figure 11 shows a high proportion of those who participated in the study were females at 64.1 % while the rest at 35.9% were males. This parity could be explained by the fact that women are majorly engaged in home making and other reproductive roles like nursing babies, cooking and tending to livestock and crops.

These responsibilities mostly tend to confine women at home unlike their male counterparts who engage in productive roles away from home. Therefore, this observation explains why more females participated in the study unlike male counterparts who at the time could not be available for the interviews.

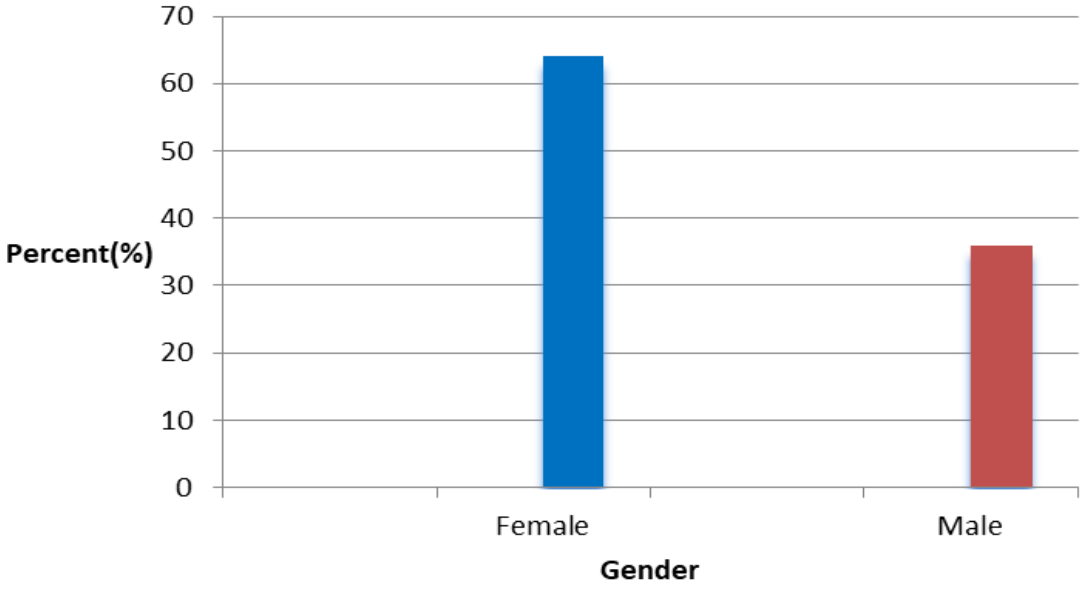


Figure 11: Gender of Interviewed Households' Respondents

4.3.1.2 Household Headship Roles

Question on who headed the household was asked as a rider on gender responsibilities of the respondents. It was found important to get information on who headed the household because headship influenced what decisions were made and who made decisions. Decisions made impacted on production, consumption and sale of food stuffs retained by a household. Results of the survey indicated that most households interviewed in Tharaka region are headed by males with 289 families translating to 73 % as compared to 106 families at 27% which had a female as the head (figure.12). These findings are interesting given that in this region despite female population being slightly higher than males at 67,215 compared to males at 62,883 persons,

males still head and control key household decisions. This is a clear indication that Tharaka community is a patriarchal society where a man heads the family besides owning and controlling family assets especially land and livestock

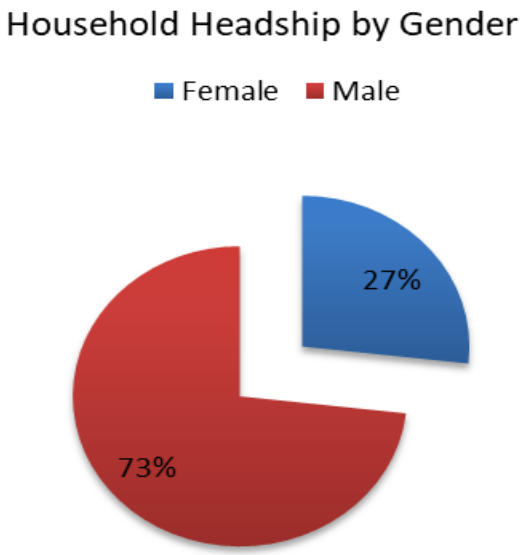


Figure 12: Proportions of Male and Female-Headed Households

4.3.1.3 Age Distribution

According to the findings as indicated in figure 13 below, majority of the population lies in the age bracket of 31 to 40 years (37.2%) followed by those in age group of 41 to 50 years (29.1%). These are economically active and productive age groups which majorly engaged in agricultural production, marketing and related agri-businesses activities. Although these age groups also comprised the largest population associated with out migration, they often returned home from off-farm employment during tilling and planting seasons to continue with farming activities. These in-migrations were observed mostly during the (OND) October-November-December long rain season which is a reliable season for cropping. Most out-migrations were reported in the months of May, June and July corresponding to a season of reduced farming

activities. These results agree with findings of a study carried out by the National Council for Population and Development (NCPD) in 2017 which established that in Tharaka-Nithi County, fifty-two percent of the population are in the working age. This means that a large proportion of the region's population are in the ages 15 to 64 years.

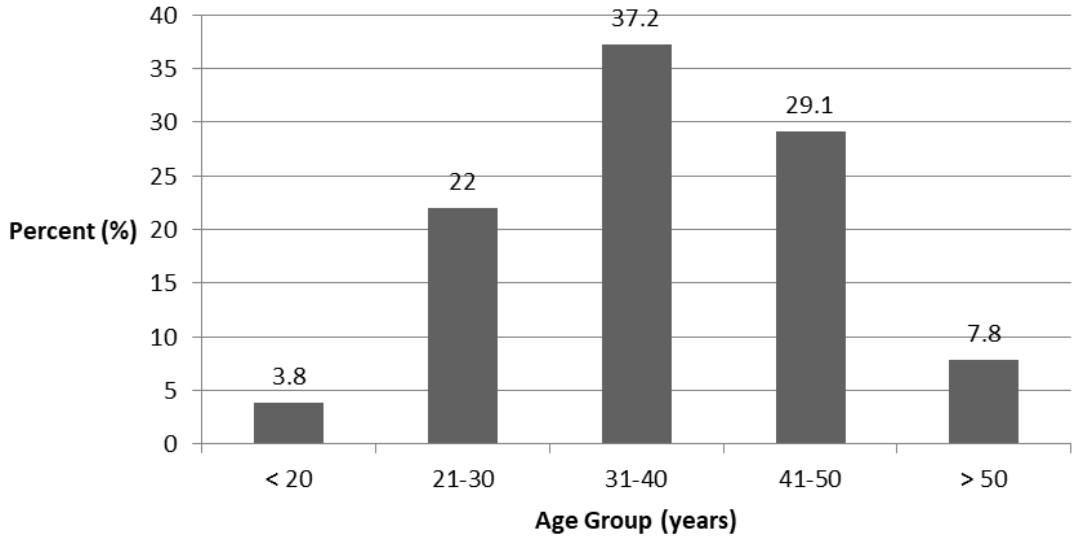


Figure 13: Age groups of Interviewed Household Population Sample

4.3.1.4 Levels of Education

In order to assess education levels of participant respondents; primary education, secondary education, college/university education and No education categories were used. Survey results tabulated in Table 9 indicate that 42.5% of the interviewed respondents had primary education, 28.6% had attained secondary education while those without any formal education were 22.3%. Only 9.6 % of the respondents had attained tertiary education which comprised or either a college or university education. This implies that majority of sampled population in the study area have some basic education and thus can read and write besides using simple technologies like mobile phones, weighing scales and calculators. The findings are consistent with

those of a study by KNBS and SID in 2013, which puts illiteracy levels in Tharaka constituency at 22.0%. In most cases, education is an important factor in decision making process as it influences how decisions are made. For instance, education of household members' influences farm management and marketing skills leading to improved decisions (Makhura, 2001). On the same note, several studies have shown that education levels can improve competitiveness of farmers (Moyo, 2010; Enitan, 2010; Mohammed & Ortmann, 2005). Therefore, education is a determinant in decision making on household food security.

Table 11: Proportion of Respondents by the Level of Education Attained

Level of Education	Frequency	Proportion in Percent (%)
Primary	168	42.5
Secondary	101	25.6
College/University	38	9.6
No education	88	22.3
	395	100

4.3.1.5 Household Membership

In order to understand influence of household membership on food security especially land cultivation and quantity sold in local markets, information on household size was collected. The specific data was on the number of individuals living with household head. As indicated in figure 14, about 2.0% of households reached by this survey said they were living with at least 1 member of the family, 22.8% had between 2 and 3 members living with them. Most households in the study area had between 4 to 6 members accounting for 42.3% of the sampled household population. Only 32.9% of

the households had more than 7 members living with them. Findings from this survey reveal that most households in the study area have 4-6 members living with the house head at any time. In this region, it was noted that labour for planting, weeding and harvesting was readily available within households especially for the case of households that had more family members living with them. Although a large family reported cases of periodic food insecurity arising from increased consumption, the situation was different for lean families that had between two to three family members. Due to limited retention of food stocks by most families in the area during the planting and harvesting period, huge financial resources were used to procure food for a large household as compared to a smaller one. This huge financial burden affected family's health care system and education as monies meant for these purposes were diverted to food purchases.

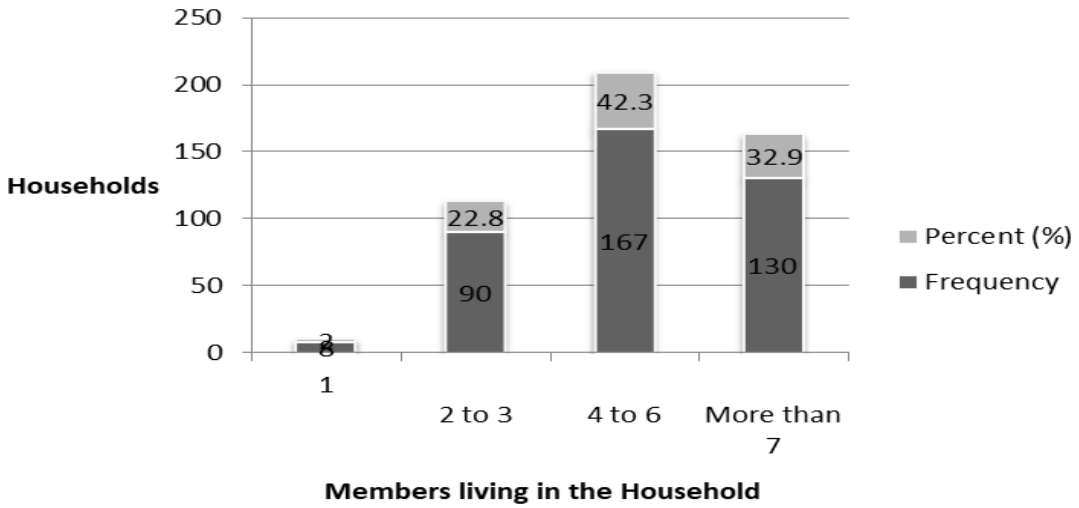


Figure 14: Household Size Distribution by Percentage of Family Members

4.3.2 Analysis of Marketing Channel for Maize and Millet

Close analysis of marketing channels gives an opportunity to understand market functions, linkages and intermediaries acting within a market chain (Zeberga, 2010). Survey results from the study area revealed that most households produced maize and

millet for subsistence although some portion was sold to raise income for families. Examination of marketing models revealed that formal and informal channels were both used by households in marketing of farm products. Informal channels include the non-organised ways households use to acquire food stuff. Formal channels include organized ways households use to sell and buy food stuff. As identified from the field survey and key informants, formal channels comprised of licensed agent traders who bought maize and millet as well as other cereals for grain handling co-operatives operating mostly in Meru town. These traders offered fixed prices across all buying stalls which they operated within selected market centers. Bulk grain dealers and handlers from Nanyuki, Meru, Embu and Nyamakima in Nairobi identified local village merchants whom they assisted establish satellite buying stalls within local markets.

This they did to target gullible households selling surplus foodstuff during harvesting season. It was discovered that formal channels operated optimally above peak during harvesting season whenever there is a perceived surplus production in the area. During this period, market prices for the cereals were relatively low due to availability of food products and oversupply in the markets. This scenario was driven by early disposal of food crops by majority of households due to lack of adequate food storage facilities especially granaries.

Table 12: Factors Affecting Choice of the Marketing Channel by Households

Factor	Associated Livelihood Cluster Zone
i. Market price of food stuff	Marginal Mixed Farming
ii. Established satellite stalls	Rain Fed Cropping
iii. Availability of cereals in local markets	Mixed Farming
iv. Adequate food storage facilities	Mixed Farming, Rain Fed Cropping
v. Means of transport availability	Marginal Mixed Farming, Rain Fed Cropping, Mixed Farming
vi. Distance to the nearest market	Marginal Mixed Farming
vii. Market related information	Mixed Farming, Rain Fed Cropping, Marginal Mixed Farming

Fourteen buying centers were sampled in the study area of which seven were cereal stalls located within RainFed Cropping Zone and only two were found in the Mixed Farming Zone. On the other hand, the Marginal mixed farming zone had five cereal buying stalls. Most of the stalls operated throughout the year more so those within the Rainfed cropping zone of diverse food items availability in the zone compared to the other two livelihood zones. Issues of food availability and diversified crop production in the rainfed cropping zone explains the presence of many cereal stalls in the area. Informal market channels were common avenues by which many households bought food during deficit seasons and even sold in the surplus seasons. Actors in the informal channel included farmers, transporters, assemblers and local grain merchants whose capacity to transact although minimal compared to bulk grain traders was substantially dictated by the market forces of demand and supply.

In order to understand type and nature of marketing channels which households used, responses gathered through questionnaires showed that most families used direct channels. For instance, 29.9% of the households used Open air marketing channels to sell and or buy food stuff. The other category was the cereal traders who comprised the major channel with 53.9 % of all grains sold and bought by households in the study area dominated by this cohort. Brokers buying at farm gate were significant with 16.2% of interviewed households saying they sold to brokers who strategically positioned themselves along paths leading to open air markets. In an attempt to understand factors that influenced choice of a distribution and marketing channel, better price offer, convenience and ease of access were initially singled out as key determinants. However, it was actually revealed that distance to the point of sale, market price, quantity harvested, market information and channel requirement determined decision made by a given household on the type of channel used in marketing farm produce.

Table 13: Responses Solicited on Marketing Channels and Stratified by Livelihood Zone.

Marketing Outlets	RFC[1]		MMF[2]		MF[3]	
	Number	%	Number	%	Number	%
Farm gate Assemblers	143	67	23	18	30	58
Institutions	37	17	45	34	9	17
Millers	2	1	10	8	1	2
Cereal traders	18	9	24	18	7	13
Other Households	12	6	29	22	5	10
	212	100	131	100	52	100

1 Rain Fed Cropping; 2 Marginal Mixed Farming; 3 Mixed Farming

Clusters comprising of villages from which responses were gathered was stratified according to livelihood zone as Rain Fed Cropping, Marginal Mixed Farming and Mixed Farming (Table 10). This was done in order to compare marketing outlets across the three livelihood zones. From the fieldwork survey, households have different marketing outlets from which to buy and or sell maize and millet produced. These outlets include local posho millers, cereal traders, other households, farm gate buyers and institutions like hospitals, schools and NGOs. As shown, the number of millet and maize buyers in the villages varied spatially across livelihood zone. For instance, in the Rain Fed Cropping zone, farm gate retail assemblers were dominant accounting for 67%, followed by institutions at 33%. The same situation was observed within Marginal Mixed Livelihood where the proportion of farm gate assemblers comprised of 23 % while institutions buying from farmers accounted for 45%.

This scenario was also mirrored in the Mixed Farming zone where 58 % of small retail traders were main farm gate assemblers followed by local institutions which accounted for 17% of farmers marketing channel outlets. It is therefore factual to claim that farm gate assemblers are the major buyers and sellers of cereal produce in semi-arid rural Tharaka Sub County. Their dominance advantage is because they buy millet and maize in small quantities preferably in a 1kg tin, quantities by which most households sell their surplus. This makes them more preferred than other marketing outlets for their availability. The high presence of aggregators in the Rain Fed Cropping zone is due to high commercialization of farm produce by households who engage in green grams and peanuts farming as alternative cash crops. This means that

many households can dispose maize and millet held in surplus since they have other crops to sell for income during lean season.

Prices of Millet and Maize fluctuated across seasons with Maize retailing at an average of K.shs 25/Kg during harvest season and K.shs 50/kg during planting season. Millet was sold at K.shs 15/Kg during harvest season and at K.shs 100/Kg during Planting season. Price seasonal variation was attributed to supply and demand forces where plenty of the two crops in the local markets during surplus seasons (February, March, April for long rains and May, June, July for short rains) attracted low market prices while lean seasons of January, August September and October pushed the market prices of millet and maize to almost double.

When inquired about the quantities by which households sold maize and millet which they produced, 48.5% of sampled households sold their produce in a 1kg tin specially to farm gate brokers. About 32.3% of households said they sold their produce in Debes to cereal traders operating stores in open air markets of Mukothima, Gatunga, Tunyai and Marimanti. Few households (9.9%) sold maize and millet in a 90kg bag. Those households selling in 90kg baggage cropped over 5acres of land and were mostly engaged in contract farming. They were supplying to schools, brewers, millers and community based organisations. Institutions were another important marketing channel outlet significantly influencing levels of foodstuff commercialization.

Close to 68% of participants in the study expressed importance of institutions as an outlet in millet-maize agri-food marketing and distribution value chain, an observation also made by Christopher, 2010 who reiterated institutions play a pivotal role in the success of value chains. Direct reference was made to schools which

topped this category as it was observed that most poor farming households exchanged farm produce for their children's schools' fees.

Although mention was made indirectly to the schools feeding program in day primary schools by World Food Program in the area, most schools especially days mixed and boarding secondary schools allowed parents to bring in maize, green grams and beans in place of monies. This occurrence was cited by most respondents within MF (34%), RFC (17%) and MMF (17%) who affirmed this was often practiced during second and third term coinciding with lean seasons when most households had limited off farm income generating activities.

Generally, more assemblers were found in RFC zone compared to MF and MMF due to high production of maize within Nkondi, Mwanyani, Thiiti and Mukothima sub locations. Maize a staple in high demand could be sourced easily from farmers in these areas compared to millet which could be bought in other livelihood zones. In the Marginal Mixed Farming livelihood zone, families buying from other households were more (22%) when compared to the same in Rain Fed Cropping Zone (6%) and Marginal Mixed Farming (10%). This is explained by constant rain failure in this area resulting to crop failure and over reliance with livestock. Interesting to note that 18% of wholesale and retail cereal traders were mostly concentrated within Marginal Mixed Farming livelihood zone.

It was revealed that these cereal traders established retail stores to sell produce procured in the RFC and MF zones because most households were food deficit and therefore sold livestock to purchase food. These periodic traders were agents contracted by whole sale cereal dealers in Meru, Chuka and Nanyuki towns. Small

scale cereal traders were more due to the bulking function of aggregating produce brought in by households from Rain Fed cropping and Mixed Farming as they perceived demand and better prices in the Marginal mixed farming livelihood zones.

4.3.3 Factors Influencing Choice and use of Marketing Outlet

It was hypothesized that the type of marketing outlet used by a given household was determined by a combination of several factors relating to market accessibility, distribution systems, availability of food and household characteristics.

4.3.3.1 Education

It is a continuous variable measured in form of education level attained by the household head. Education often increases the ability of the family head to get correct information and use it to make informed decisions. In this case, education was hypothesized to influence choice and use of a market outlet negatively.

4.3.3.2 Headship Gender

Who heads a household is considered important as far as food production, marketing and consumption is concerned. Depending on whether a family is headed by a male or female, gender of the family head has implication on marketing of household produce. Gender was a dummy variable, which took a value of one if the household head was a male and a zero if it was a female. Cheruiyot (2016) showed that male headed households were food insecure as compared to female headed households. Therefore, gender of the household was expected to have a negative influence in choosing the market outlet to use.

4.3.3.3 Information Communication Technology (ICT)

Information access and use has influence on market entry behaviour besides having significant effects on the intensity of market participation. In this particular case the source of market information was considered because the type of information channel can significantly influence quantity sold. Depending on the channels of information communication, reliability is often an issue of concern. In this study, type of ICT media owned, their uses and impacts on marketing and food distribution by farmers was assesses. ICT used was a dummy variable with formal sources taking a value of one and informal sources taking a zero.

Formal channels especially mobile phones, radio and TV as well as farmer magazines were hypothesized to influence the choice of a market channel used by a household. In this case, if the coefficient gotten was negative, it means that traditional sources of information like neighbours and friends were effective in influencing market participation and more use of a marketing channel. Access to information and its use increases the chances of farmers selling their produce from an informed point. It was hypothesized that informal sources of information communication technology were more effective in providing market information therefore ICT had a negative sign.

4.3.3.4 Land Cultivated

Refers to the area of land cultivated for the production of maize and millet crops. Land under food crop was considered to influence quantity of produce harvested and positively affected the output marketed. In this case land cultivated by a household is a continuous variable for total land cropped with maize and millet in hectares. Bessy, Nongluck and Yaowarat (2014) showed that vegetable land size negatively influenced

the choice of collector outlet and positively affects the choice of farmers' cooperative. Similarly, the land size under cultivation has significant effect on the availability of food at the household level. It was hypothesized that the area of land allocated to maize and millet production influenced negatively the use of a given market outlet.

4.3.3.5 Quantity Harvested

The choice of a marketing channel used by farmers is dictated by the quantity of produce harvested. Quantity harvested is a continuous variable measured in kilograms per hectare. Knowing how much is produced by a household is important in understanding the proportion of food which is sold and that retained by a household for subsistence. Quantity harvested is expected to influence market supply positively with households producing small quantities likely to sell to the farmgate assemblers than selling to millers and cereal traders who purchase bulk quantity. It was expected to influence the choice of a market outlet negatively.

4.3.3.6 Transport Costs

How produce from the farms reach market is important in ensuring food is available to consumers. Efficient methods of moving food from farms to markets or from markets to consumers enhance consumption and production. Specific factors especially the means of transport and the form by which the produce was packaged for the market influenced distribution type used. In this case transport cost associated with moving produce over a given distance affected the size of marketable output was assessed. This implies that households prefer to sell at farm gate rather than transporting the product to the market.

It was hypothesized that transport costs negatively influence the type of market outlet used by a household since it reduces profit margin for farmers.

4.3.3.7 Market Price

The believe that market price is an incentive to sell more and in large quantities was tested. In this case study, market price represented the average price of maize or millet paid for a kilogram of their produce in the summer of 2018/2019 season. Market price was measured as continuous variable in Kenya shillings per a kilogram of maize or millet sold. Although this notion is likely to push households to sell especially post harvesting through channels that offer the best-selling price, more marketed supply results to low food retention rates by households. Selling price influence market outlet used by a household. The negative multiplier effects of this behaviour is the problem of systematic food shortage and over reliance on local food markets by households for food needs. Given this scenario, market price was expected to influence household's behaviour to sell their produce positively

.

4.3.3.8 Distance to Market

It is a continuous variable measured in kilometers households are willing to travel to the nearest market to sell or buy. It has been shown by several studies that distance to nearest market facility is negatively associated with the likelihood of farmers selling potatoes to retailers (Bezabih, Mengistu, Mutimba & Jemal, 2015; Abera, 2016). From this, the indication is that farmers prefer to sell to buyers near their farms rather than transport their produce to markets. Therefore, distance variable was assumed to be negatively related with the choice of households selling through miller and retail cereal traders market outlets.

4.3.3.9 Household Size

Often household size explains family labour supply when it comes to crop production and at the same time influences household consumption levels (Alene, Manyong, Omanya, Mignouma, Bokanga & Odhiambo, 2008). In this study household size refers to the total number of family members in a household measured in man equivalence. In the rural setting, labour is readily availed by family members. The assumption here is that large family has adequate labour for crop production and this affects family decisions on choice and use of a market outlet. At times, large household translates to increased consumption leaving little for sale. It has been shown that the probability to choose consumer channel decreased when the number of families increased (Mohammed, Zewdu & Getachew, 2019). Therefore, large household size in this case was hypothesized to influence the choice of miller and cereal retail trade channels negatively.

4.3.4 Tobit Regression of Explanatory Variables for Using a Given Market Outlet

To analyse influence of each explanatory variable for factors considered in choosing a marketing outlet, Tobit regression model was computed in STATA version 16.0. Censored Tobit regression was used because it gives binary outcome for dependent variable. Regression Model adopted to explain factors determining the choice of a market outlet by a household is as follows:

CHOICE OF MARKET OUTLET = 3.71- (0.094) EDUCATION LEVEL+(-0.228) HEADSHIP+(-0.236) ICT USED+(-0.239) LAND OWNED+(-0.205) QUANTITY HARVESTED+(-0.033) TRANSPORT+(0.106) PRICE+(-0.132) DISTANCE+(-0.065) HOUSEHOLD SIZE.

Out of the nine explanatory variables selected to explain choice of a market outlet by household, seven were found to be statistically significant supporting the decision at 95% and 90% respectively. These independent variables are the education level of household head; headship gender; ICT used in accessing information; land size owned the household; quantity harvested; Transport; Price; distance and Household size.

Table 14: Tobit Regression of Explanatory Factors for Choice of a Market Outlet

Market Outlet	Coef.	Std. Err.	t	P>|t|	Marginal Effect(dy/dx)
Education Level	0.094	0.060	1.55	0.121**	0.093
Headship	-0.228	0.160	-1.42	0.156**	-0.227
ICT used	-0.236	0.109	-2.16	0.031***	-0.236
Land owned	-0.239	0.094	-2.55	0.011	-0.239
Quantity Harvested	-0.205	0.091	-2.26	0.024	-0.205
Transport	-0.033	0.057	-0.58	0.561***	-0.033
Price	0.106	0.163	0.65	0.514**	0.106
Distance	-0.132	0.066	-2.01	0.045***	-0.131
Household Size	-0.065	0.077	-0.84	0.402***	-0.064
Constant	3.710	0.326	11.38	0.000	

Regression Summary: Number of observations=395, LR chi2 (9) =35.10, Prob>chi2 =0.0001, Log likelihood= -598.35099, Pseudo R2=0.0285, 73 left-censored observations at market outlet 322, uncensored observations, 0 right-censored observations. ** represent 5% statistical significance, *** represents 10% statistical significance.

Based on responses obtained from the 395 questionnaires, different factors selected and analysed through Tobit regression had influence on the choice of market outlet at 90% and 95% confidence intervals as indicated in Table 11 above. Influence of each independent variable on the decision to use or not a certain market outlet by household was estimated from the calculated marginal effect for each factor. From the estimated marginal effects of Tobit regression for the nine explanatory variables, Price has a relatively high positive effect (0.106) followed by education level (0.094) of the household head. As indicated in Table 10 there is a positive and significant relationship ($p<0.05$) between market outlet and price as well as education level.

The findings show that price is a significant factor influencing decision to use a given channel to market produce by households in Tharaka North and South Sub Counties. This is true because a slight variation in the price of food stuff influence decision to not only sell but how much should households buy from markets since majority of population depend on open air markets for most their food needs. From the analysis, a unit increase in price change will positively influence a household to use available market outlet by 10.6%. Therefore, an upward rise in food stuff prices especially in the local open-air markets will result to more households selling their produce. This is because most households rely on food for income and in most instances lack of adequate food storage facilities trigger disposal of food stuffs even at low prices especially post harvesting. The findings corroborate with those of Cunningham, Brown, Anderson and Tostao (2008) who found that household heads are likely to sell more when prices are high rather than prefer to store food for household self-sufficiency.

Education level of the household head has a highly significant($P<0.05$) and positive effect on the choice of a marketing channel. This means that education status of a household head positively influences the decision to sell and buy food stuff by household. The implication is that an educated family head is likely to make informed decision on who, when and where to market household farm produce or buy by about 9.3%. This show that education increases the household ability to collect information, interpret received information and then make knowledgeable marketing decisions.

Those with at least secondary education were found to understand merits and demerits of existing market outlets and could decide on which ones were profitable. These findings are consistent with those of Makhura (2001) who noted that formal education increases household understanding of market dynamics improving decision on the amount of output sold. This also means educated household heads can read, understand and utilise information related to marketing as communicated through mass media, phones and famer magazines.

Headship gender of the household was found to negatively correlate with the choice of a market outlet at a significant level of five percent($p>0.05$). This means that female headed households are more likely to choose a marketing channel from which to buy and sell produce than their male counterparts. This is surprising because in Kenya and especially amongst the Tharaka community, men culturally are accepted as decision makers in the household. This is because husbands' decisions are usually regarded as supreme. These results contradict with priori expectation and the findings of Hyder, Maman, Nyoni, Khasiani, Teoh and Premji (2005), Holmboe-ottesen *and*

Wandel (1991) who have pointed out that men dominate the household decision making in most places while women have subordinate positions.

Therefore, when it comes to decision on food and nutrition of the family, women have upper hand on what to cook and where to buy. This explains the negative coefficient for gender of the household head when it comes to the choice of a market outlet. In this study, household headship is a dummy variable that takes a value of one if the household head is a male and zero if a female heads a household. The implication of these results is that marketing decision when made by female will lead to better food consumption and the attainment of household food security in the family. Out of the sampled 395 households, 288 households were headed by a male and 107 by a female.

Type of ICT used by household to access marketing information was found to negatively influence decision on choice and use of a market outlet. Coefficient of ICT used was -0.23 at a significant of 0.1. Lack of access to regular and reliable market information from formal sources negatively affect effective participation of households in markets. This implies that although ICT usage influences the type of market outlet used by household, the type of ICT used (mobile phones, TVs, Radios) does not necessary translate into decision on which market outlet a household can use. This negative coefficient could be probably due to the fact that most households in the study area do not use formal sources of information like mobile phones or Radio &TV to access market related information in particular. This is partly due to lack of ICT skills amongst majority of the respondents and fact that ICT infrastructure in the County of Tharaka-Nithi is not well developed (Ameru, 2019). The few who have

ICT skills do not use it frequently owing to high information cost associated with accessing market information via mobile phone supported apps.

The general indication is that informal sources of information especially neighbours are widely used by households in the study area to get relevant market dynamic related information. Often information gotten from secondary sources (neighbours, friends and brokers) is skewed especially on price figures. The findings are in line with those of Kariuki (1996), which showed that low prices due to lack of market information limits effective participation by pastoralists in commercial livestock marketing in ASALs of Kenya.

Household size had a coefficient of-0.065 at significance level of 1%. This indicates that a large household negatively influenced the type of market outlet used by a household. The probable reason could be due to high land demand for subsistence production as the family size increases. This may cause a large household to allocate small area of its already limited size land for maize and millet production and leading to small quantity sold at farmgate. From the results the likelihood to choose a given market channel decreased when the number of the family members increased. The above findings are consistent with those of Temesgen, Gobena and Megersa (2017) who found that as the number of families increased the probability to participate in onion production decreased. In contrary to this, Efa and Tura (2018) indicated that large family size enables better labour endowment so that households are in a position to look for profitable market outlets. Most households in the study area up to 166 had between four to six members and these families comprised households with large family members. The negative coefficient implies that large households produced

minimal output that could be sold due to small landholding in the area where currently land size is less than 2.9 acres. For this very reason, large households often prefer to conserve their produce for family use and if they decide to sell then it is in small quantities and at farmgate.

Transport was found to be statistically significant (P<0.1) factor in explaining household decision to sell or not through a certain market outlet. However, it negatively correlated with market outlet chosen by a household. It implies that households near market outlets will incur less transport costs when moving their outputs to the market than those located far away from the available market outlet. In rural Tharaka, human potage is the basic mode of transport used by farmers to take their produce in the market. Due to this, only small quantities can be moved to the markets especially by those households which are far located from nearest market center. Most household prefer selling at farm gate and in the near open-air markets due to problems associated with transport. Choosing far markets who translate into high transport costs of moving produce from farms to the market, constraints which lessen marketization of outputs in the study area. Distance to the nearest market negatively influence decision to sell output by household. Distance factor had a negative coefficient of -0.132 at a statistical significance of P<0.1. Geographic isolation of households due to distance from markets adversely affects quantity sold by the concerned families and by extension market price of commodities. In the study area 40% of the households live within 5-10km distance from an open-air market. Distance also influence transport cost associated with moving farm commodities to the market. In most instances, transport cost per unit distance covered increases with marketable load size transported (Omiti *et al*., 2009). These results corroborate with

those of Key, Sadoulet and De Janvry (2000) who found that distance to the market negatively influences the decision to participate in markets.

4.3.5 Marketing Models for Maize and Millet has no Significant effect on Quantity of Food Stocks Maintained by Households

A close examination on the marketing models used by households in the study area show there exist different channels through which farm produce are sold. Table 12 shows the chi-square test distribution between market channel used and quantity sold through each outlet.

Table 15: A two-way Classification Chi-square Test Results

Market_ Outlet	Quantity_ Sold through the Channel			
	0	1	2	
1 *(Open air markets*)	15	27	31	73 (18.5%)
2 *(Institutions)*	2	0	0	2 (0.5%)
3 *(Retail cereal traders)*	42	134	22	198 (50.1%)
4 *(Farm gate assemblers)*	41	47	34	122 (30.9%)
	100 (25.3%)	208 (52.7%)	87 (22.0%)	395
Chi-square		54.147		
DF		6		
Significance Level		P<0.0001		
Contingency coefficient		0.347		

From the table, almost 50.1% of all harvested produce is sold to retail cereal traders. Retail cereal traders buy any quantities of produce and operate in local market centers

where they rent stalls for temporally storing their procured merchandise. The traders deal in major cereals and pulses like maize, millet, green grams and ground nuts.

Farm gate assemblers also known as brokers buy 30.9% of farm produce according to the interviewed households. These traders operate in villages especially within Rain Fed Cropping and Mixed Farming livelihood zones where they purchase in small quantities and at farm level. According to interviewed households, these are the most preferred marketing option because they pay cash and can advance soft loans to farmers which enable them address immediate financial needs. Besides this, brokers offer farmers' convenience since they purchase directly from villages and farms regardless of distance covered which increase profit margins for the households because they do not pay for transport costs which is boned by the buyers. The high preference of brokers by most households in Tharaka sub county closely mirrors the findings by Magogo, (Mshenga, Saidi, Oradu & Ipomai, 2015) that agro-pastoral Maasai farmers in Kajiado and Narok counties preferred brokers or large retailers for their African indigenous vegetables because they catered for any additional marketing cost.

Although periodic open-air markets comprise another outlet used by the locals, only 18.5% of farm produce is sold through this channel. This is attributed to the fact that most open-air markets operate during certain days of the week and are located some distance from most villages. This translates to increased transaction costs especially transportation given the distances covered and the small quantities taken to the markets. Institutional marketing channel was also another option used by households in the study area accounting for 0.5% of all quantity sold. Institutions especially

schools purchased maize grains from small traders most of whom were farmers and used school vehicles to transport their produce. The low volume sold through this outlet was due to small surplus available to households owing to the small farm size.

In most cases poor households bring maize grain and other grains to schools as fees which is allowed in some instances to minimize the burden of purchasing food especially during harvesting season. Based on results of the two-way classification chi-squared test as indicated on table 12, calculated P-value is 0.0001 and the contingency coefficient of 0.347. According to chi-squared test, a contingency coefficient measures the degree of relationship or association of dependence of the classification in the frequency table. Similarly, if the calculated P-value is low ($P<0.05$), then the null hypothesis is rejected and the alternative hypothesis that there is a relation between the two factors must be accepted (Campbell, 2007). Therefore, null hypothesis is rejected and instead alternative hypothesis accepted. From the statistic, marketing models for Maize and Millet has significant effect on quantity of food stocks kept by households.

In order to assess how marketing models used by households influenced food stock retention rates in the families, household heads were interviewed. They attributed price volatility, lack of adequate storage facilities, availability of farm gate buyers and convenience as some of the reasons why they disposed their produce early into the season. During harvesting period due to challenges of storage, most households disposed their produce at relatively low market prices due to surplus in the markets at this time of the year.

This is reflected in comments captured from Kanyuru, a household head at Ntendera village in Gakirwe Sub location, Tunyai Location who said:

> "*During the months of February and August people around here have money because it is harvesting season and they can sell their foodstuffs to the many farm gate brokers who establish buying stalls across the village*".

A market survey in the study area revealed that the average price offered for a kilogram of maize was K.shs 18.50 and K.shs 20.00 for millet respectively. The two cereals were most traded as dual-purpose crops across the livelihood zones for they also comprised the principal staple crops for households in the study area. Market price varied seasonally across Rain Fed cropping, mixed farming and marginal mixed farming livelihood zones as was discovered during field survey. For instance, during May-April-May (MAM) and October-November-December (OND) planting seasons in the Mixed farming zone maize was retailing at an average of K.shs 27.20 per kilo while Millet was K.shs 31.70, while in the Rain fed Cropping zone maize was sold at K.shs 23.10 per kilo and millet at K.shs 28.45.

The scenario was different in marginal mixed farming livelihood zone where a kilo of maize was selling at an average price of K.shs 35.0 and millet was K.shs 44.80. Compared to the harvesting season of January-February, August-September the inter-seasonal price variation showed that average price for maize and millet in mixed farming zone was K.shs 18.24 and K.shs 20.62 while within Rain Fed cropping the same crops were retailing at K.shs. 15.00 per kilo for maize and K.shs 19.81 for

millet. In the marginal mixed farming zone, the price of maize was at K.shs 27.36 per kilo while millet retailed at K.shs 34.00 per kilogram respectively.

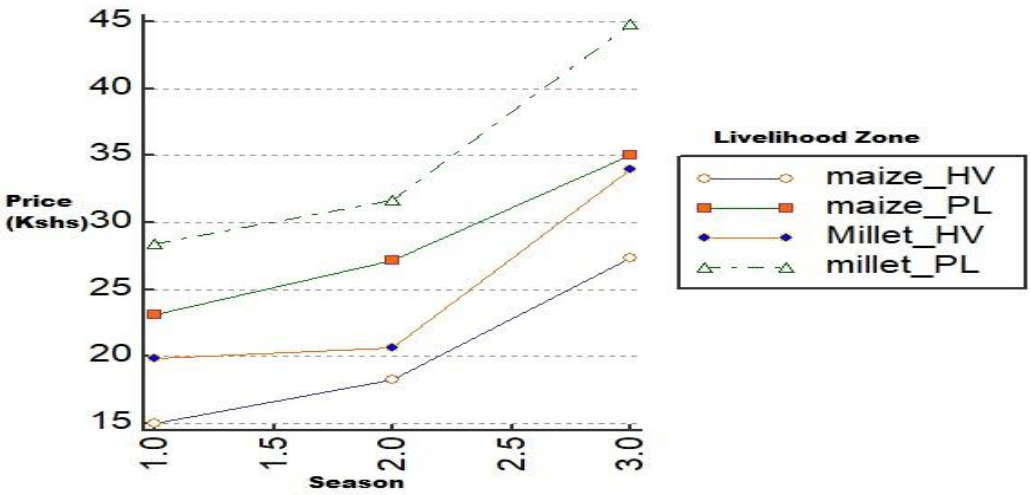


Figure 15: Average Price for Maize & Millet Across LHZs during Planting and Harvesting Season

From graph above (Figure 15), average price of maize and millet varied seasonally with relatively low unit prices for the two cereals recorded during harvesting season coinciding with January-February and July-August months. During these months, there is surplus in the local markets as households hurriedly dispose their produce. A different scenario is observed in the MAM, OND planting and growth season when there is limited supply in the markets due to shortage as most household food stock has reduced significantly due to consumption and sales. However, due to lack of adequate storage facilities in most households and that most crops are harvested at the same time force families to sell their surplus almost immediately and at low market prices. Furthermore, the presence of increased cereal traders during harvesting season in the villages increase urge for households to sell. This is convenient for most households because itinerant traders' own means of transport and can purchase in

remotest areas irrespective of quantities sold by the household. These observations relate to findings from a study by Omiti *et al.,* (2009) who pointed out that unit price acted as an incentive for marketed vegetable production in rural and peri-urban areas as it significantly increased percentage of vegetables sold. Another reason given by the households for little food stock retention rates was that most grain traders bought right in the villages on the basis of where the farmers were.

Response to a question on "what motivates you to sell your produce through the identified channel" clearly identified the presence of farm gate assemblers and small cereal traders in the villages as the reason for selling as they conveniently offered ready markets for small scale farmers. Generally, the lack of well-organized maize and millet markets especially the state-owned National Cereals and Produce Board (NCPB) in the study area has created room for assembly traders, brokers and small-scale cereal dealers to dominate cereal purchases in the rural villages. These findings closely relate to the results of a study by Lillian *et al.* (2011) on farm gate-to-consumer value chain analysis of Kenya's maize marketing system which showed that maize assembly traders have penetrated even the remote rural areas in Kenya, which reflect an increase in private sector investment in the trade. Therefore, the situation is no different in rural semi-arid Tharaka where grain sales provide the much-needed cash to pay for school fees, medical care and upkeep since informal employment is lacking largely.

4.3.6 Summary

Households in rural Tharaka sub county consume almost half of their produce and sell the remaining in open air markets, retail cereal traders and farm gate assemblers. The

type of market channel used by households is influenced positively by the education levels of household head as well as the price of the output offered in the market.

Regression analysis showed that transport, household size, distance to the nearest market, household headship and ICT type used to access market related information negatively influenced decision on which type of market outlet a certain household would use to sell farm output or even buy food stuffs. This indicates that these factors limit choices on the market outlet households use in the study area. Although land size and quantity harvested by household were considered as factors, they were statistically insignificant in influencing household's decision on the choice of market outlet. Findings from this chapter resonates well with studies by Mutua (2010) and Wambua (2014) which highlighted that low education levels, instable food stuff prices, unfavourable marketing systems and poor infrastructural facilities undermined household food security in Kenya's drylands.

The researcher has shown how socio-economic characteristics of households as well as ICT use affect market participation by rural farming households in Tharaka Sub County. By analysing factors influencing choice of market channel, the intensity of household participation in local produce commercialisation and variations in quantity sold thereof were identified. Identifying retail cereal traders and farm gate assemblers as preferred spot marketing outlets in the study area, the researcher has established that these outlets catalyse households to sell more of their produce which they could have hoarded for future consumption. This is because such channels offer opportunities for small scale farmers to sell in any quantity they want, at the pace they

wish and at the time they prefer to. This in the long run impact on the quantity of foodstuff stocked by households as retention for future family consumption.

4.4 Measurement of physical accessibility to open air markets

This looks at objective three whose aim was to measure physical accessibility to open air markets and analyse how it impacted food security locally. Physical accessibility especially distance is an important factor in the use of markets more so in rural areas where long distances negatively influence the ability to access markets for food needs, purchase of local merchandise and sale of livestock for financial resources. To realise this objective, road network data, Position coordinates of all open-air markets, population data and elevation data among others were used. By modeling physical accessibility to markets, this study showed how the problem of physically accessing food and livestock markets in ASALs is hindering the realisation of SDG number two on zero hunger. Through the development of a Compose Index of Critical Accessibility (CICA) to markets from villages, it was possible to identify areas and population at risk of inability to access markets.

4.4.1 Spatial Modelling and Geo Processing Approach

In this study, QGIS was used to carry out geoprocessing and analysis on spatial data. SIGEpi was used to model spatial accessibility using vector datasets through integration of various parameters to develop the Compose Index of Critical Accessibility. Arc pad was used to collect position coordinates of open-air markets and Land Use/Cover types. Idrisi Kilimanjaro was used in analysing raster data and modeling agro climate zones suitability using various datasets.

Input datasets required to support modeling of physical accessibility were geospatial datasets which included, location coordinates, maps and related attribute data as well as statistical data. The data was acquired from different sources and was in different formats.

4.4.1.1 Administrative Boundaries Mapped

To delineate the study area, a paper map showing Tharaka North and South sub counties was acquired from the local Tharaka Constituency Office. The paper map was scanned and then digitized in CATALINX digitizing software. The lowest administrative area was sub location which is administrative level 5. All the 48 Sub location boundaries (Fig.16) were digitized and corrected for errors through running of polygon closure algorithm to ensure there were no slivers or gaps in resultant polygons. The layer was then exported to QGIS open source GIS software where the map was reprojected into the common spatial reference system adopted all geospatial datasets used in this study

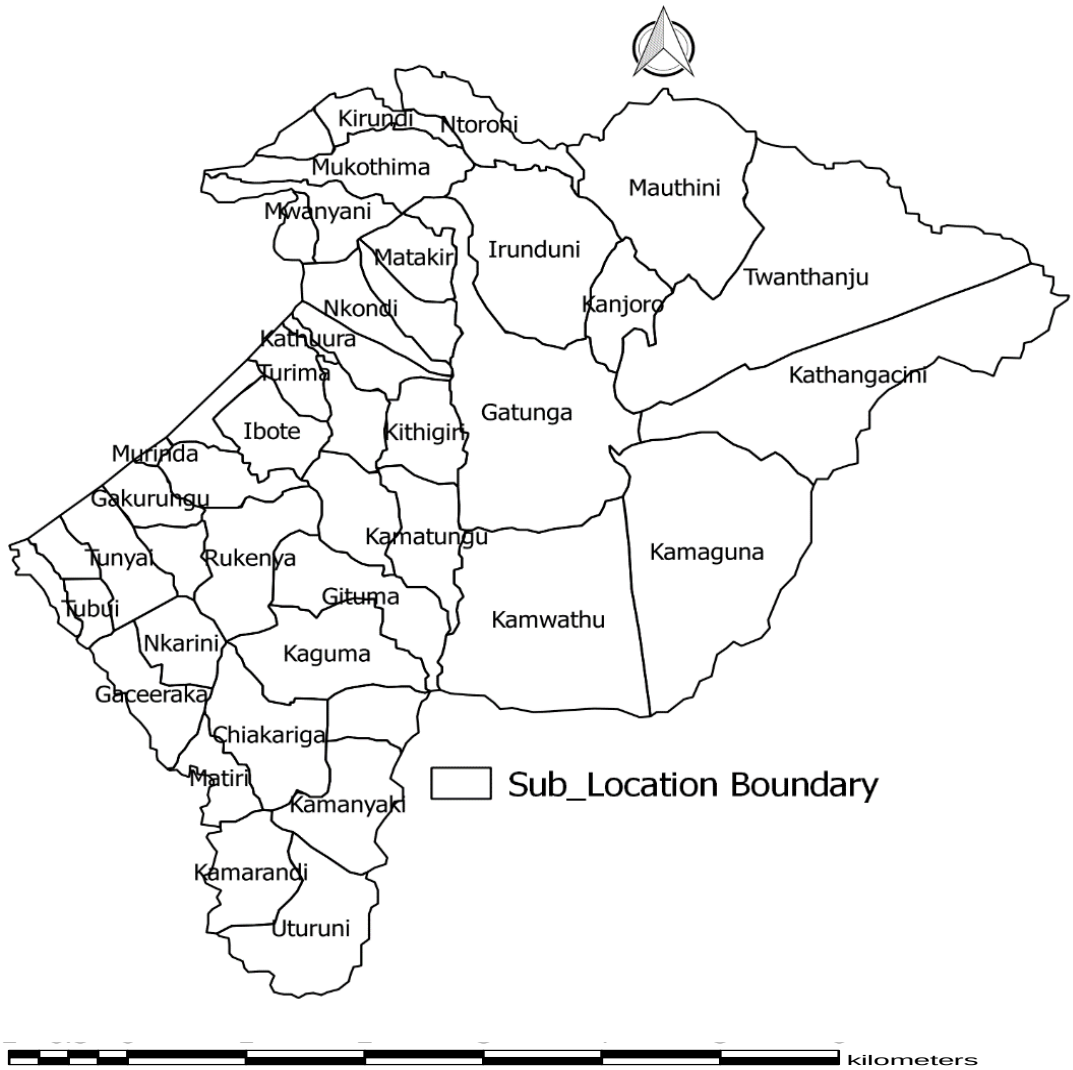


Figure 16: Spatial Distribution of Sub–locations within Tharaka Sub County

4.4.1.2 Digital Elevation Model Derived for the Study Area (DEM)

It represented the terrain gradient in terms of slope drop or rise. Slope was considered as an important parameter affecting travel time to and from markets by households. Slope was derived from the digital elevation model using slope function in QGIS geoprocessing tool box. The slope across the study area ranged between 0.6 percent to 26 percent. The DEM used was downloaded from NASA STRM in 30m to match grid resolution of other datasets used for the study area (Figure 17).

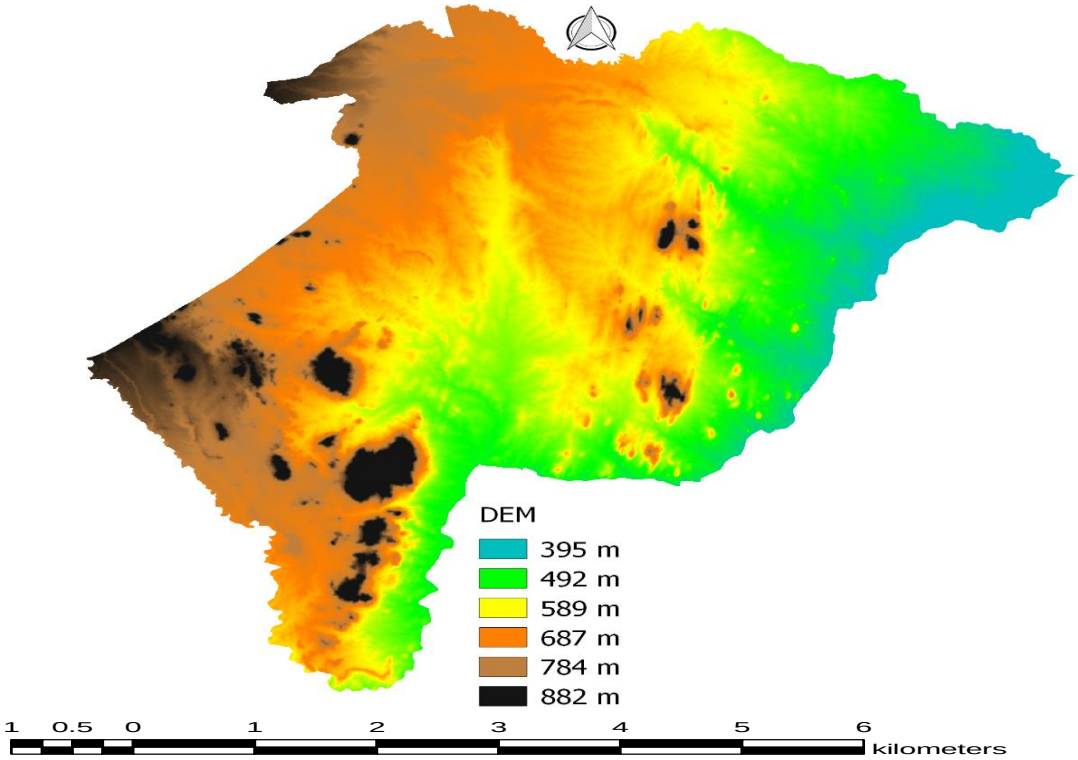


Figure 17: Raster Data showing Digital Elevation Model of the Study Area

4.4.1.3 Road Network Distribution

Road network vector format data was derived from data supplied by the County Kenya Rural Roads Authority (KeRRA) for Tharaka-Nithi based at Chuka town. The sourced data was not adequate for analysis after comparing it with Google Earth imagery. It was therefore updated using Open Street Map data accessed using OSM plugin in QGIS. Additionally, data from the World Resources Institute was also integrated to supplement the available datasets in order to make it complete as indicated in Figure 18 below.

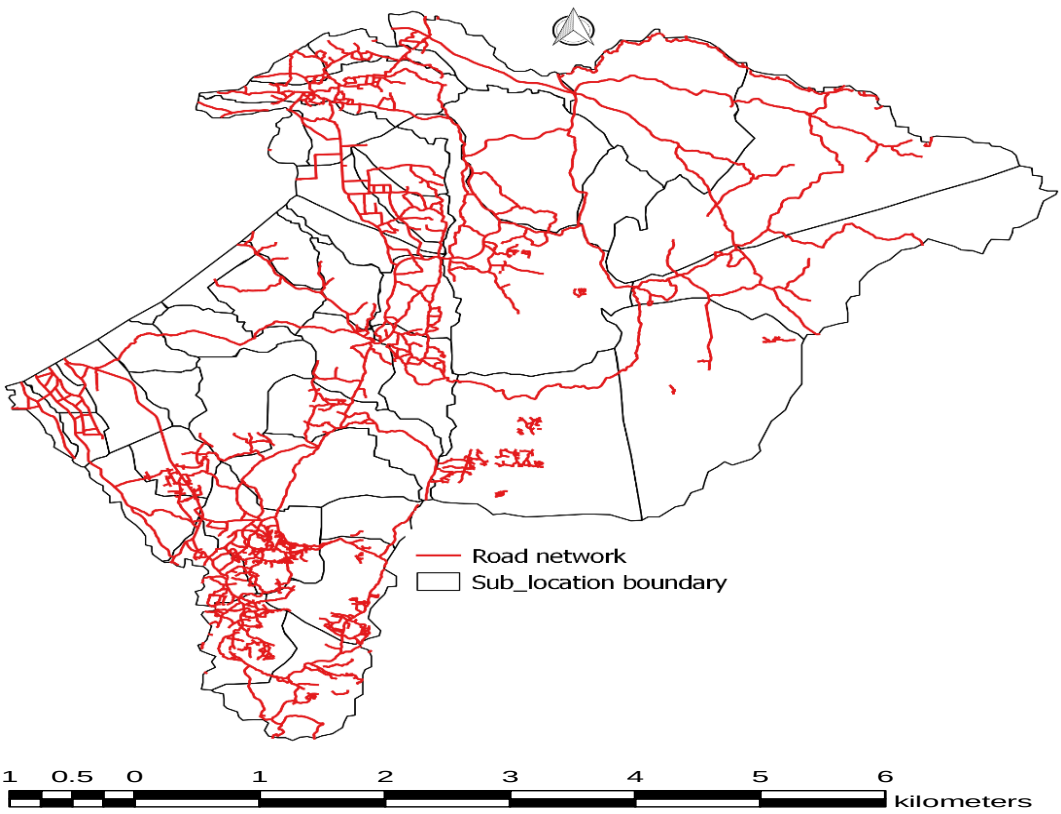


Figure 18: Road Network Layout and Spatial Coverage within the Study Area

4.4.1.4 Population data for the Sub locations

Population data projected to 2018 was sourced from Tharaka Nithi county office of the Central Bureau of Statistics. Sub location was chosen because it forms the lowest and fifth administrative level in Kenya and that all census data is aggregated to this level. Population data at sub location level forms the highest spatial resolution census data available for public access. According to the 2018 projected population data, Tharaka North and South sub counties have a total population of 147,583 inhabitants spatially spread across 48 sub locations (See Appendix 3).

4.4.1.5 Location of Open-air Markets

Each of the open-air market was visited to understand food marketing systems by examining the type of food sold, its status and functional services performed.

Geographic location was mapped by collecting coordinates of the markets using Trimble Juno C series GPS receiver. To increase positional accuracy, three readings for latitude and longitude were taken and the average reading used to give the final location for that particular market. Field survey revealed that markets in the study area vary in functional service from those dealing in food crops bulking alone or livestock alone to those dealing with both food and livestock as shown in Table.16.

Table 16: Name, Functions and Location Coordinates of all Open-air Markets

Market Type (Function/Service)	Market Name	Latitude (DD)	Longitude (DD)
Food Assembly	Mukothima	0.013272	37.945258
	Miomponi	-0.000625	37.904954
	Nkondi	-0.045627	37.957797
	Gaciongo	-0.029883	38.019463
	Karocho	-0.131622	37.885863
	Matiri	-0.319019	37.901902
	Kibung'a	-0.076775	37.919951
	Nkarini	-0.243508	37.877654
Livestock	Kathangacini	-0.094119	38.151877
	Shauri	-0.082076	38.059340
Food Assembly and Livestock	Gatunga	-0.997253	38.010969
	Marimanti	-0.157041	37.977835
	Tunyai	-0.175883	37.836882

4.4.2 Data Preparation

4.4.2.1 Creation of Sub-location Population Database

The fifth level administrative units obtained as analogue data from the sub county physical planning office were digitized as polygons and the polygon's centroid calculated to represent a point-polygon feature. Projected population for 2018 for each fifth level administrative unit was then assigned to each centroid. Therefore, a population geo database for all the 48 sub locations was created through linking the administrative units' polygon to sub location population. Resultant database contained relevant data to facilitate GIS analysis and visualisation.

4.4.2.2 Road Network Classification

Road distribution map data generated from open street map was cleaned to remove duplicate and short road segments. It was then reclassified based on the Kenya Roads Act, 2015 as primary, secondary and tertiary roads. According to the Act, primary roads are those which connect countries through international boundaries. Secondary roads on the other hand link counties, major towns as well as primary roads. Tertiary roads are those roads that connect small markets and also feed into secondary roads. Tharaka has secondary and tertiary road categories.

4.4.2.3 Travelling Scenarios based on Available Transport Modes

To understand mobility across the study area, various common transportation modes were used. The basic transportation modes considered include; walking, cycling and finally use of vehicles. The modes of movement applied here were identified during field survey and thus adopted in coming up with the different travelling scenarios. Land use/cover map for the study area was created from the recently acquired Landsat

8OLI/TIRS image using semi-automatic classification plugin in QGIS Version 3.8. Four classes of bare land, built up area, thick vegetation and crop land were developed. Speed limits associated with each land cover was based on recommendations by authors (Nelson, 2000; Ray & Ebener, 2008). Recommended speed limit assumes travelling surface is always a zero-degree slope flat surface (Flat land). To address this, speed limit correction based on the DEM was done to consider slope variation in the study area. To come up with scenario-based walking speed, adopted speed was corrected based on the digital elevation model for the area using Tobler's formula (1993);

$$W = 6 \exp \{-3.5 * abs (S+0.05)\}$$

Where W is corrected walking velocity in kilometers per hour and S is slope in degrees. Tobler's formula was chosen because it increases or decreases the effective walking speed based on the steepness of surface slope. Resultant walking speed corrected on the basis of land cover and slope is as indicated in table 14 and 15 respectively.

Table 17: Corrected Walking Speed based on Land Cover

Land Cover	Walking speed (Km/hr.)
Bare land	2.2
Crop land	1.6
Built up area	3.1
Thick Vegetation	1.0

Table 18: Corrected Walking Speed Based on Slope Intensity

Slope	Walking speed (Km/hr.)
0.6	4.7
4.3	3.6
7.9	3.3
11.6	2.5
15.3	1.8
18.9	1.4
22.6	1.2
26.2	0.8

As for road-based velocity, slope correction was not done given the flat nature of landscape in the study area and often it is the acceleration which propels the speed of movement, therefore slope was considered to have no significant influence on the overall speed of motorized transportation (motorcycles and vehicles). Speed limits used were the travel speeds adopted by Ouko *et al.*, 2019 and modified by the author as indicated in table 16 below. These speed limits were applied because they represent optimal velocities allowable in event of encountered barriers to movement.

Table 19: Optimal Speed for Motorised Travel per Road Category

Road Category	Motorcycle (Km/hr.)	Vehicle (Km/hr.)
Primary	28	60

Secondary	24	50
Tertiary	10	30

(Source: Ouko *et al*., 2019)

4.4.3 Analysis

4.4.3.1 Distance Analysis

Distance to the nearest market was computed for all the open-air markets using Distance to the Nearest Hub tool, a special spider diagram script program in QGIS. This tool was used to calculate linear distances covered by the people to the markets during movement on foot for localities where there are no roads. The result was spider diagram like straight lines connecting each sub location centroid to its closest market (Figure 19).

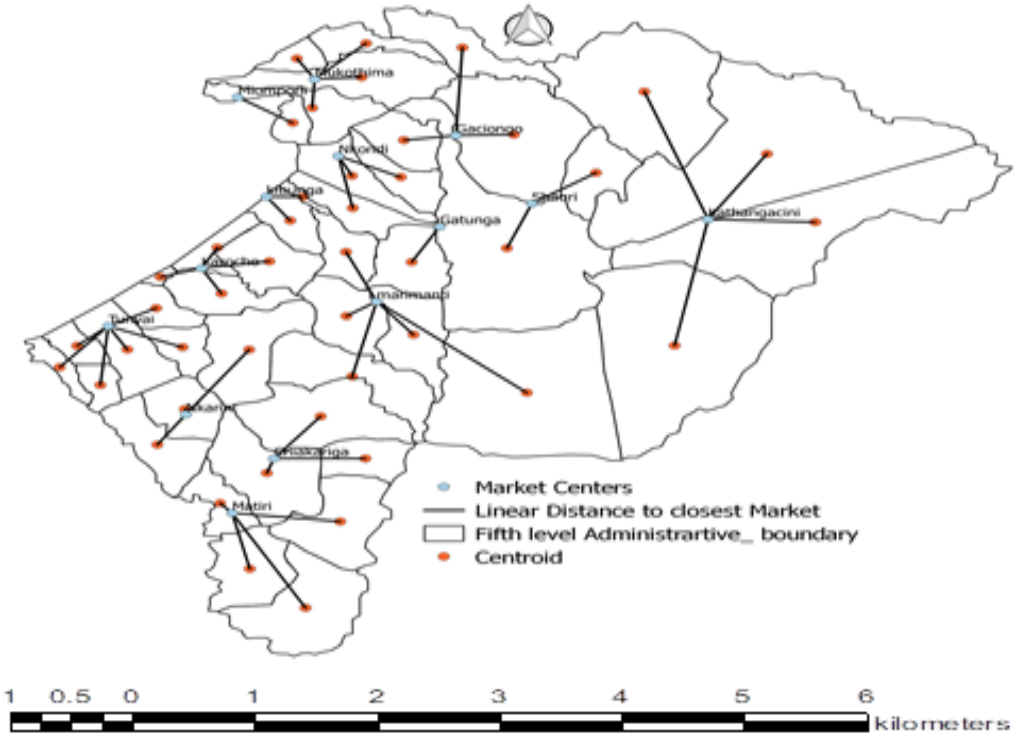


Figure 19: Spider Diagram of Distance Walked to Markets by People

Each centroid was assigned the number of villages in each sub location. Calculated distance in kilometers was classified into six-point equal interval distance scale from 0.5 - 2.4 km, 2.4 - 4.2 km, 4.2 - 6.1 km, 6.1 - 8.0 km, 8.0 - 9.8 km and 9.8 - 11.7 km. Population with access to each market at each point distance scale was then computed as indicated in table 17 below.

Table 20: Population with access to market for equal interval distance scale

Point	Distance range (Km)	People with Access
1	0.5 – 2.4 kilometers	27,415
2	2.4 – 4.2 kilometers	54,443
3	4.2 – 6.1 kilometers	35,562
4	6.1 – 8.0 kilometers	19,761
5	8.0 – 9.8 kilometers	1,780
6	9.8 – 11.7 kilometers	11,049

4.4.3.2 Travel Time Estimation

Two kinds of movement were considered by this study; pedestrian walking on foot where no clear roads exist and motorised transport on established road network. Computing travel time by pedestrians, distances derived through estimation of linear trajectories to the closest road and slope corrected walking velocity were used. Travel time for motorised movement was calculated for secondary and tertiary roads common in the study area. To get travel duration for vehicles and motor cycles, length of the closest road to each market center was divided by the optimal speed of 50 km/hr adopted for all roads used by vehicles. On the other hand, for motor cycles, average speed of 24km/hr. was used assuming that regardless of road type, barriers encountered by users to the markets were the same across all the 48 sub locations.

Travel Time was computed based on a formula by Kayode and Efosa, 2014 where Travel Time in minutes = Distance to nearest road/Walking speed corrected based on slope*60min as indicated in figure 20 and tabulated in Table 18 below.

A B

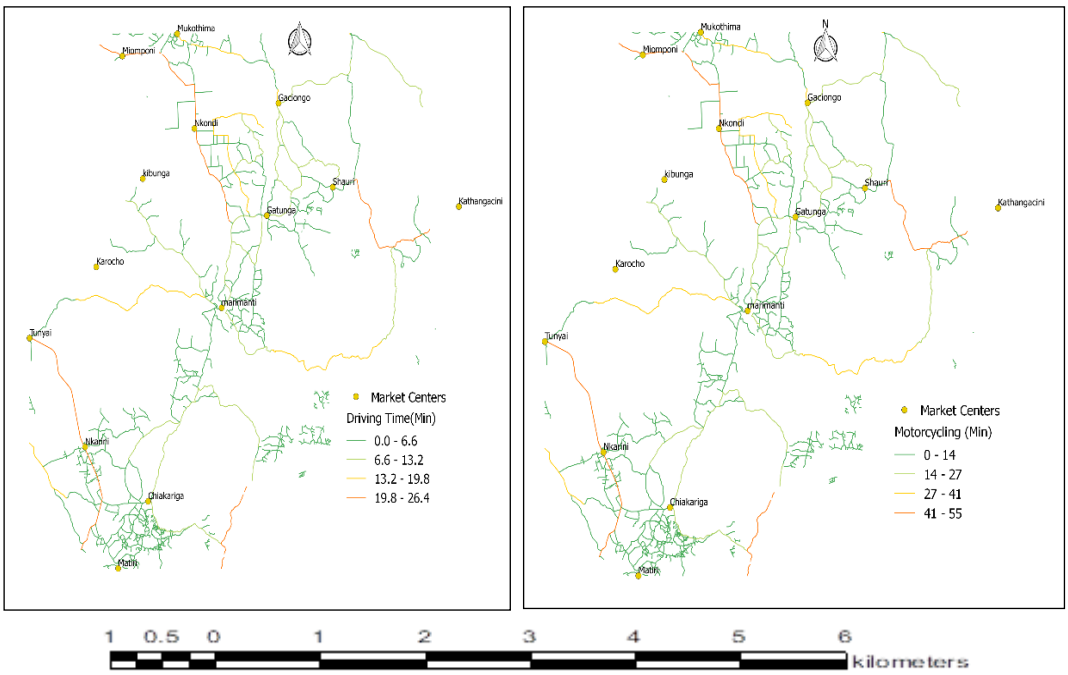


Figure 20: Driving Time (A) and Motor Cycle Riding Time (B) to the Closest Market

Table 21: Modes of Movement used, Computed Travel Time and Speed

Mobility	Mean Travel Time	Maximum Travel Time	Average Speed
Walking	18.7 Minutes	4hours.39 Minutes	5 Km/hr.
Motor cycle	3.9 Minutes	54.9 Minutes	24Km/hr.
Vehicle	1.8 Minutes	26.4 Minutes	50Km/hr.

(Source: Author)

4.4.3.3 Composed Index of Critical Accessibility

For integrated analysis, selected indicators for accessibility were combined together to compose a critical accessibility index. The index comprised of total Z score values for all indicators used in the analysis. Z values are used because they explain how many standard deviations the individual scores are from the mean (Hinton, 1999). Composed Index of Critical Accessibility was calculated in SIGEpi. The said index was calculated as shown below;

$$CICA_{j} = \sum Z^{n}_{i=1}$$

Where; CICA = composed Index of Critical Accessibility, i = indicators

j =Villages in each Sub locations, Z =Z score

$$Z = (X - x) / SD$$

Where; SD =Standard deviation, X =Indicator value for villages, x = Mean

CICA was generated for each sub location which contains aggregated population at village level for all households. In order to identify population exposed to the risk of inaccessibility, computed CICA was then classified and arranged into categories showing Very High risk, High risk, Medium risk, Low risk and Very Low risks of accessibility problems as shown in Table 19 below. In coming up with areas having problems of poor accessibility, this analysis considered population, number of populated places (villages), travel time used to reach the nearest road and distance covered as important factors greatly influencing mobility.

Table 22: Composed Index of Critical Accessibility and Indicator Component

Composed Index of Critical Accessibility	Total Population	Villages	Average Distance to nearest road (Km)	Travel Time (Min)
Very High	33,595	255	4.43	14.75
High	25,351	113	3.77	12.55
Medium	34,325	159	2.77	9.22
Low	31,888	181	1.01	3.32
Very Low	20,755	175	0.88	0.43

From the above tabulated analysis, it is evident that 33,595 people within Tharaka north and south sub counties live in areas with the highest risk of poor accessibility conditions, 25,351 in high risk conditions, 34,325 persons in moderate risk zones and 31,888 people in areas with low risk of poor accessibility. Populated regions with very low risks of accessibility problems cover 20,755 persons geographically spread across the study area.

4.4.3.4 Accessibility Surface

In order to spatially delineate and visualise areas of critical accessibility, boundary of possible accessibility surface was created (Figure 21). This was done through spatial interpolation of the composed index of critical accessibility Z values using Inverse Distance Weight (IDW). Inverse Distance Weight approach was used because it

works on the premises that each input point has a local influence that diminishes as distance increases away from that point.

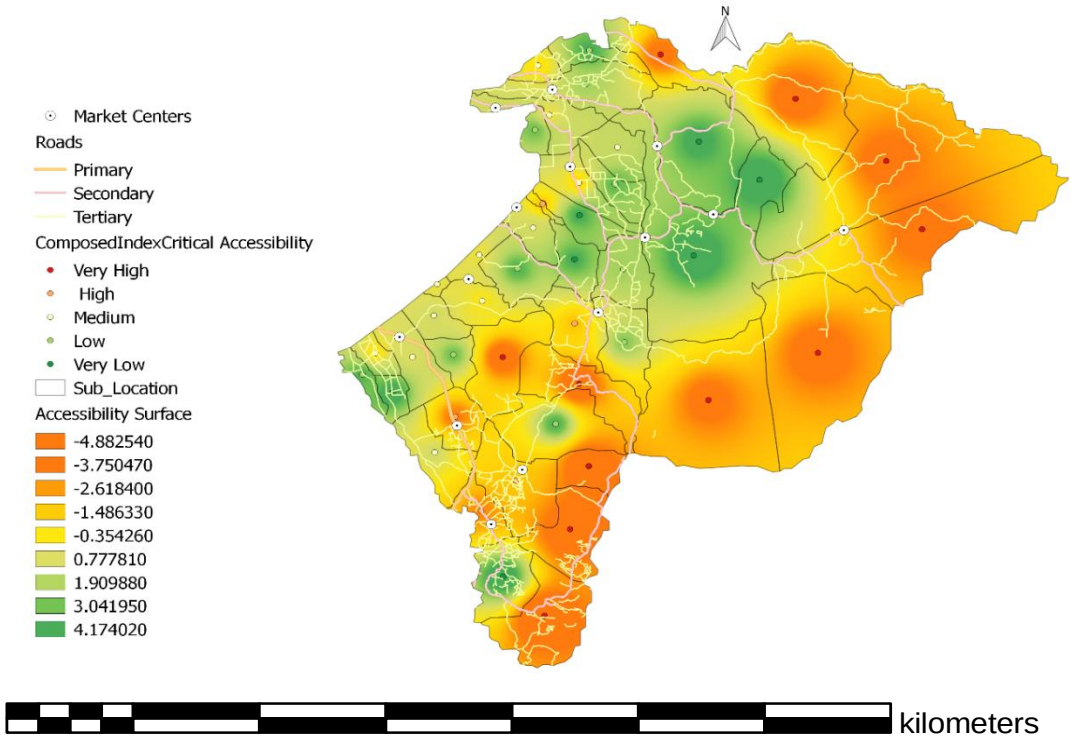


Figure 21: Accessibility Surface to the Market Centers Across Study Area

From the above generated accessibility surface, areas within this region that have low accessibility to markets, an important source of food for rural households in the study area are shown in orange colour while as areas with high accessibility to markets are shown in green colour. Areas with low accessibility to markets are those found in Kathangacini, Mauthini, Twanthanju, Kamaguna, Kamwathu, Kirukuma, Kamanyaki, Uturini, Gituma, Rukenya, Nkarini, Matiri and Ntoroni sub locations. These areas are not well served with roads and occur on the border with counties of Kitui to the East and South East and Meru County to the North and North East. Additionally, created accessibility surface has shown areas within Gatunga, Kanjoro, Irunduni, Marimanti, Rukurini, Ibote, Tubui, Gakirwe, Kaguma, Kamarandi, Tumbora, Kirundi,

Mukothima, Kithigiri, Kamatungu and Mwerera sub locations as having high accessibility. This can be attributed to the fact that these areas are well served by many feeder roads and the major road connecting Embu, Kitui and Meru Counties with Tharaka region passes through these areas. Hypothesis postulated in this study as shown here below was tested for its statistical significance.

4.4.4 Physical Accessibility and Food Security

The importance of proximity and access to markets in determining ability of smallholder farmers to participate in food market has been emphasized in many agricultural commercialisation and market participation studies. Similarly, Physical accessibility enhances food distribution and marketisation by farmers while for consumers it ensures continuous food supply and stabilisation of food prices. Distance to market influences smallholder farmers' decisions to participate in any market and the quantity to sell. This is so because geographical distance determines final market price for produce as well as transportation cost associated with taking produce from the farm to the market which forms part of transaction costs. To model relationship between physical accessibility to food retail markets and household food security, Kendall's rank correlation was applied. It was found that the duration of time it took households to retain food stock from previous harvest correlated positively with the average distance from market centers to the village centroids and the quantity of maize and millet harvested per unit acre of land cultivated. Results of this analysis are indicated in Table 20 below.

Table 23: Kendall's Correlation Results for Factors to Retain Food Stock

	Distance to Market	Food Stock Storage	Quantity Harvested
Distance to Market	0.7166		
	1.000		
Food Stock Storage	0.0719* (r =0.072, p>0.01)	0.6633	
	0.1043* (r =0.072, p>0.01)	1.000	
Quantity Harvested	-0.108	-0.0217	0.6117
	-0.0163	-0.0340	1.000

*Correlation is significant at the 0.01 level (2 tailed), N=395

(Source: Author)

From the tabulated values, significant Kendall's tau_a correlation coefficient of 0.0719 and tau_b of 0.1043 indicates there appears to have a positive correlation between food stock storage duration by the household and distance to the closest market center. When compared to the quantity of maize and millet harvested based on the sampled households, distance appeared to have negative Kendall's correlation coefficient values indicating that as distance to the closest market increased the number of baggage harvested declined although it was not significant statistically. A similar observation was made between quantity harvested and the duration of storage as indicated in table 19 above.

According to the survey, households living less than 5km from the nearest market center stored up to 2 bags of their produce for duration of 3-4 weeks. Those living within 10-15km kept between 3-5 bags for the same period or 2months. It was revealed that households living more than 15 km away retained between 3-5 bags and in some cases more than 6 bags of produce up to one season. This shows that distance has effect on marketization of produce through influencing the decision on whether to sell or not. Distance affects price of farm produce especially where food markets are located in far areas, transport costs to get produce to the market are high leading to increase in prices of farm products in the market. Towela, Thandy and Mulubua (2013) in their study on cost of negotiation and smallholder household access to maize markets in Zambia found that distance to the main market negatively affected household's decision to participate in maize markets.

A study by Kirsten and Vink, (2005) found that short distance to markets reduced the magnitude of the transaction costs by minimising the amount of time and money spent in search for market information. In another study on analysis of finger millet profitability and marketing chain in central zone of Tanzania by Rukelegwa, (2011) a logistic regression analysis indicated that distance to the village market was positively related to the supply of finger millet in the village market implying that households living near the markets in terms of distance sold more finger millet than those that lived far away from the markets.

Based on Kendall's rank correlation run to determine the relationship between "distance to market and maize/millet food storage duration" on one hand and "distance to market and quantity of maize/millet harvested" on the other hand, there

was a positive monotonic relation between distance to market and maize/millet food storage duration ($r=0.072$, $n=395$, $p>0.01$). From the above statistical analysis, null hypothesis was rejected and instead alternative hypothesis that physical accessibility to open air markets affects household food security was accepted.

This can be attributed to the fact that in the study area, poor road networks limit mobility while the small land holding (<5acres) does not produce enough for consumption and commercialisation. All these translates into low surplus production with the inability to access food markets negatively affecting households' decision to produce for the markets especially as those far away from the market opted to engage in production of low marketability alternative crops like cowpeas and pigeon peas.

4.4.5 Summary

The section has shown how to utilise network data model to analyse geographic accessibility to critical services (open air markets) when faced with environmental constraints of slope and dense vegetation cover. Underserved areas from the case study were identified as villages within the sub locations of Mauthini, Twanthanju, Kathangacini, Kamwathu, Kamaguna, Uturini, Kamanyaki and Kirukuma. In an attempt to measure physical accessibility to markets by locals in Tharaka sub county, two extremes were considered with location of people on one hand and market availability on the other. Populated places aggregated at sub location were geocoded by a centroid through assigning of associated population data to that polygon locator.

When location of market overlaid on gridded population data was superimposed on accessibility surface, it was discovered that food assembly markets occur in densely

populated low accessibility risk areas. Livestock markets were found in lowly populated areas which also were high accessibility risk areas.

The food and livestock markets were similarly found in densely populated areas with moderate accessibility risk.

Location coordinates of open-air markets was collected in the field using Trimble Juno 3C GPS receiver while road network and its associated data was acquired from the county rural roads authority offices at Chuka town. In this particular study, travel time and distance were considered important indicators of physical accessibility and geographic isolation of places. This concurs with a study by Baltenweck and Staal, (2007) that travel time and distance are market access proxy definitions.

When distance was analysed across the study area, 59% of the population live within 2.5 kilometers to 6 kilometers from nearest market with 18% within less than 2.5 kilometers and about 23% of the total population living over 6 kilometers from the closest market center. As per travel time computed for both motorised and non motorised mobility, folks walking to the nearest road from their homesteads would use on average 18.7 minutes if walking at a speed of 5km/hr. Those using motor cycles would use only 3.9 minutes riding at a mean speed of 24km/hr. while those opting for vehicular movement would use 1.8 minutes driving at an average speed of 50km/hr.

On the basis of accessibility, 52,643 people living in 356 geographically dispersed villages are found in areas with low accessibility, while 34,325 people within 159 villages live in areas with relative ease of accessibility. A total of 58,946 people

spread across 368 villages live in areas with high accessibility. These are opened up regions with improved roads and more transportation alternatives to markets for their food needs. The researcher has succeeded in showing approaches that can be used to establish conditions of critical accessibility for populated areas.

The results of this study agree with those of Bhatta (2004) which showed that households near to tarred roads in Malawi have higher chances of obtaining positive household food security compared to those who that lived away. Additionally, our current study has identified markets located in areas with higher risks of inaccessibility which can be considered by the county government of Tharaka-Nithi for possible upgrading or restructuring to aid in meeting local food demands in Tharaka sub county per se. Besides, the identified areas of very high and high risks could be targeted for food security intervention programs. Findings from this particular study have established and confirmed that physical accessibility to open air and associated food markets is a key determinant to the availability and access to food by households in the rural semi-arid Tharaka sub county.

4.5 Spatial patterns of open-air markets and levels of market utilisation

This objective analysis spatial patterns of open-air markets arising from location distribution of markets centers. By linking market location with accessibility, it will be possible to understand how open-air markets distribution influence markets usage in the area. Datasets and methods used in determining the patterns thereof are highlighted in details. Testing of hypothesis on whether the distribution is random is done. Market catchment areas are mapped while potential and real users are computed

to understand usage dynamism of food assembly, livestock as well as food and livestock markets by household in the study area.

4.5.1 Location and Categorisation of Markets

The location of markets varies spatially across the sub county. Although most markets are found close to the equator, only Mukothima market is located in the northern hemisphere while all others are to the southern hemisphere. Field survey revealed that Tharaka south and Tharaka North sub counties have 13 open air markets. These markets serve as either food assembly centers, livestock markets or both food and livestock markets. To analyse patterns of spatial distribution for the open-air markets, distance measure from an individual market to its nearest neighbour was done using distance matrix plugin in QGIS. Nearest neighbour analysis method was used to compute index of aggregation. Index of aggregation was used since it measures randomness of distribution. To compute this index, a formula by Clark and Evans, (1954) was used as indicated below;

i) $R = \bar{R}a / \bar{R}e$

Where; $\bar{R}a$=Mean Distance to nearest Neighbour, $\bar{R}e$=Expected Distance to the nearest neighbour

ii) $\bar{R}a = Ri / n$

Ri =Distance to Nearest Neighbour for each market i, n=total number of markets in the study area

iii) $\bar{R}e = 1/2\sqrt{p}$

Where; $\bar{R}e$= Expected distance to the nearest neighbour, p= Density of population in the study.

The Clark and Evans formula (1954) was used because it works best with random data and that when the boundary of elements being studied is included, it will give un biased value. In this case, the population and open-air markets considered were confined to those only within Tharaka North and South sub counties. The observed mean distance for all the markets was 5.60 kilometers and an expected mean distance of 4.30 kilometers respectively were computed for the case study. Derived observed and expected mean distances were input in equation (i) to give an aggregation index (nearest neighbour index) of 1.30. In interpreting the aggregation index values, a spatial pattern is random if R = 1, tends towards clustering if R approaches 0 and if a regular pattern then R approaches upper limit of 2.15. Since in our case the computed R was 1.30, it therefore means that away from randomness, open air markets in the study area show a tendency towards regular pattern of spatial distribution. To test the significance for deviation from randomness, the following formula was applied;

$$Z = \bar{R}a - \bar{R}e / Sr$$

Where; Z = Standard normal deviation, Sr= Standard error of the expected distance to nearest neighbour. Computed Z was 2.20 but since at a significance level of 0.05 ($\bar{\alpha}$=0.05), Z=1.96, then we rejected null hypothesis that open-air markets in Tharaka North and South Sub counties are randomly spaced and instead accepted alternative hypothesis that markets in the study area are not randomly spaced but located in a uniform pattern. Geocoding of market location coordinates indicate that most markets are located along a road network (Figure 22). This explains and visually confirms the almost uniform linear pattern of markets as computationally revealed by the Nearest Neighbour Index calculated in equation (i).

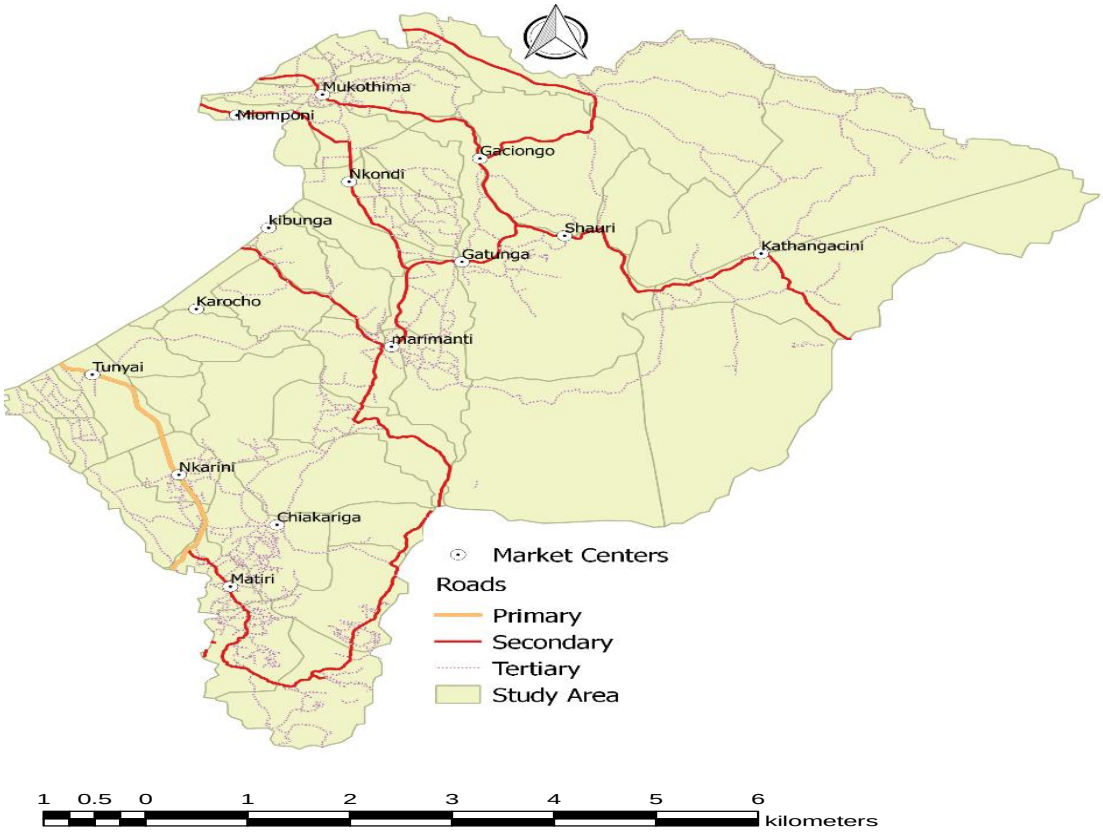


Figure 22: Spatial Distribution Pattern of Markets along Major Road Network

4.5.2 Utilisation Patterns of Markets

Patterns of access to markets by the local population were considered indicative of market utilization for the area. In particular, potential users and actual users of open-air markets were determined to aid in analysis of usage patterns. To determine the user population, proximity spider-diagram approach was used where potential and actual usage was analysed based on derived distance between each village and its nearest open-air market.

4.5.2.1 Potential users of Open-Air Markets

To analyse potential usage of market facilities in the study area, each market catchment area from the villages was generated using Voronoi polygon creation

technique. This was done by assigning each sub-location to the nearest market based on calculated Euclidean distance. This created polygon map of market catchment area as shown in figure 23 below. Attribute value of sub-locations falling within the catchment area was then exported to Excel spreadsheet.

Using Pivot table tool in Microsoft Excel, the population of all sub locations intersecting the Voronoi polygon which in this case comprised the catchment area was summed up and recorded as the potential users of that open-air market. In using this technique, it assumed that people choose to travel along the shortest paths between village and market sites and that users will always visit the nearest market facility. Additional assumption was that households in the study area experienced the same travel conditions. In this case, all market centers regardless of the services they offered were considered because in this semi-arid area, they often influence local food supply and demand value chain by acting as buying centers or retail produce stalls.

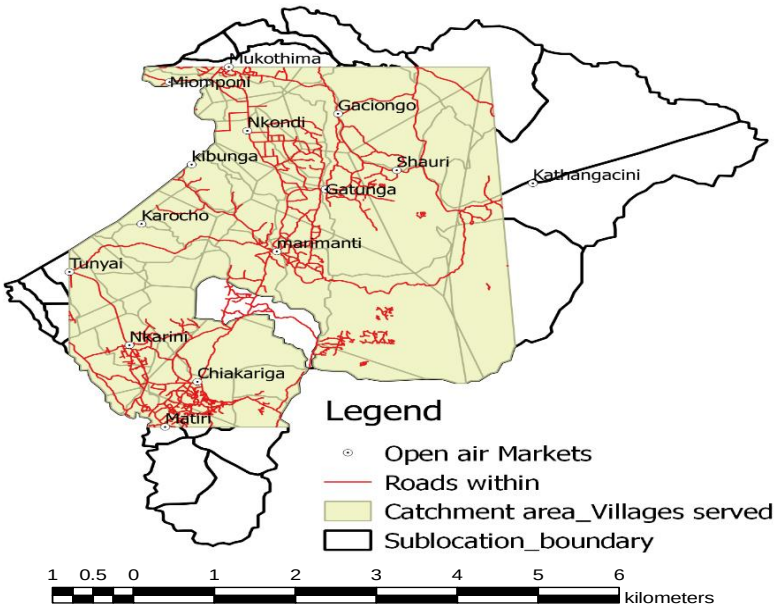


Figure 23: Map of Market Catchment Area for Open Air Markets

A total of 113,606 people was identified as potential users of open-air markets spatially distributed across the sub county. This represents 77% of the entire population in the study area. The fourteen market centers within Tharaka sub county serve 670 villages spread across 39 sub locations of Twanthanju, Mauthini, Kanjoro, Ntoroni, Irunduni, Mukothima, Mwanyani, Tumbura, Nkondi, Kereria, Matakiri, Rukurini, Kathuura, Turima, Marimanti, Kithigiri, Karocho, Ibote, Murinda, Kanyuru, Gakurungu, Mwerera, Rukenya, Kirangare, Kamatungu, Gatunga, Tunyai, Kithino, Tubui, Gaceeraka, Nkarini, Matiri, Chiakariga, Kamanyaki, Kirukuma, Kaguma, Kamwathu, Kamaguna and Kathangacini. Potential usage based on open-air market functionality was also analysed using gridded population data to give population density of users per market type as indicated in figure 24 below. From the analysis, food assembly markets exist in densely population areas with between 263 to 342 persons per square kilometer. Similarly, food and livestock market occur in areas with moderate dense population of about 224 to 303 persons per square kilometer. Lastly, it was discovered that the livestock markets exist in low population density areas with between 66 to 145 persons per square kilometer.

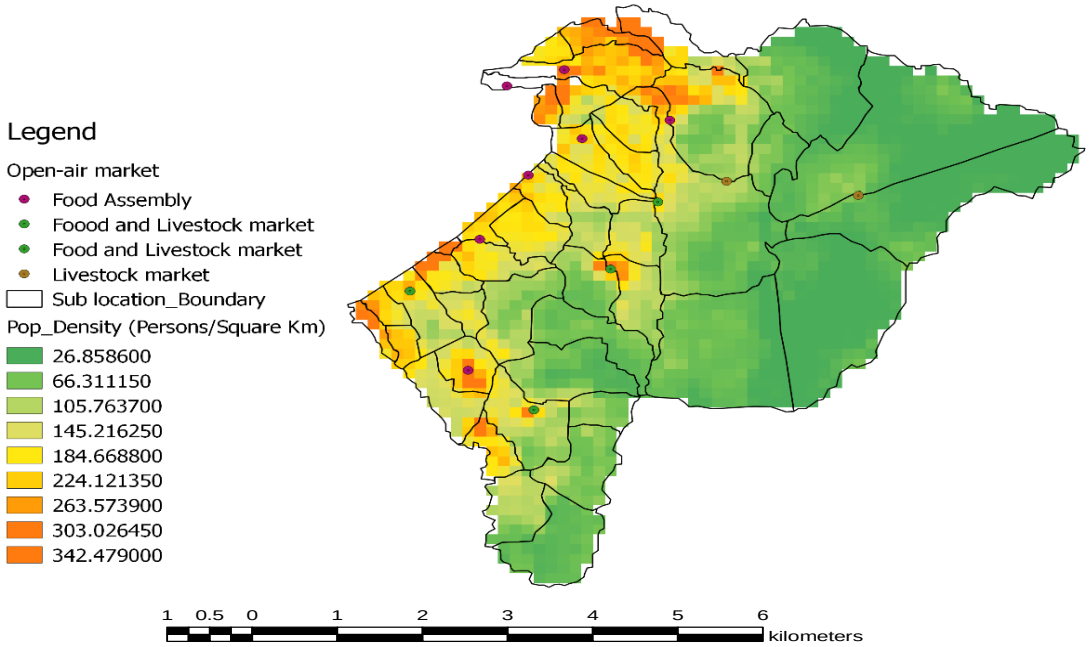


Figure 24: Population Density of Market Users per Market Functional Service

From the analysis, each of the 14 market centers play an important role in either food assembly or in livestock marketing. However, the influence of each market on the basis of the number of users derived from sub locations falling in its catchment area is variable as indicated in table 21 below. Marimanti open air market can serve 12 sub locations, while Nkarini serves 9 sub-locations. Chiakariga, Tunyai, Shauri and Gaciongo markets can serve each 8 sub locations.

On the other hand, Kathangacini and Karocho markets serves 7 sub locations each, with Gatunga, Kibung'a and Nkondi serving 6 sub locations each as well. Finally, it was found that Matiri market which is on the southernmost edge of the sub county can serve 4 sub locations while Mukothima and Miomponi market centers located on the north eastern edge of the study area each serves 3 sub locations each.

Table 24: Market Catchment Area and Population served by each Market

Open air market Name	Population - _Served	Catchment_Area (Km^2	Sublocations_ Served
Marimanti	40,912	493.2	12
Nkarini	26,928	201.3	9
Chiakariga	22,221	298.4	8
Tunyai	21,548	123.7	8
Shauri	38,766	78.0	8
Gaciongo	37,003	339.3	8
Kathangacini	31,779	733.0	7
Karocho	16,531	106.2	7
Gatunga	21,418	213.3	6
Kibung'a	19,623	83.7	6
Nkondi	17,936	91.6	6
Matiri	11,781	105.8	4
Mukothima	12,165	36.2	3
Miomponi	11,396	30.6	3

4.5.2.2 Analysis of Actual Usage of Market Centers

To model actual number of persons using available markets for their food needs, both field survey and normative data were used. In an effort to understand factors determining market usage in the study area, 395 questionnaires were administered randomly across households systematically selected from the 30 clusters (villages) chosen through probability to population size sampling. The survey revealed that distance to the market, functional services of the market and proximity across markets

were considered important factors with about 58.3% of the interviewed respondents highlighting them as determinants for the choosing a market they visited. These variables were incorporated in approximating actual population that used markets in the study area. First, the distance each household travelled to the market from the villages was computed. Then a six-point distance scale was used to get the number of people who used a market at each distance point.

4.5.2.2.1 Distance to the Market

Euclidean distance between village centroids and the markets was computed to get the distance covered by market users from the villages (Figure 25). Derived mean distances travelled by population across all the villages was computed. On average 4.3 km was straight line distance covered by most people from any village to the market center with maximum distance being 11.7 km and minimum distance 0.5km. However true distance based on the existing road network was used to get average distance covered between sub location centroid and the market center as 5.21 km. When asked how far they were willing to travel to the farthest market, 47% of the respondent households stated approximately 5 to 6 kilometers. So then 6 km was adopted as the maximum distance majority of the households were willing to travel to buy and or sell food stuffs in the farthest market.

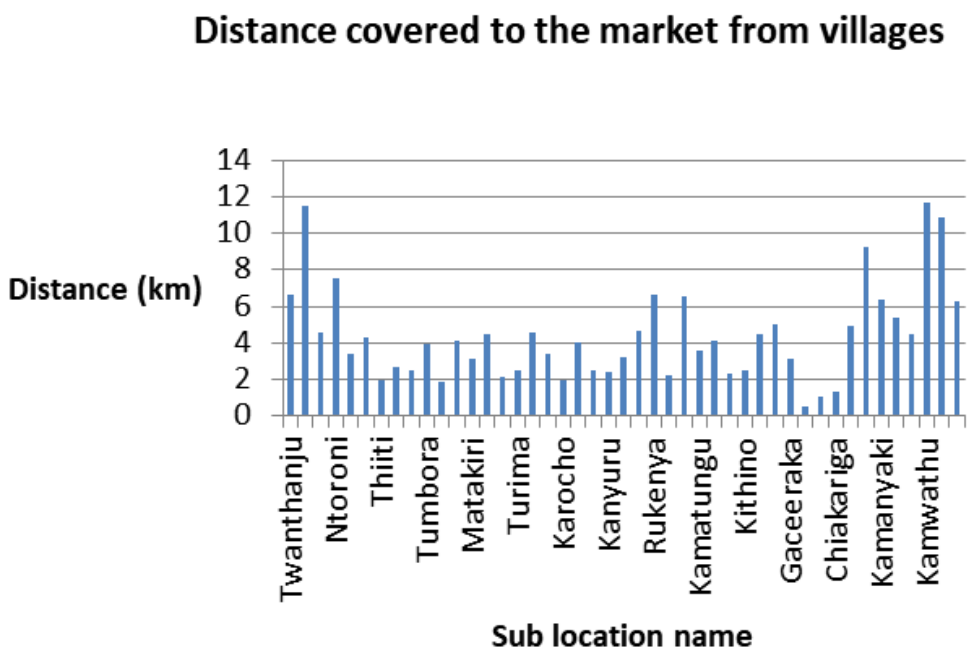


Figure 25: Average Distance Covered by Villagers to the Nearest Market

4.5.2.2.2 Functional Service of Markets

The services offered by any market influences the levels of patronage of that facility. In this area most, open air markets serve close to 77 % of the total population as revealed in earlier analysis. These markets operate periodically at certain days of the week and they offer food and non-food goods and services. During market days, it was observed that most households came to buy and or sell food stuffs, livestock, fruits and vegetables since most farm produce traders bring their commodities for wholesale and retail. Further, only 8 markets operated periodically at specific days of the week as market days. Mukothima market day is on Thursdays, Chiakariga on Mondays, Kathangacini on Tuesdays, Gatunga on Wednesdays, Marimanti on Thursdays, Kibung'a is on Fridays, Shauri is on Saturdays and Tunyai on Fridays. These days were marked by increased business especially food trades and livestock sales. For purposes of assessing the contribution of these markets towards easing food

security challenges in Tharaka sub counties, they were categorised into livestock markets, farm produce markets, farm produce assembling centers and finally both farm produce and livestock markets.

4.5.2.2.3 Proximity of Open-Air Markets from Each Other

In mapping the location of open-air markets, distance matrix for the nearest target point was used. This technique uses input point layer and the target point layer to calculate distance. In this case, the input point and the target point layers were the source ("From" market) and the destination ("To" market) coordinates of markets. To compute Euclidean distance, location coordinates for each market captured in decimal degrees units by Trimble Juno© 3C GPS were used.

Table 25: Euclidean Distance Across Nearest Open-Air Markets

"From" _Market	"To" _Market	Distance (Kilometers)
Mukothima	Miomponi	4.7
Chiakariga	Matiri	5.2
Nkondi	Kibung'a	5.4
Gatunga	Shauri	112.4
Nkarini	Chiakariga	6.3
Gaciongo	Nkondi	7.0
Karocho	Kibung'a	7.1
Tunyai	Karocho	7.3
Marimanti	Gatunga	7.5
Kathangacini	Shauri	14.7

From the analysis, distance from one market to another was computed to measure proximity of one open-air market to its closest neighbour market as indicated in table 22 above. In terms of distance, Mukothima and Miomponi are closest to each at 4.7 kilometers, followed by Chiakariga to Matiri at 5.2 kilometers. Nkondi to Kibung'a market is about 5.4 kilometers away from each other. Nkarini to Chiakariga is about 6.3 kilometers away while Gaciongo and Nkondi markets are 7.0 kilometers apart. Karocho to Kibung'a is 7.1 kilometers away from each other while the distance between Tunyai to Karocho is 7.3 km apart. Gatunga and Marimanti markets are only 7.5 kilometers apart while Kathangacini livestock market is located about 14.7 kilometers from Shauri which is also a livestock market. The farthest markets are Gatunga and Shauri located at 112.4 kilometers apart. Using the fore discussed determinants, total population of actual market users was computed and found to be 104,361 persons. This figure represents 71 % of the total 2018 projected population in Tharaka South and North sub counties which stood at 147,583 persons. In order to quantify the number of persons who use the market at each distance, 6-point distance scale was used and the population at each distance range computed as shown in Table 23 below.

Table 26: 6-Point Distance_lag and Population with Access from Nearest Market

Point	Distance range (Km)	Persons with access
1	0.5 – 2.4 kilometers	27,415
2	2.4 – 4.2 kilometers	54,443
3	4.2 – 6.1 kilometers	35,562
4	6.1 – 8.0 kilometers	19,761
5	8.0 – 9.8 kilometers	1,780

6	9.8– 11.7 kilometers	11,049

Therefore, the straight-line distance analysis revealed that 27,415 persons lived within half a kilometer to two and half kilometers from a market center. 54,443 people were found within two and half and four kilometers. Within four kilometers and six kilometers distance from a market, a total of 35,562 people was found living in this range.

Only 19,761 people lived within six kilometers and eight kilometers distance. Minimal population of 1,780 persons lived between eight kilometers and ten kilometers from any given open-air market center. The population which lived over ten kilometers from any market was estimated at 11,049 people. Using six kilometers from a village centroid to the nearest market center as maximum distance households are willing to travel to any market, 80% of the population in Tharaka area lives within 6km to the nearest market center. The mean distance of access to markets in Tharaka region was 2.3 km. In general, overall spatial concentration and distribution of population reached peak at 2.4 km and 4.2 km respectively. A close examination of each market influence area indicates that the number of people a given open air market serves within each sub location varied demographically (Table 24).

Gaciongo located in the far north which operates as a food assembly market serves close to 10,026 people with 3039 being from Matakiri sub location and 6987 persons living in Irunduni respectively. Shauri market which is located along the road leading to Meru National through Ura gate majorly a livestock market is used by 12,254 people drawn from Gatunga and Kanjoro Sub locations. Tunyai market which doubles as a food and livestock market serves a population of 10,791 persons drawn from

Mwerera, Gakurungu and Murinda Sub locations. Chiakariga is the only Food and Livestock open air market on the farthest south with about 7,969 persons from Chiakariga Sub location, Kirukuma and Kaguma Sub locations relying on the market. Marimanti both food and livestock market serve 12,795 persons from the sub locations of Marimanti, Kirangare, Gituma, Kamatungu and Kamwathu.

On the other hand, Kathangacini market being solely a livestock dealing open air market serves 3,331persons mostly from Mauthini Sub location. Gatunga which also is an open-air market dealing mostly with food and livestock serves 3,089 people majorly from Kithigiri Sub location. Finally, Kibung'a Market located on the eastern arm of the sub county is basically a food assembly market serving a population of 6,626 people from the nearby sub locations of Turima and Kathuura. Other important retail stalls-based markets in the study area act as farm gate food bulking centers were also found to play a significant role in local food distribution system. These included Mukothima serving 3,418 people in Mwanyani Sub location, Nkondi with a total of 8,727 people drawn from Rukurini, Nkondi and Kereria Sub locations. Nkarini which is a village market center located along Mitunguu-Kathwana highway serves close to 9,529 persons living within the sub locations of Nkarini, Rukenya and Gaceeraka. Karocho another important food bulking market center services a population of 18,347 people from Kanyuru, Murinda, Karocho and Ibote Sub locations.

Miomponi a retail food traders' market center situated on the north eastern edge of the Sub County along Meru-Gatunga highway is visited by 2,752 people from the nearby Tumbura sub location. Matiri village market center located on the road leading to

Uturini, Kamanyaki and Kamarandi sub locations on the far southern edge of the sub county serves about 2,845 people drawn from surrounding Matiri Location.

Table 27: Open Air Market's Catchment Population based on Sub Locations

Market_Name	Population of users
Gaciongo	10,026
Shauri	12,254
Tunyai	10,791
Chiakariga	7,969
Kathangacini	3,331
Gatunga	3,089
Kibung'a	6,626
Mukothima	3,418
Nkondi	8,727
Nkarini	9,529
Karocho	18,347
Miomponi	2,752
Matiri	2,845
Marimanti	12,795

4.5.3 There is no Significance Difference between Spatial Distribution and Levels of Market Utilisation.

Many studies conducted on factors affecting commercialisation and intensity of market participation by small scale farmers have shown access to markets and infrastructure as one of the most important determinants (Omiti *et al.,* 2009; Makhura, 2001). Responses to a question on "which periodic open-air markets do you sell maize

and millet" solicited information on the market centers utilised by households to buy food and sell surplus. This was particularly important given fact that in the study area, farmers struggle to produce for local markets which are poorly integrated while meeting their household food needs through the same markets through purchases. Despite the importance of open-air markets in addressing food needs, related uncertainties especially price volatility make most households unable to afford food when they need it. Linear discriminant analysis of market center's spatial distribution showed that all market centers in the study area have a regular pattern of spatial distribution. When a 6-point distance lag from market center was used to estimate the number of persons using a given market, the results showed that market usage in terms of patronage population greatly varied with distance covered to the market as shown in Figure 26.

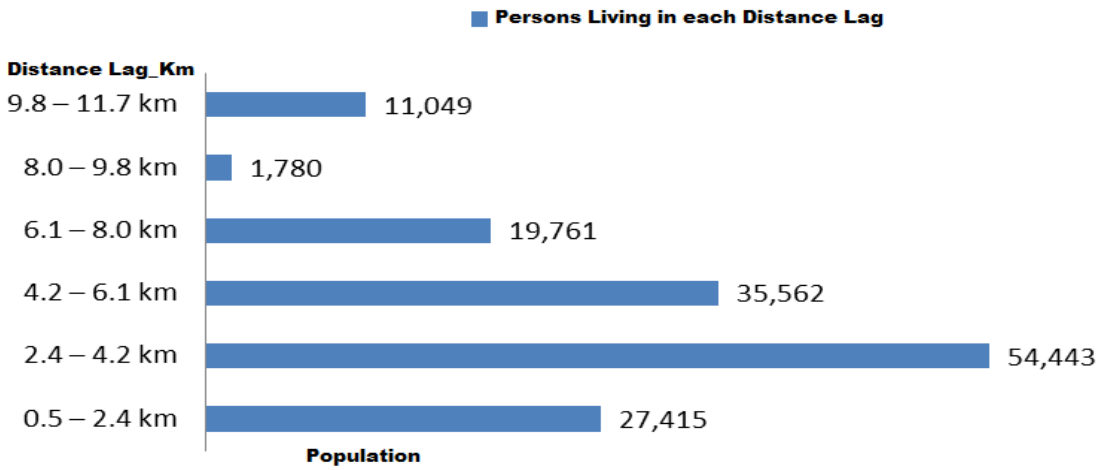


Figure 26: 6-Point Distance Lag and Corresponding Market Users

According to findings as shown in the bar graph above, 18.3% of people lived within 2.4 km from a market hub. 36.3% of population in Tharaka sub-county stay within 4.2 km from nearest village retail market. This means a large proportion of residents in the area can access market for their food needs or sell their produce.

At 6.1km from a market center about 23.7 % of residents were found while 13.1% of the Tharaka population lives 8 kilometers from a retail market. However, about 8.6% of the population in the study area resided within a distance of 8 km to 11.7 km from any nearest market center.

To ascertain whether spatial distribution influenced level of markets utilisation by people in the study area, distance from the nearest market to the village centroids was correlated with computed potential market users drawn from the sub locations. Computed Pearson's correlation coefficient(r) of distance versus users was -0.17167. The coefficient shows there is statistically significance evidence to indicate that distance adversely affects market utilisation in the study area. This is because there is a negative relation between distance travelled and the number of users. Therefore, as the distance from market increases, there are few users willing to utilise that given market center for their food needs.

This is in line with findings by Key *et al.*, 2000 and Nyein, Soojung and Sang, 2018 who in their studies found that distance to the market negatively influences both the decision to participate in markets and the proportion of output sold. Similarly, Kgabo (2012) in a study on participation and utilisation of formal vegetable markets by smallholder farmers in Polokwane Local Municipality, South Africa found out that there was a negative and significant relationship between distance to the market and farmers' decision to sell vegetables in formal markets by farmers. Formulated hypothesis about markets' spatial distribution and market usage was tested statistically. Based on the findings, the null hypothesis that there is no significance

difference between spatial distribution and the level of market utilisation was rejected and instead alternative hypothesis accepted.

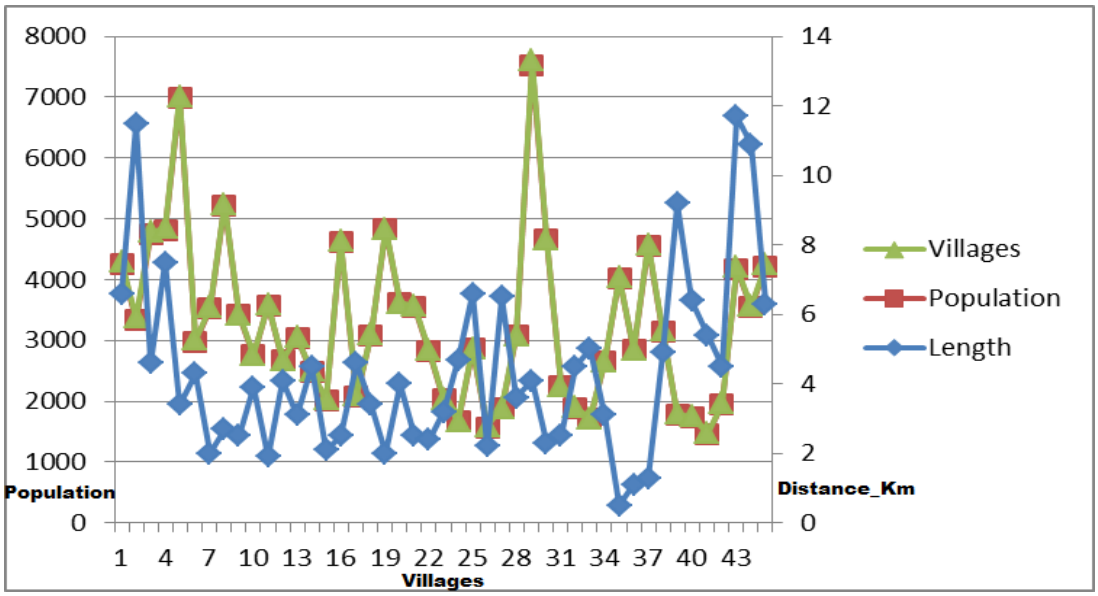


Figure 27: Line graph Indicating Market Distance, User Population and Villages served

A closer examination at the number of potential users of market centers with the distance households' travel to access that market as well as number of villages served, show that in Tharaka North and South Sub Counties, market service area in terms of villages serviced by a given market center is influenced by distance from it (Figure 27). For example, Nkarini market center which is only 0.5 kilometers from Nkarini sub location centroid serves 15 villages while the farthest recorded distance is that of between Tunyai market and Tubui Sub Location centroid at 5kilometers apart but serving only 8 villages. This is unlike Karocho market center located about 2.5 kilometers from Murinda Sub Location centroid and servicing 22 villages. An observation from these results indicate that markets located about 2.5 kilometers from a given sub location will optimally serve more villages and by extension many households. Generally spatial distribution of markets informs how "far" or "near" a

market is to users since it measures distance between the consumer and the producer. This dictates not only the number of users but frequency of how often the consumers use that particular market. Even in areas with good road linkages and networks, distance influence market participation by farmers because of costs associated with transportation and other related transactions (Mahabile, Lyne & Panin, 2002; Nkhori, 2004).

4.5.4 Summary

From the analysis, it has been revealed that all open-air and retail markets are randomly distributed across the study area. These markets show a linear pattern of spatial spread with their location being along transit routes connecting trading centers. When market functionality was assessed, services offered by open-air markets were categorised as farm produce assembly, livestock sales and both farm produce and livestock dealing markets. The findings corroborate those of Abu*et*, Ajake and Okpilia (2013) which found that the markets in Bekwarra local government area of cross river state, Nigeria were randomly distributed and varied in functions.

As in the case of Tharaka sub county, farm produce markets are found in the densely populated areas which are also food production rich zones of Mukothima, Nkondi and Tunyai wards. These are largely located in the rainfed cropping and marginal mixed farming livelihood zones which have suitable pedological and climatic conditions for mixed crop production. Livestock markets occur in some of the low population density areas especially on the north west part of the sub county. These areas are characterised by minimal farming activities due to reduced rainfall and low moisture content. Mostly this agro-pastoral region is confined within Gatunga ward and which

also lies in the marginal farming livelihood zone. The last category is farm produce and livestock markets which are located in the moderate population density areas of the sub county which are spread across Nkondi, Marimanti and Chiakariga wards respectively. These regions lie within both marginal mixed farming and marginal farming livelihood zones. Market utilisation levels was analysed into expected and actual usage by computing the number of persons to use a given market center. Population using open-air markets were categorised into potential users and actual users respectively. It was established that the number of market users varied demographically with potential users identified as 113, 606 persons while analysed actual users were found to be 104, 361 persons.

Utilisation levels of open-air markets based on categorisation and functionality revealed that farm and livestock markets have a higher patronage compared to livestock and even farm produce markets. The farm produce and livestock markets had a patronage of 42%, followed by farm produce markets at 39% and then the livestock markets at 19%. This observed trend was associated with the region's variability in geophysical factors, locations of markets and livelihood dynamics across the rainfed cropping zone, mixed farming and marginal mixed farming livelihood zones. This finding is contrary to a study by Mbuthia, Wambugu and Kayi (2018) who postulated that spatio-temporal aggregation of markets offered stiff competition to the small markets and created chances for buyers to dictate prices for farmers.

CHAPTER FIVE

SUMMARY OF KEY FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In this chapter, summary of major findings, conclusions and recommendations made here forth are based on objectives analysed in chapter four. The study sought to analyse influence of distribution systems and market accessibility on food security. This is in attempt to address existing knowledge gaps in the area of food and nutrition security especially the relevancy of spatial analysis in addressing local food distribution and market accessibility limitations. Furthermore, findings of this study will inform relevant agricultural policies to improve on local food distribution and enhance market accessibility within the rural semi-arid areas of the country. To achieve this goal, the study pursued the following specific objectives:

i. Determine biophysical factors and climatic suitability of livelihood zones for optimization of Maize and Millet production.
ii. Identify marketing models for maize and millet distribution and their influence on households' food stock retention.
iii. Measure physical accessibility to existing open air markets and establish its effect on food security.
iv. Examine spatial distribution and level of utilisation of open-air markets in the study area.

5.2 Summary of the Findings

To address these objectives, spatial analysis and statistical analysis techniques were used.

In section, 4.2 of chapter four, GIS analysis and modelling were used to determine suitable biophysical and climatic conditions that favour optimisation of maize and millet production in three different livelihood zones. Specifically, process modelling of geo-referenced climatological data and overlay analysis of geophysical data were used to derive the results. Findings from the modelling and geospatial analysis revealed that moderate humidity and temperature, well drained deep soils and undulating slope landscape are ideal for both millet and maize production. Areas with these conditions were identified as suitable for optimising the production of the two crops.

Empirically the area was classified into nine agro-climatic zones based on thermal cluster values and computed moisture index values. When stratified according to the livelihood cluster zones of Rain Fed Cropping, Mixed Farming and Marginal Mixed Farming, maize and millet production suitability areas varied spatially across the sub county. Rain Fed Cropping and Mixed Farming Zones were found the only suitable areas for the production of maize comprising a land size of 10,917.94 Ha. This is attributed to the fact that the two zones had low to medium humidity (0.3-0.45) and relatively low temperature regimes of between 20^0C to 22^0C. The two livelihood zones were also found favourable for both maize and millet production although Mixed Farming zone was well suited for maize only with 5,458.97 Ha of land utilised in the production of maize.

When evaluated for production of alternative crops the two zones could support the growth of groundnuts, cowpeas, beans as well as mangoes. However, Rain Fed cropping zone with land size of 62,999.11 Ha was the only which could support the growth of cotton. Marginal mixed farming livelihood zone with 57,649.90 Ha of land was also found moderately suitable for the production of maize and millet. The zone was found suitable for pigeon peas cassava, sorghum, green grams and sisal as the only alternative crops that can do well here despite the Rain Fed Cropping and Mixed Cropping livelihood zones have conditions that support the growth of all these crops

In section 4.3 of chapter four, censored Tobit regression was employed to analyse factors influencing choice of marketing models by households and how decisions to use a given channel outlet influenced retention of harvested food stock for household subsistence. By regressing choice of market outlet with explanatory variables, the effect of socio-economic and geographic factors in determining the use of a market channel by a household was assessed. Nine factors considered to explain choice of channels and likely to retain food stock for household use were; education level of household head, headship gender, ICT used in accessing information, land size owned, quantity harvested, mode of transport; price; distance to the nearest market center and household size.

After analysis, findings showed that education, headship gender, access to information, means of transport, market price, distance to the market and household size were statistically significant to explain the observation. However, a negative relationship was discovered between marketing model used by household and the distance to market, access to information, headship gender, household size and means

of transport. The results indicated that decision to use a given marketing model varied from household to household. This was influenced by price offered by outlet, quantity of output the household has and the distance travelled to the outlet from the farm. Generally, most households in the region sell in low quantities of *Debes* (20 tins two kilograms equivalent) or *gogolos* (2kilograms one tin equivalent) specially post harvesting to farm gate buyers who transverse villages buying in small quantities from households.

In section 4.4, geographic accessibility to retail food markets by households was measured through modeling accessibility risk surface. A composed index of critical accessibility was generated using Euclidean distance from village to the market, travel time to the road, population and number of populated places here referred to as villages. Travelling scenarios were modelled based on if mobility was by foot, vehicles or motor bikes. Composed index of critical accessibility was generated to show areas of different physical accessibility risk. With the index, accessibility risk surface was generated showing the very high risk, high risk, average risk, low risk and very low risk accessibility areas of the sub county. It was found that 40.4% of the population live in very high to high risk accessibility villages, 36.1% of the population live in low risk accessibility villages while 23.5% of the sub county population reside in moderate risk accessibility villages.

In section 4.5, nearest neighbour analysis was employed to analyse spatial patterns of markets distribution in the study area. Potential and actual market usage was computed and correlated with distance across the open-air markets. In analysing market usage, distance hub matrix and Theisen polygon were used. The study showed

that all markets in the study area are randomly located and that regardless of the markets' geographic distance, farm produce and livestock markets were more used by the locals compared to livestock markets and farm produce markets. Major findings from the analysis of the four objectives are explained in the conclusion section.

5.3 Conclusion

Objective one set out to determine biophysical factors and climatic suitability of livelihood zones for optimization of Maize and Millet production. Empirical results reveal that maize or maize and millet production optimisation within rural Tharaka sub county can be realized within RFC and MF livelihood cluster zones. These zones have optimal humidity and temperature, deep and well drained soils with gentle slope. These areas occur in Tunyai, Turima, Nkondi and Irunduni locations respectively. Equally important, temperature and moisture availability determined the suitability of various livelihood zones for the production and optimisation of maize and millet crops as supported by the analysis. Null hypothesis that biophysical and climatic factors do not determine optimization of Maize and Millet production in Tharaka sub county was then rejected because biophysical factors and climatic variables were found to determine greatly the suitability of agroclimatic zones for various crop production.

The second objective was to identify marketing models for Maize and Millet distribution and their influence on households' food stock retention. Formulated hypothesis stated that marketing models had no significant effect on food stock retention behavior of the household. Education levels of household head and price of food crops at the market had a positive effect on food stock retention behavior as well as the kind of marketing channel used by household. Of the two, price had a higher

effect accounting for 10.6% while education was at 9.3%. The null hypothesis was rejected at 1% significance level. It was then concluded that market driven trading strategies, household socio-economic characteristics and distance are important factors influencing decision to market through a given channel and quantity of food stock retained by household. These in turn has implication on household food security.

The third objective on measuring physical accessibility to retail food markets was analysed to establish how distance to markets influenced household's ability to use markets to meet their food needs. Null hypothesis formulated stated that physical accessibility to open air markets does not affect food security in the study area. However, analysis revealed that population at risk of accessing retail food markets differed based on distance to the nearest road network. For instance, 58,946 persons living at least 8 km from nearest road were at high risk of in accessing food retail open air markets for their food needs compared to those within low risk areas. These were 52,643 persons living approximately 2km from nearest road while those in moderate accessibility risk areas were 34,325 and lived about 3 km from a road network. These results indicate that distance to a road network influence accessibility to open air markets by households. Additionally, accessibility informs decision to buy or sell in a given market as supported by interview responses of household who agreed that they were willing to travel maximum distance of 5-6 km to an open-air market to buy food or sell surplus. Null hypothesis was then rejected and conclusion drawn that physical accessibility to markets especially in areas with poor road linkages positively affects household food security.

Finally, the last objective was to examine spatial distribution and level of utilisation of open-air markets by people in the study area. Analysis indicated that all open-air markets are regularly distributed which indicates a random spatial coverage pattern of population by market services. In order to see if this had implications on how these markets were used by the populace, null hypothesis formulated negated the existence of difference between spatial distribution and the levels of open-air markets utilisation by the local population. Results of analysis indicated that although markets were randomly distributed across the study area, their utilisation levels by the locals varied. This was attributed to distance between villages and the markets as well as separating distance between the markets. Utilisation levels of markets according to the findings was influenced by number of villages falling in its catchment area, distance to markets and function of the said market.

In conclusion, it is evidence that local food distribution systems and physical accessibility to food retail markets greatly influence intra livelihood zones household food availability and accessibility. This is manifested through the levels of market utilisation by the households and the number of chosen market channels by which people of the two sub counties buy and sell their produce. Market utlilisation levels as analysed showed spatial variations across the sampled villages and food retail markets.

By integrating statistical analysis and geospatial modelling in biophysical and climatological suitability assessment of RFC, MF and MMF livelihood zones for maize and millet production, measurement of physical accessibility efficiency to open-air markets, analysis of marketing channels contribution to household food

retention and lastly establishing relationship between geographic location of markets and its influence on their utilisation was done to explore ways of scaling up local intra-regional food distribution and market accessibility as an intervention strategy to address food insecurity in Tharaka sub county.

5.4 Contribution to Knowledge and Implications on food Policy

This study has contributed to new knowledge on how food distribution systems and market accessibility influence and define food security whether at a community or household level. Additionally, findings of this study can help the Kenyan government attain the second SDG on Zero hunger and more so realise her food and nutrition security policy objective on approaches to increase the quantity and quality of food available, accessible and affordable in Tharaka sub county and perhaps all over the country at all times through enhancing market accessibility and strengthening local food distribution systems.

Besides the study has identified suitable agroclimatic zones that can be targeted to increase sustainable productivity of maize and millet crops in the area. This can be realised through improving efficiency of local food distribution systems, physical market infrastructures and enhancing market accessibility.

Generally, the study has revealed that:

i. Local food distribution systems and market accessibility in Tharaka Sub county is extensively influenced by geophysical and socio-economic factors.
ii. A new Composed Index of Critical Accessibility (CICA) to food retail markets was developed to identify deprived population and more so those at risk of

physical inaccessibility to markets hereby referred as “food deserts” zones across Tharaka sub county.

iii. The composed index (CICA) has shown the number of villages with very high accessibility risk, high accessibility risk, medium accessibility risk, low accessibility risk and very low accessibility risk of physical accessibility problems

iv. Rain Fed Cropping and Mixed Farming livelihood zones are suitable for optimisation of maize production as they are the ones having agro climatic and geophysical conditions appropriate for maize growth. Although it is suitable for maize and millet production, other alternative crops that can do well in these agro climatic conditions are beans, groundnuts, mangoes and cowpeas.

v. Marginal Mixed Farming livelihood zone covers a large part of Tharaka constituency but it lacks optimal agro-climatic conditions suitable for production of maize in particular. However, the zone supports the production of maize and millet and other crops like pigeon peas, cassava, sisal, sorghum and green grams.

vi. That farm produce specialised service markets have a higher usage in the study area followed by dual purpose farm produce and livestock markets while livestock markets have the least patronage.

By examining the role of local food distribution networks in intra-regional food mobility, markets physical accessibility on promotion of food trade opportunities and the vulnerability of households to food insecurity owing to disintegration of livelihoods, this study has demonstrated the relevance and versatility of Elli’s rural livelihood approach, Sen’s entitlement theory and Sharkey’s model on access to food

resources in understanding food security as an outcome of variations in man-environment spatial interaction.

5.5 Recommendations

Based on the findings of this study, following areas as per the outlined objectives require action in order to improve on local food distribution and intra-markets trade in agricultural products.

5.5.1 Development of Intra-regional Market

In line with objective four on utilisation of open-air market, there is need to strategically develop and upgrade some selected open-air markets in the study area to serve as intra-regional markets. These centers will increase access to market by many households since besides being used for normal trading they will offer ancillary services like banking and market price information. Unlike the current situation where most open-air markets are located along road terminals serving a limited number of consumers, upgrading some of these markets would enhance commercialisation of agricultural produce. This should be done with the fact in mind that a large population lives in areas with high incidences of low accessibility problems due to poor connection to new roads and the existence of inadequate road network. In this regard, Karocho market center and Shauri periodic market poise as strategic markets to develop as intra-regional markets. In terms of market functionality, Karocho can be developed as food retail market to potential serve the Rain Fed Cropping and Mixed Farming livelihood zones. Karocho market has a higher number of potential users compared to other markets offering farm produce or farm produce and livestock market services. On the other hand, Shauri which is basically a livestock market can

service relatively a large population mostly from the marginal mixed cropping livelihood zone compared to Kathangacini another livestock market.

5.5.2 Formation of Farmer Associations and Marketing Clubs

Based on objective two about marketing models, creation of farmer cooperatives will give a competitive advantage to smallholder farmers in rural areas to market their produce. Collective marketing gives the farmers an opportunity to share risks, enhance diversification and expand market. In Tharaka, the lack of state institutions like NCPB leaves farmers vulnerable to intermediaries who exploit the producers by offering low prices. By farmers coming together to form marketing clubs or associations gives them a bigger voice to reach potential buyers and increase profit margins through pooled sales of their produce. Similarly, they can easily negotiate for contract farming from NCPB or wholesalers in major towns. This will open more opportunities for farmers in the study area to market their produce and expand their market scope. It is anticipated that farmers' association especially those specializing in marketing could provide market linkage services to the farmers who possess small landholdings. Furthermore, farmers' cooperatives will enhance distribution systems through provision of agricultural information on market availability.

5.5.3 Improvement of Existing Physical Market Infrastructure

There is a need to upgrade current market structure within the sub counties of Tharaka north and south. This is important given that out of the 14 open air market centers, only two have iron sheet roof tops and are perimetered with stone walling. These are Tunyai and Marimanti open air food retail markets. In other instances, most of these markets lack proper waste handling facilities, toilets and water supply making them

vulnerable to public health risks of disease outbreaks. In order to make these markets attractive to consumers and traders, there is a need to fence all markets for security reasons, have them roofed with corrugated iron sheets and even served with electricity. Water supply and toilets should be provided within the markets for sanitation purposes. Similarly, waste handling facilities should be availed to reduced open dumping within market stalls. In general improvement of open-air markets infrastructure will create opportunity for increased trade and commercialisation of small-scale farmers in the area.

5.5.4 Creation of Geo-spatial Enabled Market Information System and Database

Based on objective two about strengthening the current marketing models, timely access to information is key to the establishment of efficient distribution systems and access to markets. This will create awareness of the market trends and needs by the farmers and moreover, the identification of consumer' needs. Poor access to ICTs by most farmers limits penetration and utilisation of market information. To increase uptake of ICT especially mobile phone-based exchange of market in formation, Apps that are simple to use and update commodity and produce prices should be uploaded on weekly basis. Similarly, programs to improve access to market information by framers in the locality should be developed. This can be realised through improving infrastructure for mobile phone telecommunication which is now an important platform for trade and price negotiation by farmers. Development of geo dataset of markets, their location, distances and functional services besides food crop price posts will promote dissemination of market information.

5.5.5 Upgrading and Expansion of Road Networks

As per objective three on physical accessibility, existence of poor road network limits access to markets by farmers in rural areas. In affected areas, farmers fetch low prices due to transaction cost especially that associated with transport of their produce to the markets. Both county and national government should invest in opening up rural Tharaka by constructing more all-weather roads as well as expanding the existing road network to new areas. Good road infrastructure will facilitate efficient trade in local produce and lower the transportation costs and time while at the same time increasing market size through attraction of more remote producers and consumers into these markets. Efficient road infrastructure will foster local food produce market expansion and increase in consumer base as it encourages engagement in nonfarm employment.

5.5.6 Creation of Market Based Production Demonstration and Field Training Farms

In realisation of objective one on optimisation of production, there is a need to come up with farmers training farms where they can be shown innovative ways of producing various crops. Demonstration farms will instill practical farming skills to small farmers who require innovative approaches to maximize production from the small landholdings. These farms should be selected from farmers who have been trained and can demonstrate knowledge gained in their farms. The demonstration farms should be located in areas with high potential areas from the Rain Fed Cropping and Mixed Farming livelihood zones.

5.5.7 Promotion of Production and Consumption of local foods

In realisation of objective one, policies to encourage the production of local crops which act as both food and cash crops should be enactment at the county level. Crops like maize, green grams, cowpeas, cassava, sorghum and millet which can do well in most agro climatic zones can be consumed locally and at the same time be traded. County Government of Tharaka-Nithi can strengthen intra- regional food distribution systems through constructing more markets especially in food need areas of the sub county. The high inaccessibility risk areas within Kamwathu, Kamaguna, Kathangacini and Uturini should be targeted by building food hubs to bring food close to the people. Similarly, deliberate efforts to buy locally produced crops from the farmers by County Government of Tharaka-Nithi should be made to help stabilize food prices and maintain food flow across the sub counties.

5.6 Recommendations for Further Research

This study encourages further research aimed at improving efficiency of local food supply and distribution systems through market interventions of addressing food insecurity challenges. In this regard therefore, focus should be within the following areas of interventions;

i. Studies are needed that will look at how the quality and quantity of marketed food produce across the local supply and food distribution networks affects the performance of the food distribution systems.
ii. A study on traditional informal market information systems and food security in the study area is essential to shed more light on food crop price setting and transmission across the food-retail-village markets in the study area

iii. More research is needed on role of public and private entities on management and control of open-air municipal produce markets

iv. Fourthly, studies are needed which will profile the socio-economic attributes and demographic patterns of food consumers to inform planning of local market expansion programs

v. Studies focusing on trends of local food production and features of existing distribution networks will be useful in the design of market development projects by the county government

This study has added a new dimension in the current National Food and Nutrition Security Policy (NFNSP) issue on food availability and access by showing how local food supply and distribution systems as well as physical accessibility to markets can improve food availability and access at household, village and regional levels ultimately influencing food security.

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APPENDICES

Appendix 1: Questionnaire

Introduction

Hallo, my name is Dickson Kinoti, a postgraduate student at Karatina University carrying out a research on "Influence of Distribution Systems and Market Accessibility on Food Security in Semi-Arid Tharaka Sub County". This questionnaire seeks to collect information on how distribution systems and market accessibility influence food security at livelihood cluster zone level. You have been chosen to participate in this exercise. Feel free to fill in the questions that here below follow. Information given will remain confidential and be used for academic purposes only. Thank you for your time and responses.

SECTION 1: GENERAL INFORMATION

1. Name of the Respondent_____

2. Village of Resident_____

3. Sub-Location_____

4. Location _____

5. Gender_____

6. Age_____

7. Education Level;

   None [1] Primary [2] Secondary [3] College/University [4]

8. How many members live with you?

   0-person [1] 1-3 person [2] 4-6 persons [3] over 7 persons[4]

SECTION 2: MAIZE AND MILLET PRODUCTION

1. Do you grow Maize and or Millet?

   Yes [1] No [2]

2. Why do you grow or not grow these crops?

   (i)_____

   (ii)_____

   (iii)_____

3. What is the size of your land?

   0-1 acre [1] 2-5acres [2] over 5acres[3]

4. How much of your land is under Maize and Millet?

   0.5 -1 acre [1] 2 -3 acres [2] Over 4 acres [3]

5. How many bags of Maize and Millet did you harvest last season?

   0-2 bags [1] 3-5bags [2] Over 6 bags[3]

6. How has been your yield for maize and millet crops in the last four seasons?

   Increasing [1] Decreasing [2] Constant [3] I Do not know [4]

7. What do you think is the probable reason for the Maize and Millet yields you have just mentioned?

   Climate [1] Extension Services [2] Land Management Practices [3]

   Variety and species plant [4]

SECTION 3: LOCAL MARKETING CHANNELS AND STRATEGIES

1. In which Quantity do you sell your produce?

   1kg Tins [1] Debe [2] 90 kg Bags [3]

   a. How much is;

      (i) 1kg of Maize selling in the local market?_____

      (ii) 1kg of Millet selling in the local market?

      _____

2. Where do you sell the Maize and Millet harvested from your farm?

   Open Air Market [1] Supermarkets [2] Cereal Dealers [3] Brokers[4]

3. Which Periodic Open-Air markets do you sell maize & Millet?

   i)_____

   ii)_____

   iii)_____

   iv)_____

4. What motivates you to sell your produce through the identified channel?

   Better Price [1] Convenience [2] Easily accessible [3]

5. Do you interact with consumers directly?

   Yes [1] No[2]

6. Are there any standards/Requirements that govern local market operations?

   Yes [1] No [2]

7. Mention these standards if any

   i) _____

   ii) _____

   iii) _____

8. Do the prices of Millet and Maize in the local markets change on season basis?

   Yes [1] No [2]

9. Which facilities need to be put in place to promote marketing of Maize and Millet in Tharaka region?

   i) _____

   ii) _____

   iii) _____

10. Do you belong to or have any associations for marketing your produce collectively as group of farmers in Tharaka? Yes [1] No [2]

    If yes, then Mention them (i)_____

    (ii)_____

    (iii)_____

SECTION 4: DISTRIBUTION AND STORAGE

1. Which market centers are close to where you live?

   i) _____

   ii) _____

   iii) _____

2. How far is the nearest market from your home in Kilometers?

   0-5km away [1] 5-10km away [2] 10-15km away [3] Over 20km away[4]

3. Which means of mobility do you use to transport your produce to the market?

   Human potage [1] Motorbike & bicycles [2] Vehicles [3] Donkey carts [4]

4. In which form do you transport your Maize and Millet to the market?

   Unprocessed [1] Processed [2]

5. What is the nature of road network you use in transporting your produce?

   Loose soil Surface [1] Corrugation & Murom [2] Tarmac road [2]

6. Which problems do you face when transporting your produce to market?

   i) _____

   ii) _____

   iii) _____

7. Do you store the maize and or millet harvested from your farm?

   Yes [1] No [2]

8. If Yes, Why?

   Sell later [1] Assemble into large quantities [2] Future use [3] Poor market prices [4]

9. Where do you keep your produce after harvesting and before selling them?

   Food Granaries [1] My House [2] Hired Stores [3] Depot/Go-down [4]

10. How long do you store your Maize and Millet before selling them?

    i) _____ Weeks

    ii) _____ Months

    iii) _____ Seasons

11. Which problems do you encounter in storing your Maize and Millet?

    i) _____

    ii) _____

    iii) _____

12. What do you think can be done to address problems of storage and distribution?

    i) _____

    ii) _____

    iii) _____

    iv) _____

SECTION 5: INFORMATION COMMUNICATION TECHNOLOGY (ICT)

1. Do you own a radio, television or a mobile phone? Yes [1] No [2]

2. How do you access information on commodity prices, transport services, storage facilities availability and other agricultural advice?

   Mobile phone [1] Radio & TV [2] Extension Officers [3]

   Farmer magazines [4] others [5]

3. How do you use your mobile phone to access agricultural and market information?

   Calling [1] Texting [2] Electronic display [3]

4. What impact does the use of ICT have on food distribution, Market accessibility and food security?
    i. Reduced costs of distribution due to information on transport options [1]
    ii. Increased production by farmers due to market availability information [2]
    iii. Improved household income due to better market prices information [3]
    iv. Increased market access due to linkage of the consumers and farmers [4]
    v. Adoption of new farming practices and technologies [5]

5. What do you think can be done to increase the usage of ICT by farmers?
    i. Sensitization and Awareness creation [1]
    ii. More training on the use of ICT [2]
    iii. Use technologies supported by the local [3]
    iv. Automate all agricultural services [4]
    v. Others (Specify) _____ [5]

Appendix 2: Key Informant Interview Schedule

Name of the Interviewer: _____Date of Interview: _____

Start time: _____ Time end: _____

Name of Institution where you work: _____

Occupation: _____

Interviewee Name: _____ Gender: _____

Occupation: _____ Village: _____

1) Which Organisation/Ministry do you work with/for?

_____

_____

2) Describe the kind of activities you / your organisation engage in within Tharaka?

_____

_____

3) Is Tharaka a food secure sub county? Yes [ ] No [ ] . If yes, please explain

_____

_____

4) What is the major concern as far as food security is concerned in this area?

Low production [1] Access to markets challenges [2] Unstable food market prices [3] Poor road networks [4] Lack of market related information [5]

5) What are the challenges associated with food distribution systems and storage in Tharaka Sub county?

_____

_____

6) Based on your knowledge of the area, is market accessibility a problem for farmers? Yes [ ] No [ ]

7) How can the problems of poor distribution system and market accessibility be addressed?

_____

_____

8) What Information Communication Technology (ICT) tools are used in disseminating market related information in Tharaka?

Radios [ ] Mobile phones [ ] Television [ ] Posters [ ]

9) Which challenges affect adoption and use of ICT amongst farmers, traders and logistics companies

i. _____

ii. _____

iii. _____

10) What do you think can be done to increase the adoption and use of ICT in food distribution and marketing systems?

i. _____

ii. _____

iii. _____

11) Which crops are grown by most households in Tharaka as staple foods:

Maize [ ] Millet [ ] Greengrams [ ] Beans [ ] Mbaazi (Ncugu) [ ]

12) Which areas of Tharaka Sub county are known for massive Millet and Maize production hereby referred to as "Tharaka food basket"

i. _____

ii. _____

iii. _____

iv. _____

13) Which marketing channels are commonly used by traders and farmers in this area?

Retail markets [ ] Supermarkets [ ] Community Agricultural Farms [ ]

Rural assembly markets [ ]

14) How many periodic open-air markets are there in Tharaka Sub County? ----------

Kindly mention them:

i. _____

ii. _____

iii. _____

iv. _____

15) What is the state of the fore mentioned periodic open-air markets

Connected with Electricity [ ] Served by good roads [ ]

Have iron roof market structures [ ] Poorly maintained and unfenced [ ]

No power supply [ ] Difficult to reach and not well visible[ ]

Appendix 3: Geographic Unit, Population and Number of Villages Sampled

Geographic Unit (Sub location)	Population size	Cluster (Villages Sampled)
Twanthanju	4261	1
Mauthini	3331	2
Kanjoro	4739	RC*
Ntoroni	4816	3
Irunduni	6987	4,5
Kirundi	2982	
Thiiti	3521	RC*
Mukothima	5226	6
Mwanyani	3418	RC*
Tumbora	2752	7
Nkondi	3575	8
Kereria	2671	
Matakiri	3039	9
Rukurini	2481	10
Kathuura	2014	
Turima	4612	11
Marimanti	2087	12
Kithigiri	3089	
Karocho	4824	13
Ibote	3605	14
Murinda	3547	15
Kanyuru	2824	16
Gakurungu	2028	
Mwerera	1669	17

Rukenya	2858	
Kirangare	1575	18
Gituma	1881	
Kamatungu	3078	19
Gatunga	7515	20
Tunyai	4657	21,22
Kithino	2249	
Gakirwe	1891	23
Tubui	1716	
Gaceeraka	2645	24
Nkarini	4026	
Matiri	2845	25
Chiakariga	4561	26
Kamarandi	3137	27
Uturuni	1780	
Kamanyaki	1730	28
Kirukuma	1457	
Kaguma	1951	
Kamwathu	4174	RC*
Kamaguna	3544	29
Kathangacini	4215	30

Note: * Means Reserved Cluster (villages which were reserved for substitution)

Appendix 4: Monthly Temperature and Rainfall for Ten Year Period from 2010 to 2020

YEAR	MONTH	JAN	FEB	MAR	APRI	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
2010	Temp ^{0}C	19.58	20.61	19.9	20.07	19.55	19.23	18.06	18.94	20.33	20.97	19.80	19.87
	Rainfall (mm)	1.45	2.69	14.02	16.76	7.76	2.59	2.69	3.80	1.70	5.33	5.09	0.51
2011	Temp ^{0}C	20.87	22.57	22.81	21.07	20.03	19.37	19.52	19.16	20.53	20.77	20.17	20.19
	Rainfall (mm)	0.33	1.45	0.89	11.69	12.97	8.18	3.92	6.31	3.97	7.71	8.17	4.22
2012	Temp ^{0}C	21.68	22.21	23.0	21.13	19.81	18.9	18.55	19.74	21.37	21.32	20.0	20.13
	Rainfall (mm)	0.02	0.91	0.17	17.71	18.59	8.73	3.22	4.62	1.78	7.88	6.47	1.31
2013	Temp ^{0}C	21.52	22.54	22.58	21.30	19.77	18.70	18.87	19.29	21.17	21.29	20.6	20.26
	Rainfall (mm)	0.36	0.15	5.85	23.12	7.56	5.92	3.63	3.80	3.24	2.89	2.56	1.29
2014	Temp ^{0}C	21.29	22.5	22.58	21.27	20.45	19.53	19.45	19.97	20.47	21.32	20.60	20.42
	Rainfall (mm)	0.12	2.62	1.85	3.88	7.65	6.72	2.56	3.86	3.32	4.95	3.57	0.28
2015	Temp ^{0}C	22.35	23.36	22.97	21.40	20.23	19.43	19.16	20.13	21.40	22.45	20.7	21.16
	Rainfall (mm)	0.23	2.37	1.32	10.12	12.76	7.53	4.0	2.46	1.37	5.13	9.93	5.63
2016	Temp ^{0}C	22.13	23.03	24.48	21.47	19.61	18.97	18.87	20.16	20.77	22.13	21.07	21.23
	Rainfall (mm)	2.74	2.63	1.75	11.56	6.69	3.99	1.11	1.81	2.40	1.38	3.26	0.93
2017	Temp ^{0}C	22.23	22.86	23.94	21.80	20.23	19.97	19.94	20.61	21.63	22.42	21.57	22.06
	Rainfall	1.10	0.76	2.73	5.99	10.62	3.31	3.38	2.71	2.02	7.46	2.36	0.09

	(mm)												
2018	Temp ^{0}C	23.13	23.79	22.65	21.67	20.39	19.43	19.0	20.32	21.83	21.87	21.33	21.97
	Rainfall (mm)	0.02	0.54	7.10	11.02	8.99	6.04	2.08	0.95	3.05	6.47	5.22	1.27
2019	Temp ^{0}C	23.0	24.14	25.29	23.83	20.71	19.10	19.68	20.61	21.50	21.10	20.33	20.13
	Rainfall (mm)	0.80	0.29	0.88	8.95	11.63	9.35	2.17	2.26	3.23	11.18	11.87	10.05
2020	Temp ^{0}C	20.87	22.17	22.55	21.33	20.32	19.80	19.52	20.74	21.67	22.81	20.37	20.48
	Rainfall (mm)	5.48	2.60	8.32	13.67	9.58	3.51	1.31	1.54	2.83	3.33	8.26	2.23

Appendix 5: 2019 Kenya Population and Housing Census of Tharaka Sub County by Household Size and Population Density

Sub location Name	Number of Households	Population density (Persons per Sq. km)
Twanthanju	970	38
Mauthini	1096	57
Kanjoro	1160	76
Ntoroni	1101	190
Irunduni	1605	155
Kirundi	613	283
Thiiti	524	326
Mukothima	1486	330
Mwanyani	819	305
Tumbora	70	207
Nkondi	889	176
Kereria	631	125
Matakiri	728	160
Rukurini	582	130
Kathuura	69	166
Turima	743	214
Marimanti	527	124
Kithigiri	841	132
Karocho	359	224
Ibote	896	141
Murinda	548	101
Kanyuru	752	145
Gakurungu	314	134
Mwerera	379	103
Rukenya	584	79
Kirangare	409	78
Gituma	435	62
Kamatungu	1160	169
Gatunga	1815	81
Tunyai	1150	157
Kithino	460	256

Gakirwe	80	51
Tubui	381	147
Gaceeraka	641	152
Nkarini	994	182
Matiri	562	162
Chiakariga	984	103
Kamarandi	662	93
Uturuni	348	51
Kamanyaki	347	45
Kirukuma	333	46
Kaguma	474	68
Kamwathu	958	40
Kamaguna	864	34
Kathangacini	1221	37

Appendix 6: NACOSTI Permit

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RESEARCH LICENSE

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