UNIVERSITY OF NAIROBI

ASSESSING THE ADOPTION OF RAINWATER HARVESTING TECHNOLOGIES (RWHT) AS A COPING MECHANISM TO CLIMATE VARIABILITY IN KILIFI COUNTY, KENYA

BY

TULULA JANET NABWIRE
I54/83674/2015

A dissertation submitted for Examination in partial fulfillment of the Requirements for the Award of the Degree of Master of Science in Climate Change of the University of Nairobi

DEPARTMENT OF METEOROLOGY
SCHOOL OF PHYSICAL SCIENCES

UNIVERSITY OF NAIROBI

2020

DECLARATION

I hereby declare that this dissertation is my original work and has not been submitted elsewhere for examination, an award of a degree or publication. Where other people's work or my work has been used, this has been properly acknowledged and referenced by the University of Nairobi's requirements.

Signature ..……………………………. Date ……………………

Tulula Janet Nabwire

I54/83674/2015

Department of Meteorology

School of Physical Sciences

University of Nairobi

This dissertation is submitted for examination with our approval as university supervisors:

	Signature	Date
Prof. Alfred O. Opere	…..……………..	……………………

Department of Meteorology

University of Nairobi

P.O. Box 30197-00100

Nairobi, Kenya

aopere@uonbi.ac.ke

Dr. Gilbert O. Ouma	…..……………..	……………………

Department of Meteorology

University of Nairobi

P.O. Box 29053-00625

Nairobi, Kenya

gouma@uonbi.ac.ke

DEDICATION

I dedicate this work to the Almighty God for giving me the strength to conduct this study. I also dedicate the work to my loving husband and my dear daughters; Patience, Purity and Favour for their patience and support, and to my friends and all those who encouraged and walked by my side as I struggled through this challenging journey.

ACKNOWLEDGEMENT

Thanks to the Almighty God for keeping me inspired and courageous to go through all this work. My sincere thanks go to Prof. Alfred O. Opere and Dr. Ouma Gilbert, my research advisors, who accorded me genuine encouragement and support to complete the study. They spent a lot of time going through this thesis and made valuable corrections as and when needed. May God bless them abundantly.

I am very grateful to the Government of Kenya through the Ministry of Water and Irrigation for giving me the opportunity and above all granting me the financial support needed to complete this study.

Mom and Dad, thank you for being there for me in all my needs. You helped me out in every aspect of my life while carrying out this study. I am humbled to fulfill a part of my parents' dream about me.

My special thanks also go to the Dean school of physical sciences, University of Nairobi, and all the staff of the Department of Meteorology for their moral support.

Finally, yet importantly, my thanks are to all the people including household heads in the rural areas of Kilifi County who helped me during the research. Their willingness and cooperation meant a lot to me.

To those people who contributed to the realization of this thesis, lack of mention by name or otherwise, does not imply in any way that your contributions are not recognized. I do appreciate your contribution and to all of you, I say thank you.

TABLE OF CONTENTS

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Kilifi is categorized as a poor county with a high poverty level estimated at 71.7% and experiences food and water insecurity affecting approximately 67% of the households. Rain-fed and small-scale agriculture is a major source of revenue in the County and it offers employment to more than half of the total number of people in the County.

There exists seasonal water scarcity in Kilifi County. Droughts and floods occur frequently, thereby compromising productivity and food security in the county. This is expected to pose even greater challenges in the future, as future climate projections predict increasing drought and flood risk in the country. Furthermore, water demand for human, agricultural, and animal needs has been increasing due to population increase and an adaption action is therefore called for.

The general objective of this research was to assess the adoption of the existing RWHT as an adaptation to climate variability in Kilifi County.

Temperature and monthly rainfall data were collected from the Kenya Meteorological Department (KMD). Filled in questionnaires from field surveys, Focus Group Discussion (FGD), and key informant interviews also provided additional source of data. Questionnaires were issued out using simple random sampling, with a sample size of 385 households and 10 key informants from the seven sub-counties were interviewed. Data quality control was carried out using simple mass curve and time series analysis was done using Mann Kendall Trend Test to examine the trend in the temperature and rainfall data. Variability in the datasets was determined by working out the coefficient of variation in both rainfall and temperature data. Descriptive statistical analyses (using percentages) were used to assess the adoption of the existing rainwater harvesting technologies and determine the social economic factors that hinder rainwater harvesting. Determination of the significance of the factors that hinder the adoption of RWHT was done using Logistic regression model.

Analysis of the rainfall data showed that Kilifi County experiences bi-modal type of rainfall (AMJJ and OND) with a threshold average monthly rainfall of 87mm.

Time series analysis of rainfall data showed variations that are not statistically significant. Analysis of AMJ and OND rainfall seasons using coefficient of variation indicated that there is a temporal variation of rainfall with drought spells from year to year although the trend was not statistically significant.

Time series analyses for rainfall showed a high degree of inter-annual variability. The study further showed an increased occurrence of rainfall that is below normal that may cause drought although the trend was statistically insignificant.

Time series analysis for temperature just as the global observation, maximum and minimum temperatures have increased in all seasons in Kilifi County.

From the findings, majority of the household surveyed (40.3%) obtain their water from springs as compared to other water sources. There is water scarcity in the county shown by longer distances (4-7km) travelled by most people in search for water. Findings on the adoption of the RWHT by the community in the County showed that 92.6% of households in Kilifi County practiced roof top water harvesting Technologies followed by water pans/ponds (3.5%). Majority of the people (93.5%) in Kilifi County are eager to organize and harvest more superficial water runoff.

Analysis on the significant of all the socio-economic aspects that affect the adoption of RWHT ,showed that distance from the existing water source to the household with the highest odds ratio of 7.203 affects the adoption of RWHT the most. Followed by education level of household respondent with an odds ratio of 5.909 and household income with an odds ratio of 5.257.

Analysis from Key Informants and FDGs indicates that some of the private development partners/ NGOs have played a vital role in helping households in reducing food and water insecurity as well as adapting to climate variability in the county by facilitating communities in construction of some water technologies.

These will inform the decision-making in policy development to enhance water and food security in the county

CHAPTER ONE

INTRODUCTION

The chapter highlights the introduction to this study, presents the statement of the problem and the research questions to be answered. It also defines the overall and specific objectives, justifies, and outlines the significance of the study.

1.1 Background

Water is life and very essential for achieving food security, reducing poverty, and conserving ecosystems. Water in itself is a precious resource whose inadequacy is the main bottleneck to sustainable development in the world (Berger, 2011). According to Aroka (2010), the key limitation to growth in many parts of the world is inadequacy of water in both quality and quantity. Adequate quality and quantity of water influences every aspect of social existence: healthiness, agricultural yields, food safety, technical growth (the overall growth in innovations), and the economy at large. Water shortage is a major problem for agricultural production in the dry land areas of the world; with global blue water withdrawals for agricultural purposes being estimated to account for 70 percent of the entire water consumption (Lindoso, 2018).

Kenya is a water scarce country**,** with an average per capita fresh water use of 647 m^3 (NWMP 2013) against an international water secure average of over 1,000m^3. Kenya is projected to experience a greater per capita water shortage of 400 m^3 by 2020 due to climate change and the high population growth rate of around 2%, giving an expected population of about 85 million people by the year 2050 (UNEP, 2012; Otieno, 2005).

Kenya frequently suffers from challenges of alternating intensive flooding and biting droughts due to variability in the rainfall patterns, poor land management, and high surface runoff of over 52% of annual rainfall (NWMP, 2013). According to NWMP (2013), about 52% of Kenya's annual rainfall drains into the Indian Ocean and Lake Victoria as surface runoff within three (3) weeks of rainfall, while Rift Valley Water Catchment (RVWC) area of internal drainage (drainage within the rift valley basin) channels its waters to the salt lakes of Rift valley. This excessive surface water runoff, which is most likely due to deforestation, land degradation and climate variability, is the principle cause of the frequent flooding followed by biting droughts as reported by (IPCC, 2014a).

Behnassi et al. (2014) stated that a country should consider rain as a significant source of water that can be managed by households for use as an alternative source to rivers and groundwater. To fight poverty it is essential to expand the delivery of water for irrigation agriculture by encouraging households to adopt RWHT on their farms. Furthermore, households can improve their livelihoods by carrying out irrigation farming, securing accessibility to water through water rights and investing in water harvesting and storage. This, according to Aroka (2010), justifies the necessity of adopting of RWHT, as a way of amassing and keeping rainwater for domestic, livestock, and irrigation farming.

According to (UNEP, 2012), Kenya has rainwater-harvesting potential of more than 300 billion cubic meters and with proper capturing and proper management; this water can sustain 233 million people or near to five times the Kenya's present population for five years.

However, Kenya has very low per capita surface water storage of about $103m^3$ and of this amount only $3.1m^3$ is for domestic, livestock, industrial and irrigation and the rest is for hydroelectric power production. This has declined from $11m^3$ since 1969 to the current estimate of $3.1m^3$ - against a basic per capita minimum of at least $1000m^3$ as stated by (UNEP, 2012).

This calls for focus on RWH in the country. Kenya's total per capita storage compared with some countries in East Africa and from other continents is as shown in figure1.

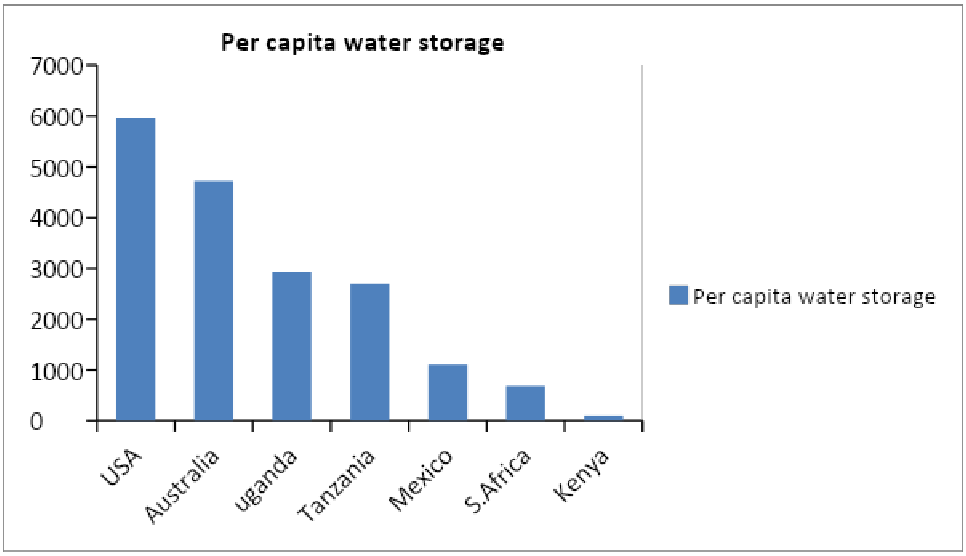

Figure 1: Estimated per capita Water for selected countries, FAO (2008) and UNEP (2012)

The ministry of water and irrigation at national Government level is determined to enhance per-capita storage from below 200m^3 in 2017 to 7, 400 m^3 by 2030, by working together with the communities and other stakeholders to invest in construction of micro and macro RWHT. The ministry is also committed to increase water coverage of piped water from 60% to 63% in 2018/19, in an attempt to achieve universal access to water (NWMP 2013).

Kenya being an agricultural country it relies on its land and other natural resources such as water to meet livelihood needs of its rapidly increasing population. In the ASALs of Kenya, insufficient water for household, crop and livestock production has been the major constraint to development, noted by Abdelfadeeel (2012) who argued that water is a vital restrictive factor for agriculture during dry period in Kenyan ASALs.

The world's water resources are decreasing and struggle for fresh water for domestic, industrial, environmental habitats and for irrigated agriculture is getting stiffer. Therefore, water users and other water sector stakeholders have raised various suggestions on how water-saving irrigated agriculture can be used in order to minimize water use while maximizing agricultural production. Alternatively, irrigation stakeholders can adopt a low cost alternative, which is Rainwater harvesting that would avail more water for other water users as stated by (Bates, 2008).

A report by ATPS (2013) stated that Rainwater harvesting (RWH) is not only and alternative for providing water for irrigated agriculture but also provides water that enhances economic and social development, reduce poverty and creates income for rural households through promoting conservation of the environmental, modification of the production method, and enhancing crop yield.

Rainwater harvesting covers all those techniques where rainwater is collected and used where it first falls on the earth or other surfaces like rooftops as defined by George et al., (2015). By convention, rainwater harvesting is defined as the act of collecting rainwater from rooftops and other purpose made catchments, or the act of collecting mass overflow from fabricated ground or normal superficial catchments and rock catchments for domestic, industrial, agricultural, or environmental use. According to Makau, et al. (2014), RWH is a very well-known exercise in numerous parts of the world and when practiced in the correct location it provides a very suitable, less expensive, and a manageable source of portable water. In principle, RWH is a less expensive, very simple technique that needs little expertise and has more potential paybacks as reported by Otti, and Ezenwaji (2013)**.**

Rainwater harvesting technologies (RWHT) includes rooftop tanks which could be plastic or concrete and either be elevated on platforms, placed on the ground or underground especially concrete. Other rainwater harvesting technologies (RWHT) are dams, pans, farm ponds, bunds, terraces, sand, and earth dams/sub-surface, rock catchment, Contour earth ridges, and zai pits. These facilities have variations in the designs and dimension, extending from small farm ponds dug by hands to large community earth dams and sand dams (Black, et al., 2012).

Seepage should be minimized and this can be attained by compressing the base with clay soil, or by coating them with impervious material like plastic pond liner.

Both county and national governments in Kenya encourage communities to participate in RWH by establishing community- based rainwater harvesting projects (Rockström, 2002, Makau, et al. 2014). The national policies that support RWH in Kenya include The Country's Water Policy of 2017, Water Act of 2016, the National Adaptation Plan of 2015-2030,the National Climate Change Action Plan2018-2022, the Environmental Management & Coordination Act (EMCA) of 1999, and the Climate Change Act 2016.

For the last thirty years, focus on rainwater harvesting (RWH) has highly increased in Kenya, with implementation of projects witnessed throughout the country as a long-term way of enhancing water security. The Kenya government is trying to implement the Water Act 2016, by launching a National Water Harvesting & Storage Authority (NWHSA) on Mar 5, 2018, with the mandate of undertaking the construction of public water works for water resources storage and flood control countrywide on behalf of the national Government. NWHSA is working out plans to harvest and conserve rainwater through construction of large dams, drilling and equipping of boreholes, small dams and pans, and flood mitigation.

Kenya's water needs can be satisfied by undertaking RWH, with comprehensive approaches and suitable designs for effective execution (Berger, 2011). This research focused on the assessment of the local peoples' experience with rainwater harvesting systems in an effort to minimize the adverse effects of Climate variability, the paybacks related to rainwater harvesting, and the challenges faced during implementation of rainwater harvesting strategies. According to Berger (2011) report, the government can only achieve this through a participatory process involving not only governments but also all stakeholders including other Government agencies, development partners, Civic Society Organizations, and private sector.

1.1.1. The Study Area

This study was carried out in the County of Kilifi which is situated at the coastal strip of Kenya lying between longitude 39^{o} 05‟ and 40^{0} 14‟ East and latitudes 2^{o} 20‟ and 4^{o} 0‟South. The county was established in 2010 after merging Malindi and Kilifi Districts. Its headquarters is Kilifi town and Malindi is its biggest town. Kilifi County is located 420km southeast of Nairobi and 60km north of Mombasa. Kilifi County has an area of 12,609.74 square kilometers and shares boundary with Mombasa and Kwale to the south, Tana River to the north, and Taita Taveta to the west. Kilifi County is made up of seven constituencies; Kilifi South, Ganze, Malindi, Magarini, Kilifi North, Kaloleni, and Rabai. The county has a population of 1,453, 787, (male – 704,089 (48%), female 749673 (52%), and 25 inter-sex, (K NBS, 2019).

The county receives an average annual rainfall that varies from 300mm (hinterland) to 900mm to 1,300mm (the coastal belt). Mtwapa area and areas along the Arabuko Sokoke Forest receive the highest rainfall. The evaporation rate varies between 1800mm (along the coastal strip) to around 2200mm in the interior of the Nyika plateau.

The entire county experiences the highest evaporation rate in the months of January to March. The annual temperature for the county ranges from 21^{0}C-30^{0}C in the coastal belt and 30^{o}C-34^{o}C in the hinterland. The wind speeds in the county are relatively low and range between 4.8 km/hr and 12 km/hr.

The three communities that occupy Kilifi County are the Chonyi, the rabai and the Giriama and their main economic activity is farming followed by other activities like small businesses and coastal beaches tourism.

Kilifi County is bestowed with both underground and surface water in rivers like River Sabaki, Kombeni, Nzovuni, Rare and Mwandeje that channel their waters into the Indian Ocean. Most of the rivers have great potential for multi-purpose dams construction to satisfy the demand for water by the growing population.

Most rivers, water pans, and earth dams are commonly located in the ASALs of the county where piped water is either inadequate or not available, such areas include, Ganze, Magarini and Kaloleni. The population that depends directly on earth dams and water pans for their water needs is 19.1%. The surface water sources are largely prone to contamination since they unprotected.

Despite the fact that the county of Kilifi is gifted with both underground and surface water, water shortage is still a big problem in the county. The county had a water gap of 80,884m^3 per day in 2018, which is projected to 99,784 m^3/d, 118,684 m^3/d and 137,584 m^3/d by 2022, 2026 and 2030 respectively. The highest (30,637m^3/d) demand for water is experienced in Malindi while the lowest (6,902 m^3/d) demand for water is experienced in Ganze. Kilifi North and Kilifi South currently delivers 8,380m^3/d and 7,810m^3/d respectively to the population. They both have higher possibility for shallow wells and have higher tap water (Kilifi CIDP, 2018). The county spends a lot of money on water tracking during droughts especially in semi-arid areas like in Magharini, Kaloleni and Ganze.

Countywide, most people have tap water and boreholes as their major sources of water. Most of the population covers a walking distance of 3.5km to their nearest water source.

About 60% of the county's households have access to piped water that is supplied by Malindi Water and Sewerage Company (MAWASCO) and Mariakani Water and Sewerage Company (KIMAWASCO) (Kilifi CIDP, 2018).

The Government of Kilifi county and other water sector stakeholders are enhancing water sources by drilling boreholes, extending piped and construction of water pans to meet the growing urban and rural water demands. Hence, deliberate efforts to increase the development of RWHT and construct climate proof water schemes in the county are needed in ensuring adequate provision of cleaner and safer water to all (Kilifi CIDP, 2018).

Kilifi County has high poverty levels of over 70% and the livelihoods of its' communities are dependent on the climate sensitive economic activities including agriculture, tourism, and fishing. The County frequently suffers from challenges of intensive flooding often followed by biting droughts resulting from the marked variability in the rainfall patterns and poor land use activities that promote high surface runoff and all these leaves thousands of people without food. Therefore, these communities rely on relief support from the national, county governments and other development partners (Kilifi CIDP, 2018).

This reduces the budget meant for other development projects at both national and county levels hence affect the general economic development both at the county and nationally. The community has also has developed a dependence syndrome, which has made them to be unwilling to mobilize themselves and enhance self-reliance in terms of food production (Kilifi CIDP, 2018).

Crop failure is a common experience in Kilifi County. Whenever drought occurs, about 500,000 people get affected, with 200,000 being directly affected (Tuva, 2016). To respond to this production gap, the communities cut old indigenous trees to produce charcoal and timber. This further degrades the environment and hence worse droughts occurrence and accelerates desertification. In 2016 (May to July), the National and County government together with international NGOs such as the World Vision and Red Cross societies (World Food Programs) used approximately KSh100 million to fight hunger and famine caused by the prolonged drought in Kilifi County (GoK, 2016). To spare both governments from these huge emergency budgets we need to embrace and promote RWH in the County.

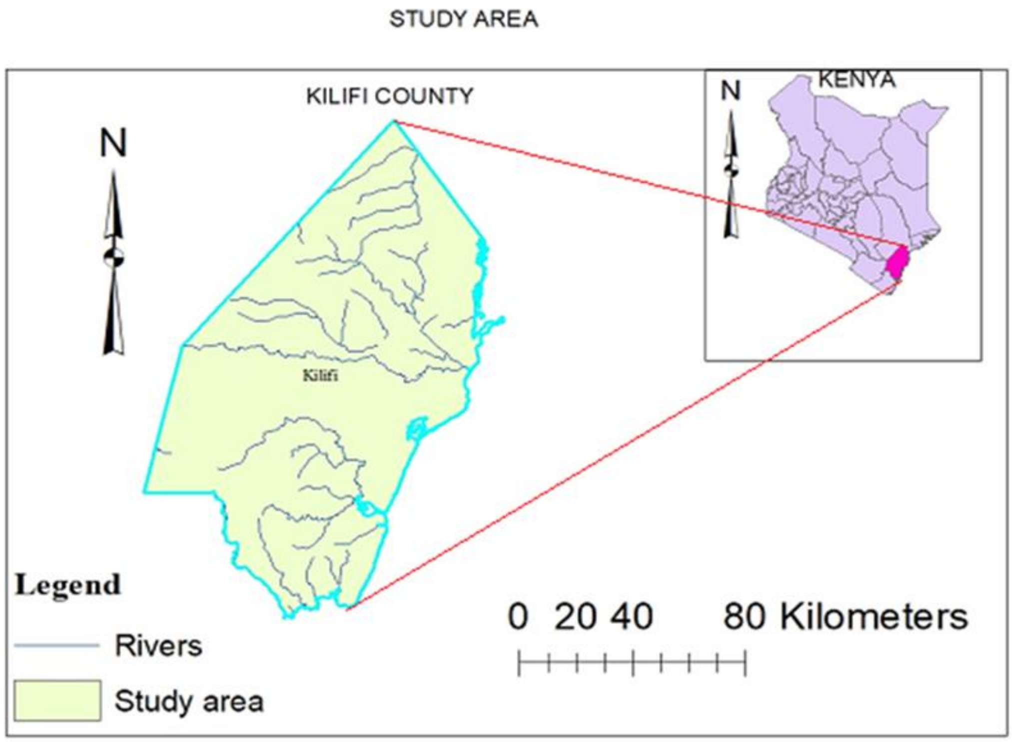

Figure 2: Map of Kilifi County with livelihood Zones (Source: Tuva, 2016)

1.2 PROBLEM STATEMENT

Despite the fact that the county of Kilifi has both underground and surface water, water shortage is still a big problem in the county. The county had a water gap of over 80,000m^3 per day in 2018, which was projected to over 99,000m^3/d, 118,000 m^3/d and 137,000m^3/d by 2022, 2026 and 2030 respectively. This has led to a major challenge of access to adequate water, to meet the need for irrigated food production in the absence of rainfall. This calls for increased investment in RWH to enhance the capacity of the residents to cope with climate variability, induced water scarcity and reduce the county's public expenditure.

However, despite of the availability of simple and low cost rainwater harvesting technologies in Kilifi County, the adoption of these technologies by the community is still low. In spite of high proven potential of RWH to enhance attainment of the SDGs and the Vision 2030 with a view to provide safe drinking water, promote gender equity and reduce poverty and hunger, it has not been widely adopted by communities in Kilifi county. Furthermore, RWH has not received adequate interest among policy makers, planners and water project managers in the county because it is considered competitive rather than an additional water to the tapped water supply systems.

To date, despite the high rooftop and runoff harvestable volume potential of 12351.9m^3 during the two rainy seasons that is above the inhabitants' water demand even at a higher per capita requirement of 200 l/c/d the adoption of this RWHT in the county is still low.

In spite of the increasing interest in RWH projects in Kilifi County, implementation of these projects in the field by third party has experienced many problems and some even stop functioning immediately after completion of the project.

This study therefore, bridges this information gap, by documenting the existing state of matters of RWH in Kilifi County, and recommends what is required to enhance its adoption.

1.3. Research Questions

i) This research adopted the following study questions.
ii) How does the climate of Kilifi County vary?
iii) Are there any water harvesting initiatives in the county?
iv) What are the major challenges faced by communities in adopting rainwater harvesting technologies?

1.4. Research Objectives

1.4.1 General objective

The overall aim of this study was to assess the adoption of the existing rainwater harvesting technologies as a coping mechanism to climate variability in Kilifi County.

1.4.2 Specific objectives

i) The specific objectives were:
ii) To determine the temporal and spatial variability of rainfall and temperature in Kilifi County;
iii) To determine the level of adoption of the rainwater harvesting technologies in the county;
iv) To identify and document the challenges and opportunities in the adoption of rainwater harvesting technologies in the County;

1.5. Research Hypothesis

The adoption of rainwater harvesting technologies in Kilifi County will not enhance coping capacity to the effects of climate variability.

1.6. Scope of the Study

This study targeted smallholders households in the rural areas of Kilifi county, Focused Group Discussions (FGDs) and Key Informants from the seven sub-countries Kaloleni, Kilifi North, Ganze, Kilifi South, Rabai, Magarini, Malindi and with a total a population of 1,453,787, male – 704,089 (48%), female 749,673 (52%), and 25 inter-sex, based on statistics by KNBS (2019). The study also assessed the adoption of both ex-situ and in-situ rainwater harvesting technologies (RWHT).

1.7. Assumptions

The following three assumptions were made during this study.

Most of household heads (the target respondents) would be present in their homesteads to respond to questionnaires. This was not the case because most of the respondents were always busy to participate in the study.

The harvested rainwater would be of the acceptable quality. In reality, most of the rainwater collected was of deprived quality other than that from roof water harvesting.

The topography of the county is uniform and hence it could support all RWHT. In practice, RWH is not recommended in places whose gradient is steeper than 5% due to non-uniform runoff distribution and the enormous earthwork required which turns out to be non-economical.

1.8. JUSTIFICATION

Kilifi County is situated in the semi-arid parts of the Kenyan coast that experiences frequent flooding due to excessive surface runoff followed by intense droughts due to marked climatic variability. Kilifi is among the poorest counties in Kenya whose level of poverty is about 70% and each year, the county is affected by famine, due to frequent floods followed by severe droughts that leave thousands of people without food. The worst hit part of the county is the livestock and ranching livelihood zone. The affected people rely on relief from the national, county governments and other donor partners.

One of the sustainable techniques to reduce flooding, cope with droughts, and raise the amount of available water in the county is RWH, a technology of gathering, channeling, and keeping rainwater for later consumption. If both rooftops and runoff water gathering is well in- cooperated and executed in the coastal areas, the region can no longer be water insecure (Gateri et al., 2016).

RWH is an ecologically and economically sustainable technique that can be a solution to water scarcity problems and, in addition, an appropriate adaptation strategy to the increased impacts of climate variability.

RWH has a potential to stabilize rural communities because it reduces migration of people from current flood prone areas/ lowland areas to uplands. It also enhances the utilization and development of local innovations and living standards of thousands of vulnerable people living in famine stricken areas.

There is therefore, hope that RWH will contribute solutions to the climatic problems of global water shortage. However, in spite of its proven potential and low implementation costs, RWH has not been widely adopted by the people in Kilifi County. In addition, rainwater harvesting and management (RHM) has not received adequate interest among policy makers, planners and water project managers in Kenya because it is considered rival rather than complementary to the predictable and motorized water source systems (Makau et al., 2014)**.**

At county level, Rainwater Harvesting (RWH) initiatives have always been slow due to limited resources allocation for applying Rainwater Harvesting (RWH) technology. In addition, the enabling environment in form of capacity development and governance has not been adequately addressed. Trans disciplinary approaches have not been adequately adopted.

Therefore, there is need to assess the status of adoption of Rainwater collecting and storage as a coping mechanism to Climate variability in Kenyan ASALs in order to offer information to policy and decision makers, to enable the government to attain Sustainable Development Goals (SDGs), Vision 2030, Third Medium Term Plan and the Second Generation CIDPs (2018-2022).

1.9. Significance of the research

This study tried to establish the current level of implementation of Rain Water Harvesting technologies in Kilifi County in order to assist in policymaking and implementation in enhancing water and food security. The study aimed at identifying challenges faced when adopting rainwater-harvesting technologies in the county and other similar areas located in the ASAL regions of the country.

Moreover, the study contributes to the enhancement of literature on the factors affecting adoption of RWH techniques in Kilifi County and other related counties in Kenya.

Therefore, the conclusions of this study may give additional facts that may be of great importance to policy formulators and managers advocating for higher adoption of RWH as strategies, in achieving water security in the county.

CHAPTER TWO

LITERATURE REVIEW

This section represents an evaluation of past studies related to this study. It presents contextual issues on the adoption of RWH technologies in coping with climatic variability and induced water scarcity and socio-economic aspects that are associated with the adoption of RWHT in Kilifi County.

2.1 Water Status in Africa

There is no life without water. However, availability, distribution, and quality of water has been declining with time due to increase in population, change in climate, and other evolving burdens driven by economic and populace growth. Water is an extremely vital resource among other natural resources and its scarcity necessitate a need for supplementing from rainwater harvesting systems (Gateri et al. 2016).

Many parts Africa are water-stressed, and the situation is even more severe when riparian countries need to share water amongst themselves (Otti and Ezenwaji, 2013). In Africa, pressure on water resources has increased and currently, several nations of the world suffer from unpredictable rainfall, life-threatening floods, and droughts due to climate variability and its impacts (Ishaku et al., 2012).

One of the driest continents that are inhabited is Africa. This makes water availability and accessibility more vital for life (UNEP, 2012). A large population in African developing nations experience inadequacy in supply of water whereas 40% have unreliable sources of water that is portable (UNEP, 2012). One of the basic human rights is accessibility to adequate portable water and need not to be overlooked. About 1.1 billion people in Africa faces a high risk of water-borne diseases and even death as a result of inadequate access to portable water (UNEP, 2012).

In Africa females have the burden of fetching water and they can take a third of their time in a day collecting water in the scorching sun from the nearby sources of fresh water (UNEP, 2012). This strenuous work renders approximately half of the people in the country susceptible to grave disasters like water borne diseases, drought, and famine (Behnassi et al., 2014). Chronic water insecurity in Africa could be due to some areas over-using their available water or pollution (contamination) of the available water sources while other areas are naturally water-insecure due to limited supply through the process. In some cases, water could be available but of poor quality like salinity and because of inadequate technical and financial means to process it, people may not utilize it fully (Gomoro et al., 2014).

In developing countries in Africa, 1.1 billion people (16% of the world population) face inadequate supply of clean water, and globally, 1.8 million children die yearly, due to water-borne diseases like diarrhea as a result of unclean drinking water (UNEP, 2012).

Water scarcity is projected to increase owing to the projected increased population, water stresses, water pollution, and poor governance that strain water supply systems in several nations of Africa (Ishaku et al. 2012; Mbogo, 2014; Lindoso, 2018).

IPCC, (2014b) projects that 2.9 – 3.3 billion people mostly from developing countries especially in Africa and Asia will be inhabiting watersheds that are water stressed by 2025. It will be difficult for these people to fulfill their basic water needs. This water scarcity might lead to conflicts between water users who use the same water sources since each group would be struggling to secure its own perceived fair share of water.

According to (UNDP, 2015), guaranteeing worldwide accessibility to safe, clean and cheap drinking water for all by 2030 as stated in the SDG goal (6) requires more investment in suitable structures, providing health facilities, and high hygiene at all levels. Safeguarding and restoring of all water-related environments like forests, mountains, wetlands, and rivers can help address the challenge of water scarcity (Mcsweeney et al., 2007).

2.2 Distribution of water scarcity in Africa

Many African countries have extremely high water scarcity leading to high competition for available water, high vulnerability to droughts and floods, and seasonal rainfall variability. In Africa one person in every three people faces shortage of water and approximately 400 million persons in sub-Saharan Africa face denial of supply of basic drinking water (Nathaniel et al., 2019).

Some of the important factors in Africa and around the world, which drive water stress, are climate change and poor management of water resources and services. Climate change has made rainfall more erratic and has increased the risks of droughts and floods. Therefore, investing in better ways of managing water and infrastructure is more essential. Such investments could strengthen economies especially they involve the poorest people, alleviate poverty, enhance creation of jobs and reduce vulnerability to climate change.

The figure below is the map of Africa displaying nations with Physical and economic water shortages.

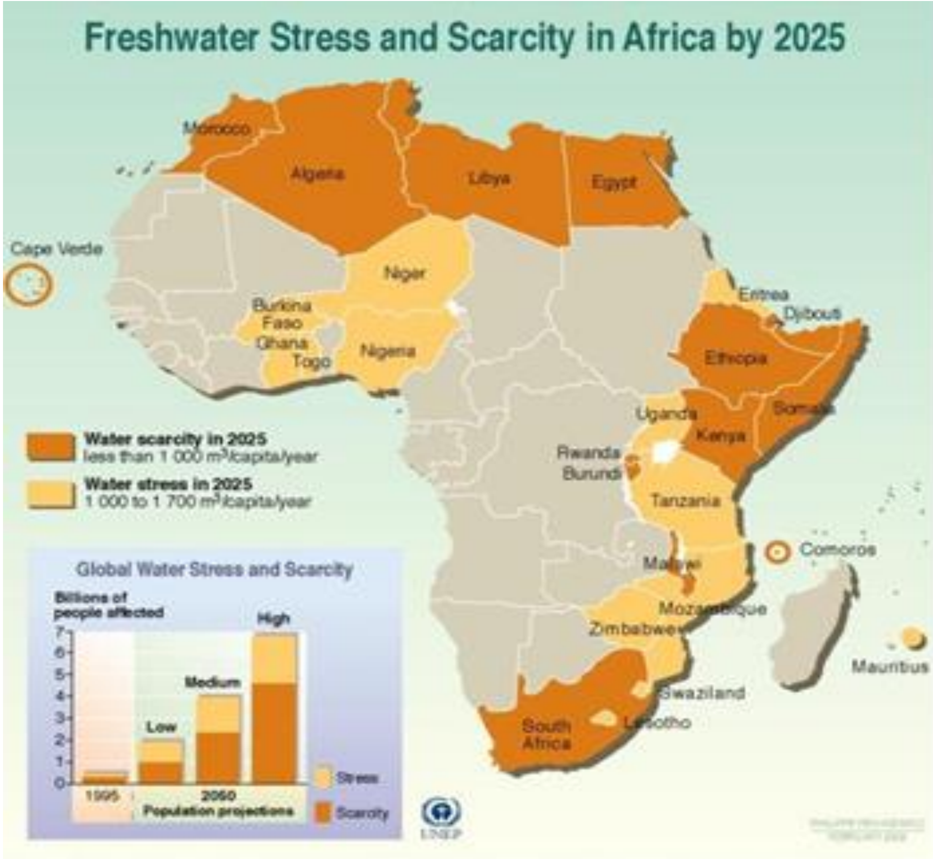

Figure 3: Map of Africa displaying nations with economic and Physical water shortages (FAO, 2012)

2.3 The general outline of Rain water harvesting

Rainwater Harvesting (RWH) is a technique where rainwater is collected at a point where it first reaches the earth's surface and either kept in tanks (cisterns) or used to revive groundwater (Behnassi et al., 2014). Water is a limited and scarce resource throughout the world as a result of the increasing demand created by the increasing population. This therefore, raises the need to conserve this natural resource.

In Kenya, provision of water for domestic, agriculture, pastoral, and industrial use for millennia has been through implementing RWH. In addition, Governments, government agencies and some of the development partner have recognized RWH as a local solution to water shortages in Kenya (Mbogo, 2014).

Elsewhere, Rockström (2002) noted that RWH has been practiced in Palestine and Greece since about 4000 years ago. A combination of paved courtyards and individual cisterns were used to harvest rainwater from aqua ducts for residential construction in the city of the ancient Rome. In the third millennium BC, irrigation agriculture by people in Baluchistan and Kutch used harvested rainwater (Rockström, 2002).

Jessours have been used in Tunisia for several centuries to harvest surface run-off from hilly areas where farmers constructed earthen dams across the floors of valleys to harvest surface run-off together with silt (Rockström, 2002). In the Arizona and northwest New Mexico deserts, farmers have been carrying out floodwater farming for the past 1000 years. In India, constructed earth bunds are used to harvest floodwater, then crops are planted to utilize the residual moisture after infiltration (in the "Khadin" system) and in the Great Horn of Africa (in the spate irrigation system) (Aroka, 2010).

In Kenya water and agricultural production policies, have mainstreamed rainwater harvesting especially for water conservation and quality preservation, through rainwater harvesting on the farms and hence reducing surface run off (GoK, 2013).

The Sustainable Development Goals (SDGs) the blue print for the world, contains a set of time bound and measurable goals and targets that enhance sustainable development of a country. Water of good quality and adequate quantity is very important for any country's achievement of all the SDGs (UNDP, 2015).

Kenya Vision 2030 presents various ways to attain sustainable development and better water management for people, their crops, livestock, rangelands, ecosystems, and economic development, especially in the ASALs. It draws from examples of successful water interventions in other dry zones of Africa and the

Middle East, focusing on technologies and practices that are generally adaptable by poor and smallholder land users.

RWHT has been used to provide water for livestock, particularly under pastoral and agro- pastoral farming systems, harvested rainwater stored in structures or in the soil profile recharges shallow aquifers (Lloyd, 2015).

Owing to the increase in huge and unified systems of water supply, RWH has been abandoned, in spite of the high-energy required and grave ecological impacts associated with these unified water supply systems (Aroka, 2010).

2.3.1 The foundation of Rainwater Harvesting in Kenya

Kenya experiences scarcity with a per capita fresh water estimated at 647 m^3 compared to the United Nations requirements (1,000m^3), with the relative to the neighbouring nations; Per capita fresh water of 2,940 m3 (Uganda) and 2696 m^3 (Tanzania). Current statistics indicate that the country is experiencing (declining water levels even as its demand continues to grow. Many rivers flow during the rains and dry up during subsequent droughts (NWMP, 2013).

Kenya's water storage per capita is a measly 105.3m^3 , when compared to some countries with ASALs such as South Africa (687m^3), Mexico (1,104m^3), Australia (4,717m ^{3}), and USA 5,961m^3 (NWMP, 2013). The national RWH&S on average is estimated to be in the range of 9 – 11%, leaving a huge untapped potential of approximately over 80% (Mogaka et al., 2006).

Supplementary supply of water (for instance rainwater harvesting) and sustainable managing of Kenya's limited water resources for domestic and industrial use , is important for the achievement of the Kenya Vision 2030's economic, social, and political major developments and the Sustainable Development Goals, since all the top projects – tourism, agriculture, industry among others require water NWMP (2013).

Kenya Vision 2030 and other national development goals will continue to be elusive until the country undertakes to harvest, harness, and store additional surface water to enhance agricultural land productivity and water security for other development sectors. The national water storage per capita for domestic, livestock, & industrial use has declined from $11m^3$ in 1969 to the current estimate of $5.0m^3$ against $100m^3$ a basic per capita minimum requirement globally (GoK, 2013).

About 60% of Kenya annual rainfall is lost to Indian Ocean and Lake Victoria as surface water runoff, while Rift Valley Water Catchment Area (RVWCA) loses water to the salt lakes of Rift valley (Magut et al., 2014). Excessive surface water runoff due to change in Climate and poor land use practices could be the principle cause of the frequent flash floods, followed by severe droughts, which are sometimes prolonged Despite water shortage having reached crisis levels, there is very limited activity in rainwater harvesting nationally. During drought, water trucking in the arid lands (ASALs) is no longer sustainable due to prohibitive costs. Therefore, trapping and harnessing rainwater and breaking the floods – drought cycle for ASALs should be a priority (Aroka, 2010).

Developing countries (like Kenya) are hit hard by climate change because they have weak infrastructures; weak policies on climate change; poor implementation of international climate policies and; they have few social services to intervene during climate risk reduction. Effective mitigation of climate change requires policies, conventions, and legislations that regulate behaviors of individuals and nations to water and food security (Behnassi et al., 2014).

Thus, Policies for climate change reduction should target capacity improvement and in Kenya priority areas include; development of a comprehensive National Water Harvesting and Storage Policy (NWHSP) and accompanying strategies and legislations. Followed by exploring Financing options for small and large scale water storage, Finalization of Land Reclamation Policy and, Capacity building of land owners/communities, technical staff of county and national governments on land rehabilitation, reclamation and rainwater harvesting and management strategies (NWMP, 2013).

In Kenya, many systems of water harvesting and management are practiced throughout the country as an approach to supplementary water supply in order to reduce over exploitation of natural water sources especially in ASALs (Berger, 2011). The selling point for RWH is the fact that most of the technologies used are simple since their construction and maintenance either at individual or community level does not require very sophisticated training from specialists or technicians (Mugerwa, 2007).

It is envisaged that RWH will contribute to the solution of both national and global water scarcity. Mbogo (2014) noted that despite the depletion of water resources, governments can safeguard this resource by enhancing harvesting and conserving water amongst communities and by integrating water resources management, and adoption of better water policies and implementing investment actions using new technologies.

For the country to improve its water resources, the problem of RWH projects' sustainability should be looked at when replicating the same projects in other parts of the country (FAO, 2008).

2.3.2 Importance of Rain Water Harvesting

RWH is an ecologically and economically sustainable technique that could offer solutions to problems of water shortage and in addition, serve as an adaptation strategy to the adverse climatic impacts.

The collected rainwater can be used for many different purposes including irrigated subsistence farming, aquifer recharge, storm water abatement, and if treated it can be used for domestic uses such as drinking (Makau et al. 2014).

Black, et al. (2012) argued that RWH in rangelands could be used to restore depleted lands for pasture and offer water during droughts for livestock and wildlife, kitchen gardening and industrial uses. It reduces livelihood insecurities such as risks of crop failure and hence a technology for reducing poverty and enhance food security. It also could reduce the rate of migration and inter-tribal/clan and interstate water and pasture related conflicts and wars. Furthermore, it ensures environmental sustainability and reduces the great impacts of climate variability.

Lloyd (2015) noted that RWH is very significant in the following cases: (1) In ASAL areas there is poor distribution of rainfall, and this makes agricultural production that depend on rains more risky because of variability in the rainfall seasons. However, if other factors of production (soils) are available, and even in the deficiency of other water resources RWH could enable farming. (2) In areas with insufficient rains, low crop harvests and great risk of crop failure, RWH could supplement rains and lead to increased and stabilized industrial, domestic and livestock and crop production in these areas. (3) In ASALs that suffer from desertification, declined agricultural production because of poor soil and poor water managing, RWH can provide water to irrigateable lands leading to improved vegetation cover and reduced degradation of the land. Therefore, RWH is the most appropriate approach to solving the problem of water shortage in the country and the only way of combating the menace of desertification in Kenya's ASALs. This is because most of the land is mostly becoming unproductive due to inadequate rainfall especially in the degraded lands provision of water to these lands would restore life to them.

The above advantages give rise to many indirect socioeconomic and other non-tangible benefits including, rural communities' stabilization due to reduction in migration; improvement and application of indigenous knowledge especially during the construction of RWHT; and improving the living standard of the millions of people living below the poverty level in areas frequently affected by drought. RWH if well implemented (where all constructions in the cities incorporate RWHT) could reduce flooding in the cities after a heavy downfall of the rains and reduce contamination of piped water (Black et al., 2012).

2.3.3 Forms of Water harvesting

Rainwater collection systems could be grouped according to the process that generates the runoff (rivers, lakes, and rainfall); the extent of the area of the catchment and the facility used for storage. The facilities for storage can be either inside an underground tank, a cistern or a reservoir. The dimensions and scale of the type of facility makes it to be either a micro or a macro scale facility (Black et al., 2012). There are three main forms of Water Harvesting based on the methods or technologies employed. These comprise Groundwater Harvesting (GWH), Floodwater Harvesting (FWH), and Rainwater Harvesting (RWH),

2.3.3.1 Rainwater harvesting (RWH)

This is where Rainwater is harvested and concentrated or retained at the point where it falls. It involves collection as well as storage of water from the rains for a particular use like production of plants (crops, trees, or pasture), and for domestic or industrial needs (Black et al., 2012).

RWH makes use of various technologies in order to concentrate, collect, and store rainwater and surface runoff for various usage through linkage of a runoff producing area with a another area receiving the runoff as stated by both Aroka (2010) and Mbilinyi, et al. (2005). Kattel (2015) states that RWH could be defined as any interventions by humans to locally collect and store rainfall for various human activities.

According to Lindoso (2018), RWH can either be called in-situ or ex-situ systems. In-situ is where rainwater is retained in the topsoil whereas ex-situ is where a storage facility (e.g., cistern, dam) is used to direct the rainwater or overflow that is in the drain basin and store it for later use**.**

Ex-situ RWH can be further grouped into sub-groups including rooftops RWH (RRWH) where rainwater is captured locally from roofs or other kinds of surfaces and kept in in-built reservoirs (used by mostly home) and infield RWH (IRWH) where the rainwater is collected, kept**,** and utilized in the area where it was collected, especially for farming (Kimani et al., 2015)**.** The purpose of rainwater harvested (e.g., farming, groundwater boost, aesthetic use) determines the choice of the best RWH system and the storage facility to be used. Furthermore, the choice of the best RWH system depends also on the site in terms of; altitude, landscape, distance from the rainfall collection, dam height, among others (Lindoso, 2018; Lloyd, 2015).

2.2.3.2 Floodwater Harvesting (FWH)

Ngigi (2009), George et al. (2015) and (ATPS 2013) stated that FWH is where rainwater surface runoff is spread over low laying farms for planting of crops, or trees seedlings (or spate irrigation), and it entails collecting and storing of creek flow for flood irrigation.

Floodwater Harvesting is also called floodwater diversion where the natural course of part of the water in a particular creek bed, stream or river, is changed and directed and allowed to flood a nearby area for farming of fast maturing crops especially during heavy rainfall (Black et al., 2012).

During FWH stormy passages of water movements are collected either by changing its direction or by scattering floodwater in a passage floor of a a river valley/bed and the rainwater overflow is kept in the soil profile to be used by planting fast maturing crops during dry period (Mbogo, 2014).

FWH can be grouped into two types depending on the catchment area. These comprises macro- catchments and large catchments. Macro (Medium sized catchments) is commonly identified by medium flood zones located outside the area of farming. In most cases, farmers use techniques like small (20,000m^3 to100, 000m^3) dams, pans, and bunds to focus, transmit, collect, and keep the overflow. These methods according to Ngigi (2009) can only be considered as FWH only when the availability of the collected water is throughout the year.

As Mbogo (2014) puts it, large catchments FWH is where water harvesting is made up of catchments systems that are of several kilometers squared by size away from where runoff water flows before it flows into a greater streambed, calling for more sophisticated structures of large dams and large conveyance systems.

Floodwater harvesting in large catchments can be, either floodwater harvested within a streambed or floodwater diverted and spread in the nearby area for cropping. In streambed floodwater harvesting, water flow is blocked and allowed to flood over the entire valley of the flood plain and enable the floodwater to percolate into the ground and which is later used by planting fast maturing crop or pasture.

2.2.3.3 Groundwater Harvesting (GWH)

Groundwater harvesting, as stated by Black et al. (2012) is the collection and storage of rainwater and surface runoff either in a pond structure or in the soil profile itself. In ASAL zones where soils often cannot absorb the intense downpours, ground catchment RWH acts as a tool to intensify infiltration and reduce runoff (Ngigi, 2009).

Groundwater harvesting involves all approaches, both traditional and modern, that are used for water harvesting on the land for a fruitful use. Furthermore, GWH is usually used as a storage way for the other methods of collecting water mentioned above, where most of these technologies require a certain type of landscape to allow the water abstracted can infiltrate into the soil profile for crop use. Traditionally, GWHT involve the use of earth dams, ditches or terraces, zai pits, bunds, and reservoirs (Behnassi et al., 2014).

2.3.4 Factors that hinder the implementation of rainwater harvesting technologies

Rainwater harvesting provides an opportunity to solve problems of water insecurity in the country, thus it is necessary to address factors that hinder the adoption of appropriate RWH technologies with a view to increasing the adoption of RWHT by target populations (Mbogo, 2014). The main step in adoption of RWH is changing the people's mind on RWH (Ahmed, et al., 2013). This is because it is now recognized that there is enough freshwater on yearly basis from the rainfall to satisfy the water requirements of current world's population (Gateri et al., 2016).

Globally ASALs are a home to a larger number of people therefore, it important that search for solutions to water insecurity in these areas is key to enhance universal development without marginalizing some regions. It is not good to have an assumption that a technology that functions in a certain region, will also do well in another, this is because of technical variations in the rainfall, or soil types and differences in separate socio-economic factors, and many others as explained by Aroka (2010).

Several socio-economic factors should be considered when selecting the appropriate RWH technology that should be implemented in a certain area (Lloyd, 2015). These socio-economic factors that the adoption of RWHT include; age, level of education, land tenure, accessibility to water, household's income, social capital of a family, and the level of training/extension of the family head have significant influences on adoption of RWH (Mburu et al., 2015).

These factors have been discussed in this study in chapter four. Other determining factors include water rights conflicts and disputes, inadequate characterization of rainfall, soil properties, Evapo-transpiration, weak institutions and inadequate policies to guide the management of both green and blue waters (Ngigi, 2009).

2.4. Climate change and water harvesting

According to Ogallo et al. (2017), changes and variability in climate and the future projections is a reality. Worldwide change and variability in climate are already happening and it is evident many people in developing countries are experiencing many climatic extreme events.

Gateri et al., (2016) stated that a change in climate would lead to a high escalation of the world's hydrological variability in the next 100 years, causing an increase in the rainfall, evapo-transpiration, incidences of storms and substantial changes in biogeochemical processes that influence the quality of water.

Okumu (2013) concurred with the observation that extreme climatic manifestations like stormy rainfall/ hurricane, floods, aridity, heat wave, drought, cyclone, are projected to impact greatly on human beings than the slowly changing climate. As culture and climate interact, there is a general human response to adjust and alleviate the sufferings related to such climate extremes. Social and traditional responses to extended drought comprise of people dislocating, people abandoning their dwelling places, extensive migration, and state breakdown, (Otti et al., 2013).

For many years response strategies to climate change impacts like drought and floods by people living in arid areas has always been through people migrating to safe and fertile places. Nevertheless, since culture and climate interact in many ways, it can be proposed that instead of people migrating to other areas, they may just modify their home conditions by undertaking strategies like RWH to augment the existing water through harvesting rainwater or surface run- off (Magut et al., (2014).

Magut et al., (2014) proposed that in a varying climate, societies may adopt rainwater harvesting and remain in their traditional homelands rather than relocating. It is commonly said that humanities do not give up unless they have exhausted avenues of their existence in the area they lived for long time.

2.5 Conceptual Framework

This gives the revelation about the cause-effect relationship between the independent and dependent variables in the study (Rodriguez et al., 2007). Therefore, it helps in identifying variables required for the research. According to Bordage (2009), Conceptual Framework is a "map" that is pursued during the research.

Depending on the statement of the problem, conceptual framework puts down a platform where certain study question driving the study will be presented (Adom, 2018). According to Adom (2018) it is a framework which the researcher can use to best illustrate progression of a natural occurrence to be studied and it links ideas, empirical research and the used theories in promoting and systemizing the knowledge espoused by the study.

Figure 4 presents a graphical conceptual framework that was adopted in this study. this figure shows the key variables or constructs that were investigated and the presumed relationships that exist between them. In this study, the social and economic aspects that affect the embracing of RWH were the independent variables while the adoption of water harvesting technologies constitutes the dependent variable to be measurable in this study.

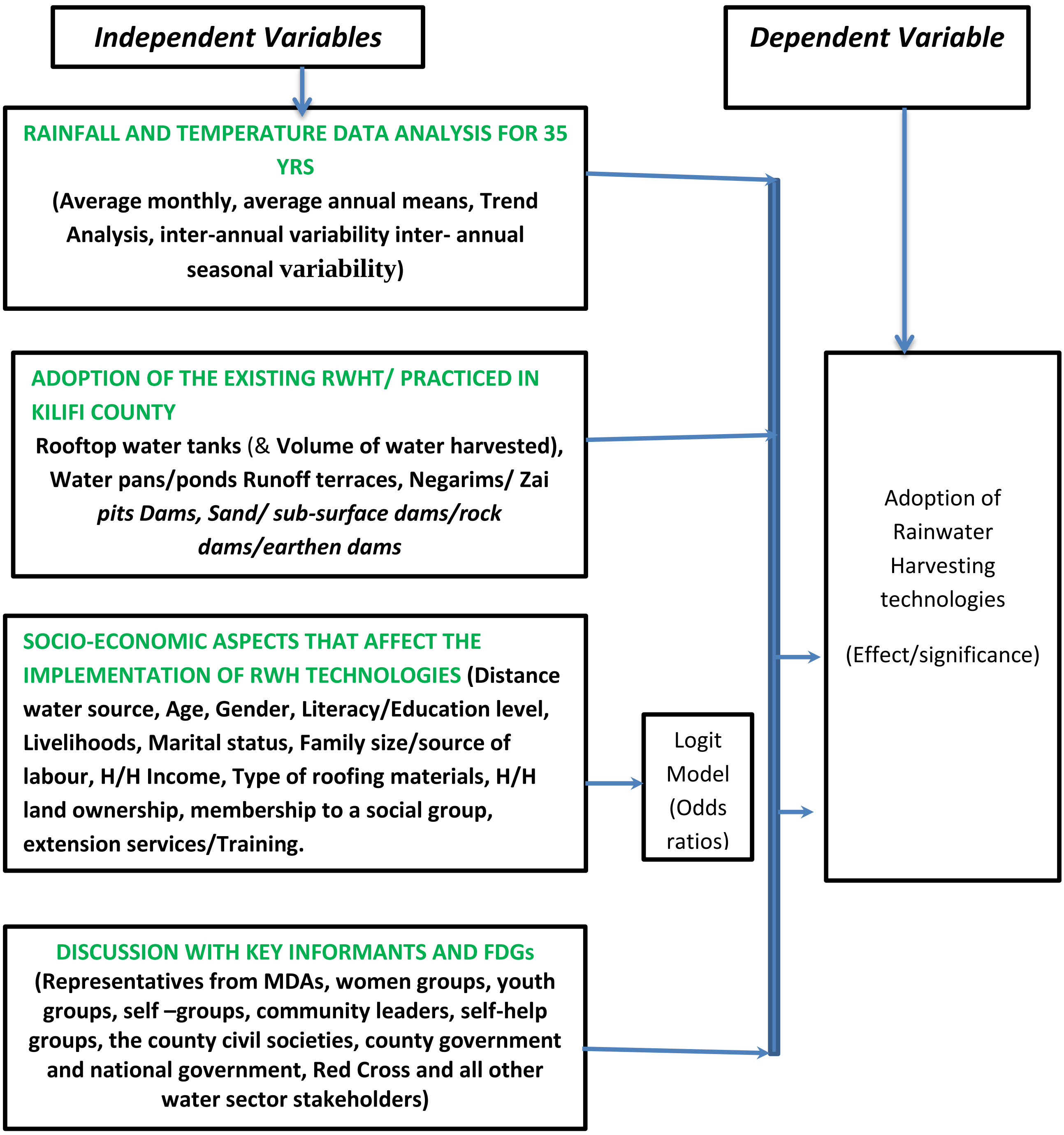

Figure 4: Conceptual Framework

To evaluate and assess the significance of all the socio-economic issues (as independent variables) to the adoption of RWH technologies as a dependent variable, Logistic regression model was used (Fidell, 2013). This methods determines the log odds of a factor. This was explained in details under methodology section.

CHAPTER THREE

RESEARCH METHODOLOGY

This part presents the data types and sources used in this study. It also outlines data quality Control, determination of the size of the sample and the procedures for sampling, gathering of data, the adopted study design, and methods of data analysis in order to realize the outlined aims of this research.

3.0 Introduction

Trend and Variability in both temperature and rainfall were analyzed using Mann-Kendall test and co-efficiency of variability respectively, and the results presented in graphs and models derived from the data analysis. Primary data was obtained from the respondents by use of semi-structured questionnaires, Focused Group Discussions, and target key informants interviews drawn from county government ministry of water officers, NGOS, development partners, self-help groups, and county administration personnel through Random Sampling with a Sample size of 385, and analyzed through distributive statistics (e.g. percentages). The study identified socio-economic aspects that influence the implementation of RWHT as the independent variables and adoption of RWHT as the dependent variable. These were classified based on the viewpoint of causation. These methods were discussed in the subsections below.

3.1 The Study Design

The diagram below (figure5) represents the study design that was used in this study.

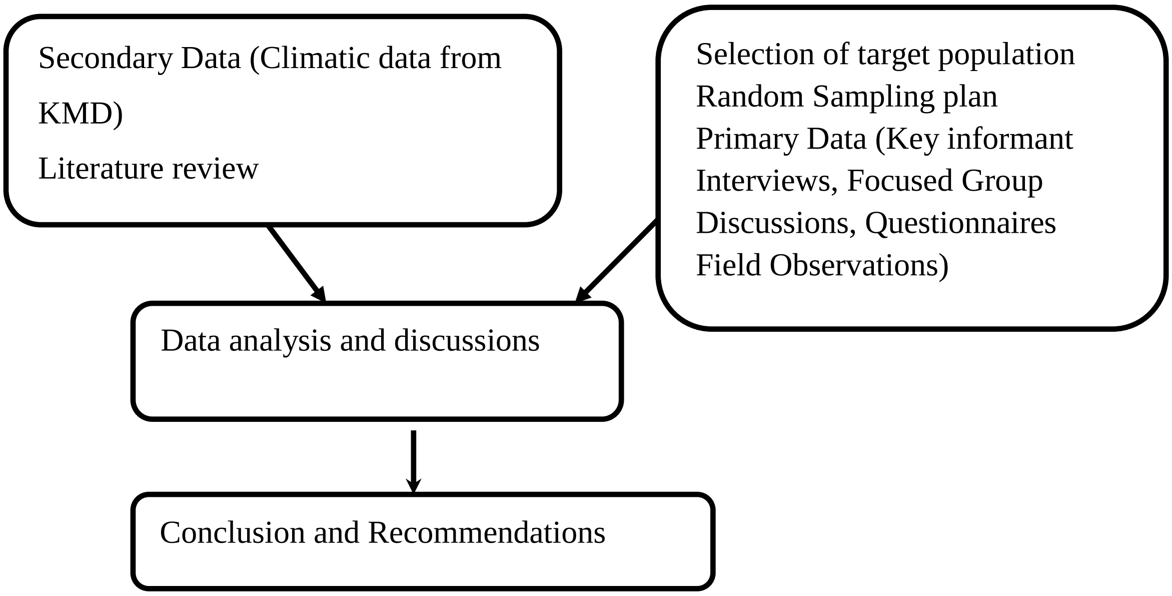

Figure 5: Diagrammatic representation of the study design

The research used both qualitative and quantitative data collecting tools. A plan in form of a theoretical framework (figure 4) was formulated to guide the study and a conceptual framework structure designed to illustrate the major stages and processes of the study. A strategy was set by identifying and obtaining suitable data for rainfall and temperature ensuring quality processing, control and analysis. The study design was based on the nature of the investigation assuming a 'cause-and effect' relationship.

3.2 Data Types and Sources

This research relied on data gathered from both secondary and primary data sources. Data was either qualitative or quantitative. Qualitative data is descriptive while Quantitative data is arithmetic. Qualitative data may not only be in words or text but may also be composed of videos, sound recordings and photographs. It should be noted that the basis of all quantitative data is qualitative findings. While qualitative data is descriptive and can be presented in numerical form (Trochim, 2006).

3.2.1 The Primary Data and their sources

This data is first-hand experience evidence collected by the researcher based on a specific research purpose from an original source. This is categorized as either primary quantitative data collected using structured interviews and questionnaires or as primary qualitative data collected by a participant's observation and unstructured interviews. Interviewing and observation are qualitative methods of collecting primary data that gives a researcher a deeper and wider understanding of the findings based on documented interpretation (Creswell, 2007).

For this study, primary data on distribution of households in percentage by household size, the adoption of the existing RWHT and the socio-economic factors that hinders the implementation of RWHT for the seven sub-counties (Kilifi North, Ganze, Kilifi South, Malindi, Kaloleni, Rabai, Magarini) and was obtained from issued questionnaires, observation, photography, unstructured interviews and focused group discussions (FGDs).

3.2.2 The Secondary Data and their Sources

These are documented facts that were collected and recorded by others other than the person that uses this information. It is already collected data from other sources. It is also categorized as secondary quantitative data collected from official statistics and secondary qualitative data collected from published letters, journals, and articles (Kang et al., 2015). For this study, data was gotten from both qualitative and quantitative secondary data sources. For this study, secondary data used was Climate data, which were rainfall per month and minimum and maximum temperature per month for Malindi Meteorological Station, for the period 1962 - 2018 for rainfall and 1974 to 2018 for temperature respectively. These data was gathered from the Kenya Meteorological Department (KMD).

3.2.3 Selection of target population

The study targeted smallholder farmers in the rural areas of Kilifi county.

Other target population included water officers and water engineers from the Ministry of Water and Irrigation, county extension officers from the ministry of agriculture, the county administrators, NGOs, the civil society members and self-help groups, that are involved in the implementation of RWH activities or projects. The elementary component of study used was households and the unit of observation used in each sub-county was the household respondent. In this study, selection of a household was through simple random sampling.

To identify key informants and to choose representatives in the FDGs who are involved directly or indirectly with societies and water programs, purposive sampling was used.

3.2.4 Determination of the size of the Sample

The sample size was obtained by using Cochran (1963) formula as stated by Israel (1992) in equation 10.

$$n = \frac{z^2 pq}{e^2} \quad \text{--} \quad (10)$$

Whereby n is the sample size, z is the desired Z-value yielding the desired degree of Confidence, p is an estimate of the population proportion and e is the absolute size of the error in estimating p that the researcher is willing to permit and q is 1-p. The study used a 95 percent level of confidence in order to be more precise, thus Z= 1.96, and the allowable error in this study was 0.05.

Since the population involved was larger (more than 10,000 people) and the estimation of the percentage of the targeted population expected to have the features of concern was not provided, thus 50% p was used. Consequently, with the percentage of the target people being .50, then the Z statistics is 1.96 as starts by Memba (2015). By use of the above formula, the sample size was 385 respondents in each of the seven sub-counties. The above stated values of the parameters were applied to equation 10 to give a total of sample of 385.

3.2.5 Sampling procedure

In this study, Simple random sampling was used, where household heads were randomly selected and questionnaires administered. This ensured that each household in the county had an equal opportunity of being selected. In this case, a lottery technique was carried out where a symbol of numerals of homes in the sub-County was put in a box, assorted and then fortunate numbers were picked one by one to form a sample of 385 households.

Primary data was gathered from the respondents by use of questionnaires that were semi-structured, Focused Group Discussions, and interviews from key informants, that involved county government ministry officers, NGOS, self-help groups, development partners, and county administration personnel), through Random Sampling with 385 being the Sample size and analyzed through distributive statistics (e.g. percentages).

3.2.6 Questionnaire

According to Kabir (2018), a questionnaire comprises a group of questions that the respondent has to answer in a particular set format as stated by the researcher. Questionnaires used in this study contained both open-ended and closed-ended questions. Questions that are closed-ended allowed the respondent to tick an answer from a given number of options. While a questionnaire that is open-ended allowed the respondent to write his/her own response (Annex3 and 4). For a questionnaire that is closed-ended, the response options would be both exclusive mutually and exhaustive.

Questions in the questionnaires sought to establish the status of the existing water harvesting technologies and the socio-economic issues that hinder the acceptance of RWHT.

3.2.7 Key Informants Interviews

As stated by Kabir (2018) key informants interview involves face-to-face conversation with the known respondents. A disadvantage arises if the respondent refuses to give information deliberately; otherwise, this method gives rich information. The person interviewing should not just write the information given by the respondent without considering the respondent's reactions to the questions like body language and expressions in order to draw conclusions easily.

In this study, the interviewees were; a county water director or his/her representative and one water engineer/water resource management officer in the Ministry of Water and Irrigation, one water engineer/water resource management officer from Coast Water Services Board, and five county meteorological officers from meteorological department. Others included five county agricultural extension officers, a county Kenya Red Cross relief officer, a county world Vision water officer, and one micro finance officer from KCB and Kenya Women Finance banks. One head teacher or his or her representative from the following primary schools shaka (Kanze),

Mikiriani (Kaloleni), Baricho (Magarini), Ngoloko (Kilifi south), Dabaso (Malindi), Bofu (Rabai) and Chasimba (Bahari) in each sub county and from the following secondary schools Bamba (Ganze), Jila (Magarini),Malindi high(Malindi),Bahari girls(Bahari),Mtwapa North (Kilifi North),Kaloleni girls (Kaloleni), Rabai secondary (Rabai). One administrative representative from Pwani University, Kilifi technical training institute and Kilifi institute of Agriculture were also interviewed. The choice of representation was biased towards water sector stakeholders.

More key informants included the managing director from Coast Water Services Board (CWSB), the managing director Coast Development Authority (C.D.A), one ASAL development officer from National Drought Management Authority (NDMA), and one humanitarian officer from Kenya Freedom from Hunger Council (KFHC).

3.2.8 Focus Group Discussion (FGD)

A FGD according to Kabir (2018) is field method, which is in-depth and it involves a small group of six to twelve homogeneous persons that discusses topics on the research agenda. FGD was used to encourage respondents to disclose various fundamental reasons, sentiments, and attitudes ('how' and 'why'), for their conduct. This was done by use of a group interview process that was semi-structured. The discussion was carried out in a conducive environment where participants were free to express themselves without any personal fears.

One FGD was conducted in the county to gather information on the implementation of RWH and storage technologies in the County. FGD also sought to know if there were any efforts made by local/national partners, including private sector, Companies, NGOs, and Research Institutions or Governmental agencies to promote RWH in various locations within the county.

Participants included two representatives from women groups, youth groups, community leaders, self-help groups; two county civil societies involved in rainwater harvesting activities, two technical staff form Ministry of Water and Irrigation, and related parastatals, and seven county agricultural extension officers, one representative from NGOs, Faith Organizations, KCB and Kenya Women Finance banks, County government and county administration. One water engineer/officer from Coast Water Services Board (CWSB), Coast Development Authority (C.D.A), National Drought Management Authority (NDMA), and one meteorologist from Meteorological Department (KMD) and one officer from Kenya Freedom from Hunger Council (KFHC) .The choice of representation was biased towards water sector stakeholders.

3.3. Data quality Control

Data quality Control was done by filling in missing data in the rainfall and temperature data sets to ensure that data had no gaps. Data quality Control was also done through carrying out Homogeneity tests on rainfall and temperature data to ensure consistency of the data sets. These methodologies are described in the sub-sections that follow.

3.3.1. Estimating Missing Data using the K-Nearest Neighbor Method (K-NNI)

The filling of gaps for missing data was carried out using the K-Nearest Neighbour Imputation identified as the most suitable method to ensure continuity. The K-nearest neighbor method is where the mean of the previous observation and later after the missing gap for single observation gaps in the monthly data was used. The nearest neighbor method is reliable and practical to treat missing data through the application of KNN imputation by Lee and Kang (2015) in equation 1. The average of k is calculated using the weighted mean estimation in equation 2.

$$d(x_a, x_b) = \sqrt{\sum_{j=i}^{m} (x_{aj} - x_{bj})^2} \qquad \text{...} \; 1$$

In the equation $d(x_a, x_b)$ denotes the distance between the target observation, x_a and observation x_b , x_{aj} is the value of the variable -j on the target observation x_a .J= 1,2,3,…m and x_{bj} is value of the variable -j on the other observation x_b. J= 1, 2, 3,….m

$$^{\wedge}x_j = \frac{1}{W} \sum_{k=1}^{K} w_k v_{kj} \qquad \text{...} 2$$

Where jv_{kj} are the values of the variable-j at observation k, k=1, 2, ..., K; W= $\sum_{k=i}^{n} w_{k,}$, w_k are the nearest observation weights of k, which is formulated as follows: 2 $w_k = \frac{1}{d(x, v_k)^2}$.

3.3.2 Homogeneity Test

Data quality Control was also done by conducting a Homogeneity Test**.** This entails a process of testing of homogeneity of data or data consistency thus ensuring that the used data is as close as possible to what would have been observed if there were no errors (Andang'o, et al. 2016). Detecting discontinuity in the data arising from influences that are non-natural for instance, instrument changes, changing of station location, urbanization, observational errors and other subjective errors is one of the most important processes of controlling data quality.

This research made use of the single mass curve technique to ascertain homogeneity of both Temperature (minimum and maximum) and rainfall data for Malindi station for the period of study. The mass curve involved plotting of cumulative values of rainfall and temperature against time. A result out of a straight line showed that data used was homogenous whereas heterogeneity was shown by deviations of some of the plots from the straight line that were statistically significant (Muthama, et al., 2014). The coefficient of determination values (R^2 values) were determined by assuming a linear trend line. The R^2 significance is any number ranging from 0 to1 that shows how nearly the expected values on the trend line relates with the actual data. Once the R^2 value is at or near 1, then the trend line is more consistent according to Muthama, et al. (2014).

3.4 Data analysis Methods

The following methodologies were used in data analysis as discussed in the subsequent sub- headings.

3.4.1 Annual Cycles of Rainfall

This examined the seasonal pattern in rainfall and temperatures in Kilifi County. It involved time series of monthly average rainfall. Threshold of 87 mm monthly from a study done by Gateri (2016) was adopted in order to determine the amount of rainfall that leads to sufficient RWH since this value is appropriate for RWH at the coast because over the coastal region, the type of precipitation received is mainly rain showers as suggested by Gateri et al. (2016).

3.4.2 Trend and Variability in the Rainfall and Temperature in Kilifi County

This research involved trend analysis using Mann Kendall Trend Test (the M-K test), while Variability analysis was achieved by determining coefficient of variation (CV) in both temperature and rainfall data for the County. These methods are discussed below.

3.4.2.1 Analysis of trends in the Rainfall and Temperature of Kilifi County

The Mann-Kendall (M-K) test was carried out to test for presence or absence of the trends in both rainfall and temperature. Time series analysis was done to determine the general trend in rainfall and temperature data of the study county. Analysis of trends involved the seasonal Mann-Kendall test that was done at a confidence level of 95%.

As stated by Ahmad et al. (2015), M-K test is a non-parametric test that works for all distributions thus the data does not need to conform to the normality assumption, and should lack correlation. According to Pohlert (2018), M-K test is done to determine trend in series of climate, hydrological and environmental data that is monotonic.

In this study, the null hypothesis (Ho), was that, the data are not identically dispersed thus; there is no monotonic trend in the series, while the alternative hypothesis (Ha), is that the data follow a monotonic trend and this trend can be positive or negative.

According to Mondal et al. (2012) and Timo et al., (2002a), the Mann-Kendall test statistic(S), and standardized test statistics (Z) is calculated according to the equations (3, 4, 5 and 6) below. If the number of data values is less than 10, equation (3, 4, 5 and 6) below is used where the number of annual values in the studied data series is denoted by n. Missing values are allowed and n can thus be smaller than the number of years in the studied time series. Thus, the formula for Mann-Kendall test statistic (S) is as shown below;

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(Xj - Xi) \quad \text{--} \quad (3)$$

Where S is the Mann-Kendall test statistic, n is the length of time series ,and xj and xi are the time series observations in chronological order, or the annual values in years j and i, j>i, respectively, and

$$sgn(X_j - X_i) = \{+1\ if\ (X_j - X_i) > 0\ 0\ if(X_j - X_i) = 0\ -1\ if\ (X_j - X_i) < 0 \quad \text{---------} (4)$$

If the number of data values (n) is 10 or more, then the normal approximation test is used where the variance of S is computed first by the following equation, which takes into account that ties may be present:

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

Here n is the length of time series, q is the number of tied values, and tp is the number of ties for the pth value. The presence of a statistically significant trend is evaluated using the Z value. The values of S and VAR(S) are used to compute the test statistic Z as follows:

$$Z = \{\frac{S-1}{\sqrt{VAR(S)}}\ if\ S > 0\ ,\quad 0\ if\ S = 0\ and\ \frac{S+1}{\sqrt{VAR(S)}} if\ S < 0 \text{--------------------} (6)$$

Positive Z values indicate an increasing trend in the hydrologic time series; negative Z values indicate a decreasing trend. If $|Z| > Z\ 1-\alpha/2$, (H0) is rejected implying that a statistical significant trend exists in the hydrologic time series. Where $Z1\text{-}\alpha/2$ is obtained from the standard normal cumulative distribution tables.

3.4.2.2 Analysis of Rainfall and Temperature Variability

Determination of variability in the temperature and rainfall was done by calculating the Coefficient of Variation (CV) for the monthly, seasonal and annual rainfall and temperature for Kilifi County. Statistics like averages, mean, and standard deviations were also calculated and results presented in tables and figures and discussed accordingly.

CV is the ratio of the standard deviation to the mean. Thus, was determined by dividing the standard deviation for each year and the mean annual rainfall or temperature then multiplied by 100 to give the answer in percentage. This involved determination of the mean values and standard deviation from the annual or monthly rainfall/Temperature values and there after getting the ratio between them. This ratio gives the value of the coefficient of variation.

The equation used for the determination of the coefficient of variation (CV) is given as equation 8.

$CV = \delta / \mu \times 100$ -- (8)

Where: CV is the coefficient of variation, δ is the standard deviation, and μ is the mean of the variables being analyzed.

CV is a statistic for relating the magnitude of deviation from one data series to another. It is expressed as a percentage and the greater the coefficient of variation, the greater the dispersion around the mean, and the lower the CV the more precise the estimate is as stated by Odhiambo (2016).

Mwanthi (2015) stated that it is useful in understanding the nature of the temporal patterns of rainfall for a given season since higher coefficients above 60% signify high variability while lower values (below 60%) indicate low variability. According to Kattel (2013), a CV that is greater than 60 percent is an indicator of large rainfall variability and vice visa.

For temperature analysis a CV > that is greater than indicates high variability while CV < 1 indicates low variability in both annul maximum mean and annual minimum mean temperature for the study climatic period (Ouma, 2015).

3.4.3. Evaluation of the adoption of RWH technologies

To evaluate the adoption of RWH technologies in the county, quantitative and qualitative data was obtained from semi-structured questionnaires and analyzed using percentages and the results presented in tables and figures.

3.4.4. Determination of socio-economic factors that hinders the adoption of rainwater harvesting technologies in the County

To establish the socio-economic issues, that hinder the adoption of RWHTs in the county, quantitative and qualitative data was obtained from semi-structured questionnaires and analyzed using percentages and the results presented in tables and figures.

3.4.5. Determination of the significance of socio-economic factors that hinders the adoption of rainwater harvesting technologies in the County

This was done by use of Logistic regression model/Logit model to predict the degree of influence of each factor on the adoption of RWHT. Whereby all the socio-economic factors were treated as independent variables to the adoption of RWH technologies as a dependent variable. Logistic Regression according to Rodr´ıguez (2007) is a binomial regression model that is used to associate a vector of random variables to a binomial random variable. It is used to model the probability of a certain existing class or event. Logistic regression was used to analyze the log of odds of an event.

In this case, the Odds Ratios (log odds) that stands for the constant influence of a predictor variable X, on the likelihood that one outcome will occur was used. It detects the association between a binary outcome variable and a group of predictor variables. It models the Logit-transformed likelihood as a linear relationship with the predictor variables (Fidell et al., 2013)

Fidell et al., (2013) reported that if the correlation coefficients for independent variables are less than 0.90 then the assumption is true. This type of Logit model is given by equation 9.

$$logit(p) = log\left(\frac{p(y=1)}{1-(p=1)}\right) = \beta_0 + \beta_1 - x_n + \beta_2 + x_n + -\beta_p - x_{in} \text{-------- -----} (9)$$

where Logit (p) is the Logit-transformed probability and x_n... x_{in} is a set of predictor variables that estimates parameter values for β_0, β_1. . . β_p.

The Logit model applied in this study used the statistics of Hosmer and Lemeshow and was seen to be within the ranges. The general precision of the model was 80.5%, Chi-square of 31.056, p-value of 0.751 that is larger than .000, d.f of 8, Nagelkerke's R^2 of .702 showing an important difference between the various socio-economic issues and the level of implementation of RWHT

The outcomes of this analysis were useful for decision makers on where to put the first priory when it comes to investment to enhance the adoption of rainwater harvesting technologies since resources are always scarce.

3.4.6 Piloting

A pilot survey was carried out for sixty households in December 2017 in Malindi sub-county to pre- test the contents of the two study questionnaires (individual and institutional questionnaires) before main survey.

3.4.7 Focused Group Discussions (FGDs)

The data collected from FGDs and Key Informants was presented inform of a textual description/explanation of the situation.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the results of this study in accordance with the specific objectives.

4. 1 Data Quality Control

Results for questionnaire return rate, homogeneity tests, and estimation of missing data within the data sets for this study are presented in the subsections that follow.

4.1.1 Return Rate of Questionnaires

A Total of 2,426 out of 2,695 questionnaires given out in all the seven sub-counties were filled and brought back. This represented 90% return rate which was adequate for the analysis as recommended by (Techo 2016) and (Ebrahim 2018).

4.1.2 Estimation of Missing Data

The missing values were estimated using the K-Nearest Neighbour Imputation and it was observed that the missing climate data percentage was less than 11% for both rainfall and temperature (maximum and minimum) for the entire study period.

4.1.3 Homogeneity Test for Rainfall and Temperature data

The single mass curves for both rainfall temperature (maximum and minimum) are represented in figures 6, 7 and 8.

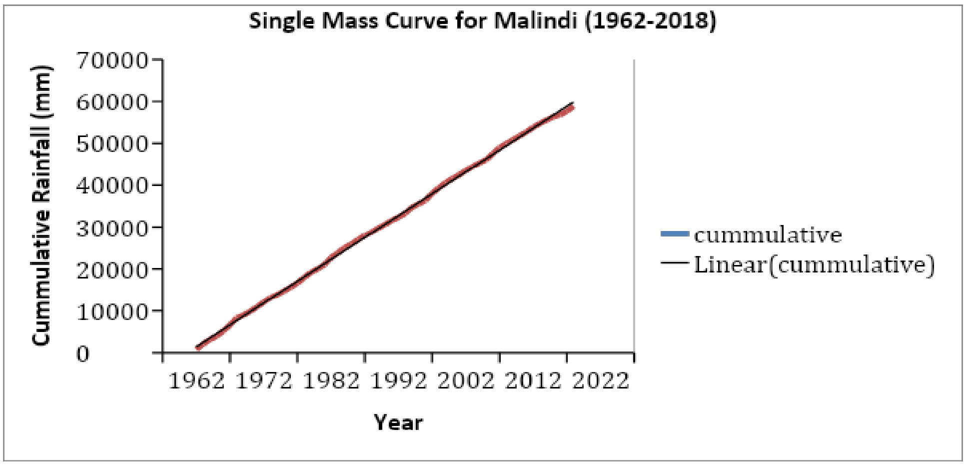

Figure 6: Single mass curve for Rainfall data

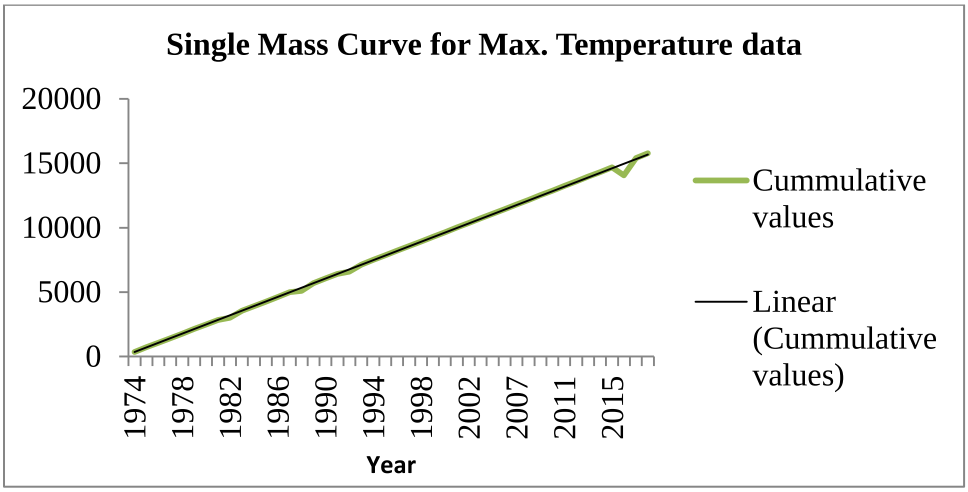

Figure 7: Single mass curve for Maximum Temperature data

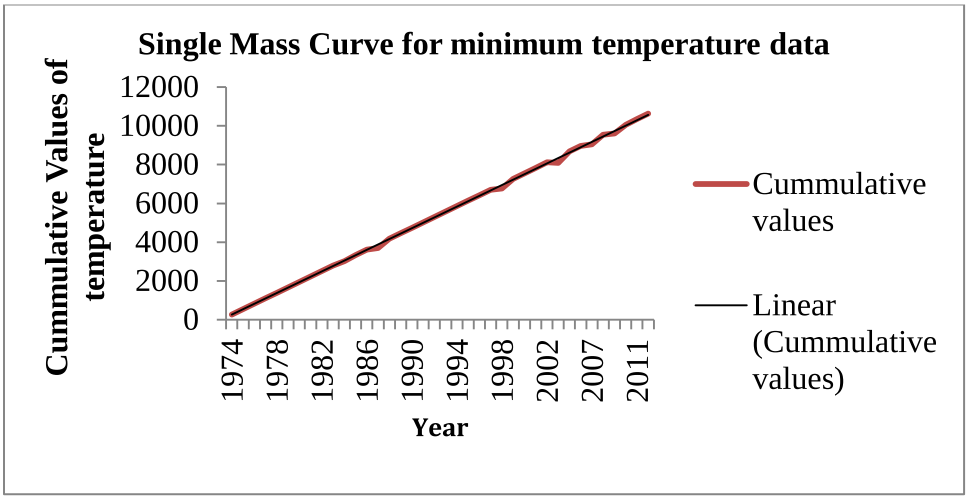

Figure 8: Single mass curve for minimum Temperature data

Figures 6, 7, and 8 give straight lines or plots whose coefficient of determinant was a unit. This indicates that the data used in this study was homogeneous and therefore of good quality and hence reliable and suitable for climatological analysis. However, the homogeneity test line for the rainfall data shows some observations that are spread out, some are above the mean while others are not. This could be due to instrumental or observation errors.

Muthama et al. (2012) and Andang'o et al. (2016) when they used monthly precipitation totals covering 12 climatic zones of Kenya to investigate if the monthly rainfall data were homogenous also reported homogeneity in both rainfall and temperature data for Malindi station.

4.2.1 Monthly/ seasonal rainfall in Kilifi County

Malindi Agro-meteorological monthly rainfall data were plotted to determine the annual rainfall pattern or cycle within Kilifi County for planning and implementation of rainwater harvesting in the county as shown in figures 9;

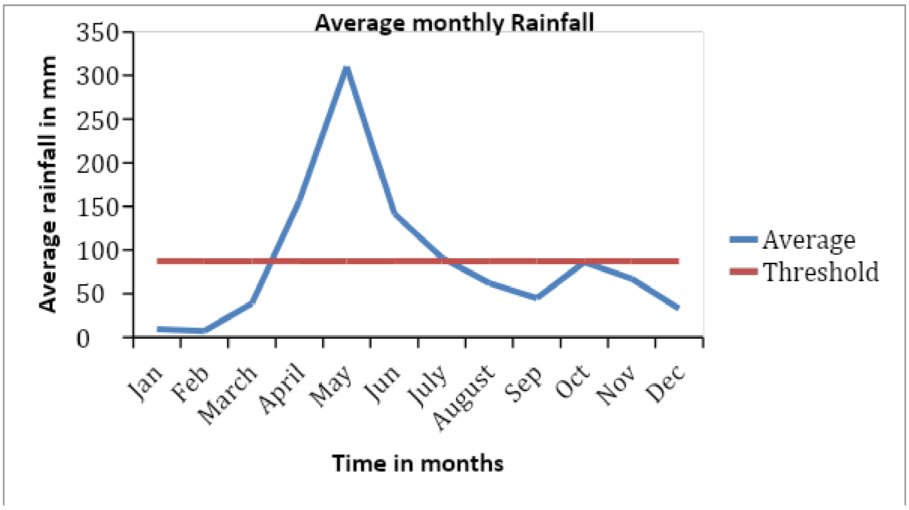

Figure 9: The Bi modal Rainfall (AMJ and OND) for Malindi Meteorological Station.

The results in Figure 9 above shows that Kilifi County receives a bi-modal type of rainfall. This county has its extensive rains in the months of AMJ, while their short rains come in the months of OND. The peak rainfall is in the months of May (about 300 mm) and October (about 100 mm).

The threshold rainfall (the annual average rainfall) for the rainwater harvesting for Kilifi County as adopted from research done by Giteri 2016 is 87mm as shown in figure 9. Water harvesting is encouraged during these two rainy seasons AMJ and OND, since during these seasons, the harvestable volume of water is sufficient (usually at the threshold and above) especially when harvested by rooftop water technologies and other surface runoff water harvesting technologies.

The above outcomes are in agreement with Gateri, et al. (2016) who concluded that AMJ and OND rainfall seasons for Kilifi County, experiences harvestable volume of water that is abundant to fulfill the least water demand levels of the individuals in the county during the desiccated seasons.

The above results are also reported in the KILIFI CIDP (2018) which reports that usually from July to September, the county would experience a dry season but the prevailing south-east trade winds that collects heat and humidity from a warmer sea in this season causes some thunderstorms, especially in July. There is usually another normal dry season, in which showers are rare from December to March, especially in January and February, which are the driest months, and in which it almost never rains. In October and November there would be the normal second rainy season, or the "short rains season", which is more evident in other areas of Kenya, but it's not evident in Kilifi county, although there is some variability between the years, so in some years the rains come in plenty, like in October and November 2009, when there were floods. While in some years the rains fails completely.

Therefore, communities in Kilifi County should be encouraged to adopt rainwater harvesting in order to store the little rainwater available during long and short rains instead of losing it through surface runoff. This water can be later used during times of droughts hence help households in the County to adapt well to climate change events like floods and droughts.

4.2.2 Monthly/seasonal temperature in Kilifi County

Temperatures are usually higher in the months of January, February, March, April, October, November, and December. The highest temperatures are normally experienced during the month of March while the coolest months are July and August. The results are as shown below (figure 10).

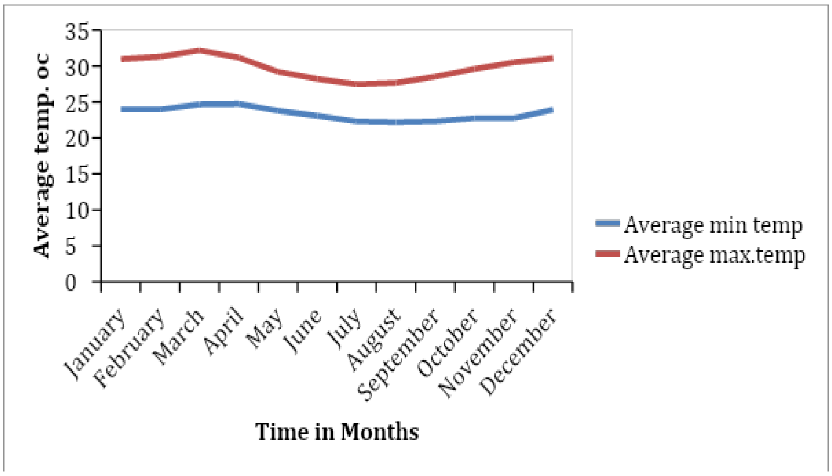

Figure 10: Plot of mean monthly Rainfall with Minimum and Maximum temperature.

4.3 Results on Trend and Variability of Rainfall and Temperature in Kilifi County

Mann-Kendall (M-K) Test was done to test for trend while coefficient of variation was carried out to test for variability in rainfall in the county.

4.3.1.1 Trend Analysis of Rainfall

The results are shown in table 1, figure 11 and 12.

Table 1: Rainfall Mann-Kendall Trend Test

Variable	observation	missing data	Min	Max	Mean	STD	Kendall's tau	S	Var(S)	p-value	alpha
Annual Mean Rainfall	52	0	19	177	86	26	-0.09	-120	1605	0.35	0.05

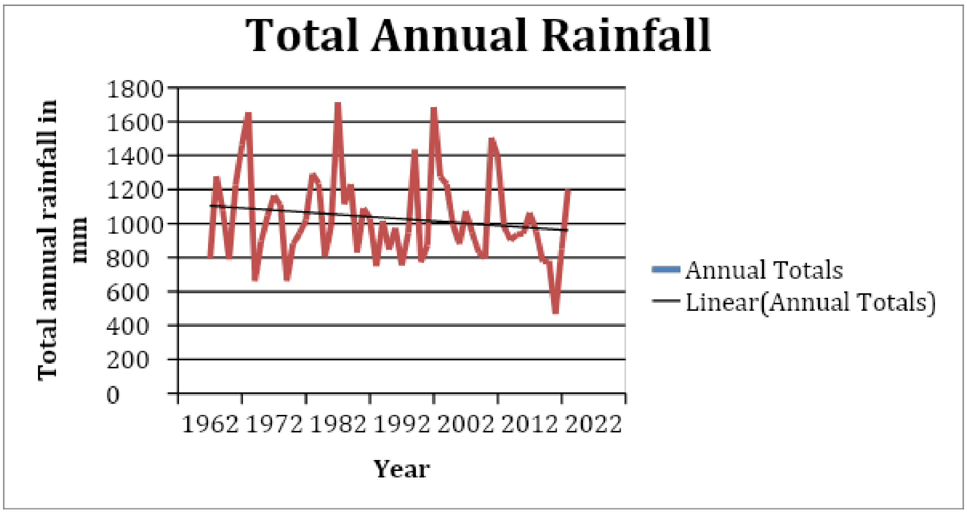

Figure 11: Time series of total annual mean rainfall over Kilifi County.

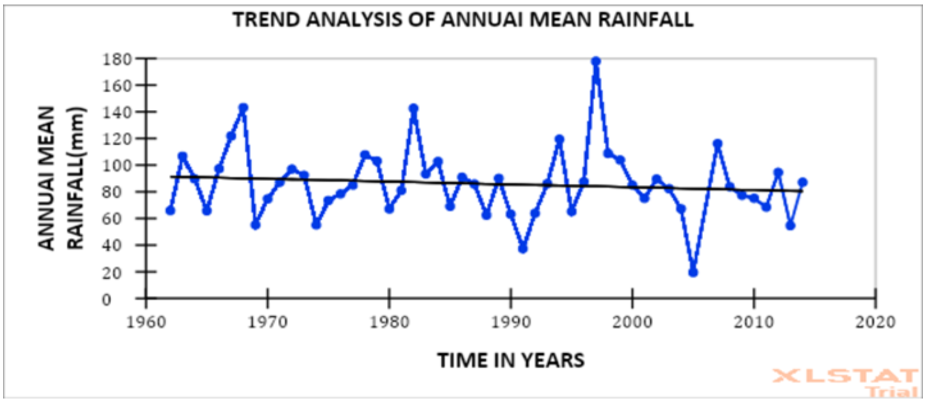

Figure 12: Time series of the annual mean rainfall over Kilifi County.

From Table1 and figure 12, the P-value is 0.35 for rainfall data, and since the P-value is larger than the significance level alpha (0.05) then, the null hypothesis (HO) should be accepted as the alternative (Ha) one rejected. Thus, there is no seasonal trend in the rainfall data. However, since the tau test statistic (from table 1) is a negative value (-0.09) then it shows a negative trend.

Furthermore, the trend line from figure 11 and 12 shows a slightly decreasing trend but statistically insignificant. From figure 12, it is observed that between the periods of 1962 to 2018 the dry years are1964, 1969, 1972, 1980-81, 1991 and 2005, the driest being 2005.While the wet years were 1969, 1982, 1997.

The results in figure 11 shows the years with high annual rainfall being, 1968, 1982, 1994, 1997, 2006 and 2018.The years with the highest annual total rainfall are 1982 followed by1997 and 1968. The years with low annual total include; 1969, 1974, 1980, 1984, 1988, 1990, 1992, 1995, 1996, 2000, 2002-2004 and 2014-2016. The year with lowest annual mean rainfall being 2016.The linear trend line from Figure14 shows a slightly decreasing trend in the total yearly rainfall in Kilifi County.

To adapt to the decreasing annual total rainfall RWH should be encouraged or enhanced in the County. Communities in ASALs should be supported to store enough water to cope with insecurity of this resource and any environmental changes as stated by Lindoso (2018).

These results are in agreement with study done in Kilifi county by Gateri et al., (2016), who stated a similar change in the long rains and short rains over time that are very likely due to climate change, although most of these rainfall trends are not statistically significant.

4.3.1.2 Trend Analysis of Temperature

The results are shown in table 2 and figures 13.

Table 2: Trend Test for Temperature by Mann-Kendall

Variable	**observations**	**missing data**	**Min**	**Max**	**Mean**	**STD**	**Kendall's tau**	**S**	**Var(S)**	**p-value**	**alpha**
Annual Mean Temp	39	0	29	30	396	82	0.30	219	6831	0.008	0.05

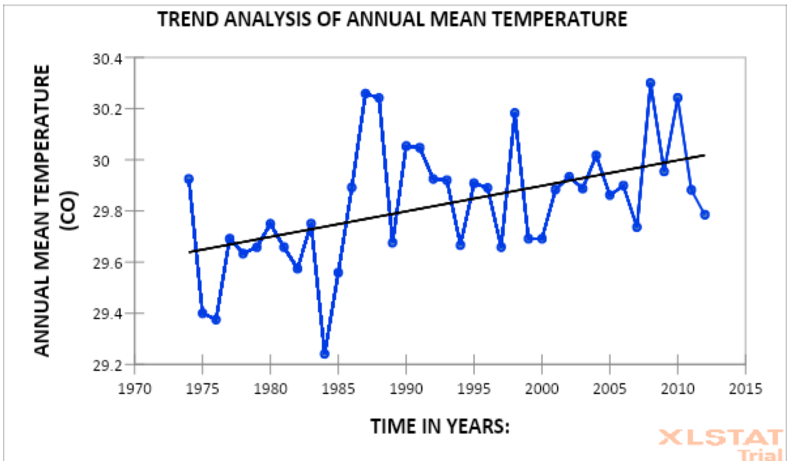

Figure 13: Time series of annual mean temperature.

Table 2 shows that the computed p-value (0.008) is less than the significance level (0.05) indicating that the null hypothesis (H0) of non-significance trend should be rejected. Thus, there is a significant increasing trend in the mean temperature of

Kilifi County.

Table 2 shows tau test statistic that is positive (0.30), which thus demonstrates a rising or positive trend in the annual mean temperature and the trend line from figure 13 slopes upward indicating an increasing trend. County CIDP 2018 reports that this increase in annual mean temperatures is sometimes associated with increase in annual mean rainfall that may lead to high surface runoff, which causes flash floods followed by biting droughts or famine in Kilifi County. Therefore, for the community to cope with these climatic extreme events, adoption of RWH should be advocated for in the county.

The trend line slopes upward (increasing), indicating an increasing trend in the annual maximum temperatures in Kilifi county.

Research done by Tuva (2016) is in agreement with this results since he concluded from his time series analysis for inter-annual variation of temperatures in the county that the county experiences an increasing trend in the annual maximum and minimum temperatures hence this study area is warming.

Figures 16 and 17 present time series plots for annual means of maximum and minimum temperature over Kilifi County.

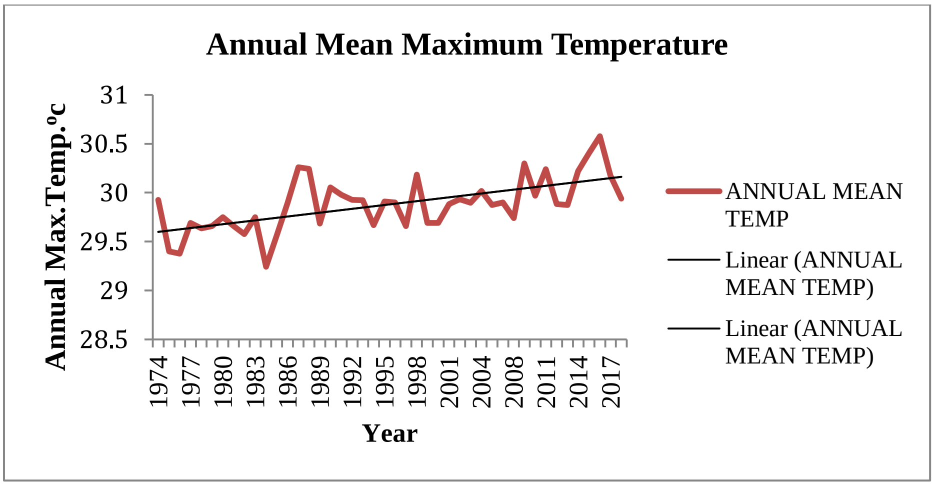

Figure 14: A line graph showing Max. Annual mean Temperature for Kilifi County

Figure 14, indicates that years with high maximum annual mean temperature includes; year 1987, 1988, 1990, 1998, 2004, 2009, 2011, and 2014-17.The year with the highest maximum temperature is 2016 (30.58^{o}c). These hot temperatures are always associated with high rainfall as reported by the CIDP 2018. The years with the lowest annual maximum mean temperature is 1975 and 1984(29.2^{o}c).

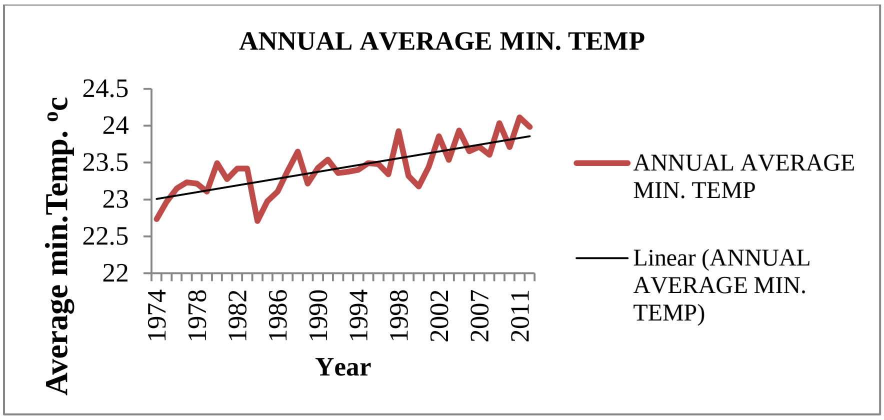

Figure 15: A line graph showing min. annual mean Temperature for Kilifi County.

From figure 15, years with low minimum annual mean temperature includes; year 1974, 1975, and 1984.The year with the lowest minimum mean temperature is 1984.The years with high minimum annual mean temperature is 1976, 1977, 1980,1981,1982, and 1986-2017. The trend line slopes upward (increasing), this indicates an increasing trend in the annual minimum mean temperatures in Kilifi county.

From figure 15 above the R^2, value is close to one meaning that there is increasing trend in minimum temperatures. The linear trend line i.e. changes per unit time period (in this case a year) shows an upward increase in both minimum annual mean temperatures.

4.3.2. Analysis of Variability of rainfall and Temperature in Kilifi County

Results were discussed in the sub-sections below.

4.3.2.1 Inter-annual variability of rainfall in Kilifi County

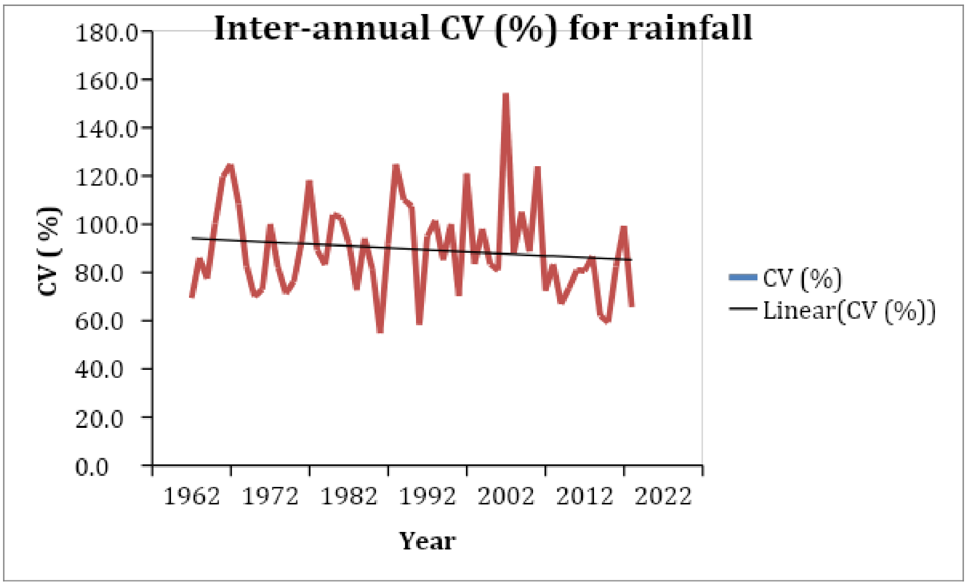

Figure 16: Time series of Inter-annual variability of rainfall in Kilifi County.

Figure 16 show high values of variability in the inter-annual rainfall. The variability in these regions reach CV(%) values that are greater than 60%.all the years had high CV(%) apart from 2015. The highest CV (%) being for years of 2002 (154.2%) followed by 1967 (124.8%) and 1988 (124.8%). the years with the lowest CV (%) is1986 (54.9%) followed by 1991(58.5%).

Variability is considered high when CV is above 60% and low when it is below 60% (Mwanthi, 2015). He noted that CV is generally higher in the eastern and coastal regions of East Africa, which are predominantly arid and semi-arid lands (ASALs).

4.3.2.2 Inter-annual Variability of mean maximum and mean minimum Temperatures in Kilifi County

This involved calculation of annual mean maximum temperature, annual mean minimum temperatures, the computation of their respective CV for Kilifi County.

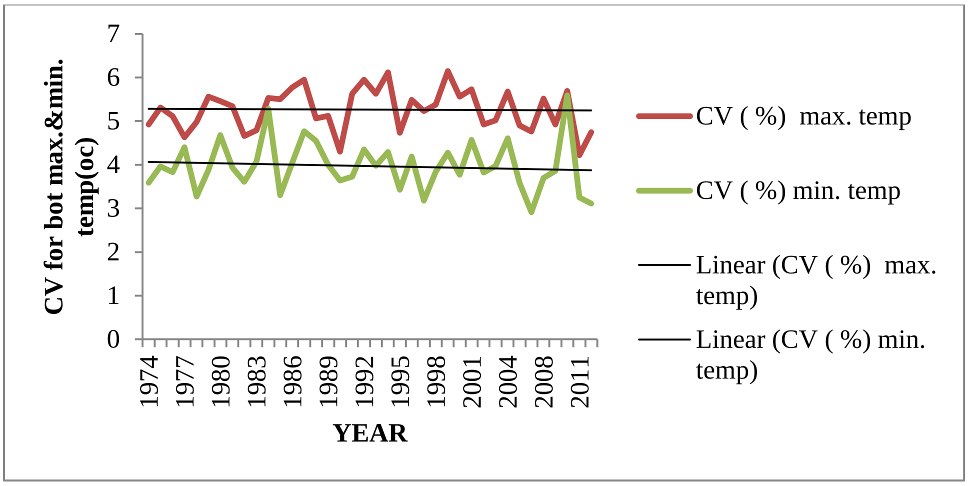

Figure 17: Showing percentage Coefficient of Variation (CV) for both min. & max. Temperatures in Kilifi County.

From figure 17 above, variations in the percentage CV values shows the significance of a given deviation from the mean. CV > 1 indicates high variability while CV < 1 indicates low variability in both annul maximum mean and annual minimum mean temperature for the study Ouma, (2015). For this study, results from table 4 and figure 18 show very high values (CV > 1) of CV for both annual maximum and annual minimum mean temperatures for the entire study period. The years with the highest annual maximum mean temperature are 1887, 1992, 1994, and 1999. While the years with the lowest annual minimum mean temperature are 1978, 1985, 1997, and 2007.

From figure17, it is observed that years 1979, 1987, 1988, 1992, 1994, 1999, 2004, and 2010 were hot years. These hot temperatures are associated with high rainfall. While the cold years are, 1978, 1982, 1985, 1995, 1997, 2007 and 2011.These years are usually associated with little or no rainfall especially for seasonal annual mean temperatures. The trend in Figure 18 shows a slight decrease in the variability of minimum annual mean temperatures unlike in annual maximum mean temperature where the linear trend line is constant (UNICEF, 2016).

Mcsweeney et al. (2007) reported that mean yearly temperature in Kenya has gone up by 1.0˚C ever since 1960 at an average rate of 0.21˚C per ten years supporting the above observations. This rising in temperature has been more rapid in MAM (0.29˚C per decade) and slowest in JJAS (0.19˚C per decade).

It is noted in report by UNICEF, 2016 for Kilifi County that day-to-day temperature observations indicate significant upward trends in the frequency of hot days and much larger upward trends in the occurrence of hot nights.

Overall number of ‘hot’ days per year in Kenya has risen up by 57% (15.6% additional days) amid 1960 and 2003. The rate of increase is seen most strongly in MAM when the overall number of hot MAM days has risen by 5.8 days per month (18.8% of an additional MAM days) over this period. The overall number of ‘hot’ nights per year has risen by 113 (31% of additional nights) amid 1960 and 2003.The increasing rate is more strong in SON when the overall number of hot SON nights has risen by 12 days per month (38.2% of an additional SON nights) over this period. Occurrence of cold days has declined meaningfully in yearly and SON readings. Incidences of cold nights has however, reduced more swiftly and meaningfully in all seasons. Overall number of ‘cold ‘days per year has declined by 16 (4.4% of days) amid 1960 and 2003. This rate of reduction is hastier in SON when the overall number of cold SON days has lessened by 1.8 days per month (5.7% of SON days) over this period. Overall number of ‘cold’ nights per year has declined by 42 (11.5% of days) (UNICEF, 2016).

4.3.2.3 Inter-annual Seasonal variability of rainfall in Kilifi County

Table 3 presents the CV of seasonal rainfall in Kilifi County.

Table 3: Inter-annual Seasonal variability of rainfall in Kilifi County

SEASON	AMJ	OND
Monthly Mean total	606.32	179.12
STDEV.P	186.24	126.96
CV (%)	31	72

This table shows that rainfall in the OND season depicts the highest CV (72%) compared to that of AMJ (31%). According to (Shisanya et al., 2013) a CV > 60 percentage is a pointer of large rainfall inconsistency.

These results also agree with results from Makokha et al., (2011) who observed that MAM and OND inter-yearly rainfall unpredictability in Tharaka district showed that the OND disparity from the mean is larger than the MAM.

Therefore, communities in Kilifi County should be encouraged to harvest rainwater especially in OND season and store it for later use. This would help the societies in the County to adjust well to the impacts of climate change induced events like floods and droughts.

This results agrees with a research done by Shisanya et al., (2013) who noted that rainfall that is above normal is usually experienced during OND season than in MAM rainfall season especially in ASALs of Kenya and are linked to El Nino rains.

Shisanya et al., (2013) also states that the seasonal variability of rainfall strongly affects livelihoods in a region. For instance, periodic rainfall in Kilifi County fluctuates a lot around the mean, with cases of persistent succeeding beneath average rainfall that risk peoples' livelihood and leaves them susceptible to malnutrition and famine due death of livestock and crops failure, encouraging shipment of relief food in the county. Therefore, for the community and the governments to reduce the risk to these climatic extreme events, RWH should be encouraged in Kilifi County.

Any rainfall that is beyond a threshold of 87mm in both seasons leads to plenty of water, most of which causes flooding and go to waste because of inadequate floodwater harvesting technologies (Gateri, 2016). Therefore, adopting rainwater harvesting and storage methods can reduce wastage of water during rainy season and this water will be available for livestock and domestic use during dry periods.

4.3.2.4 Inter-annual periodic Variability of both maximum and minimum Temperatures in Kilifi County

Table 4 presents the inter-annual variability of both maximum and minimum temperature for Kilifi County.

Table 4: Inter-annual Variability of both maximum and minimum Temperatures in Kilifi County

TEMP	MAXIMUM		MINIMUM	
SEASON	**AMJ**	**OND**	**AMJ**	**OND**
MEAN TEMP	29.90	30.47	23.90	23.47
STDVEV	0.43	0.40	0.42	0.36
% CV	1.44	1.31	1.76	1.53

Table 4 shows high CV (CV (%) >1) in both AMJ and OND annual mean maximum and minimum temperatures. Result from table 5 also shows a slightly higher variability in AMJ annual mean maximum and minimum temperatures than OND for Kilifi County.

According to UNCEF (2016) climate is changing in Kilifi County and from 1981, the first wet season has been associated with a very high (2.0ºC) increase in mean temperature and this has led to reduction in crop cycle, a significant increase in heat stress days, and a strong trend for decrease in precipitation (on the order of 20%). The increased temperatures and decreased rainfall increases drought risk during first wet season. The second wet season is associated with low increase in temperature (~0.5oC), with little change in precipitation.

4.3.2.5 Intra-annual variability of rainfall in Kilifi County

Table 5 represents intra-annual variability of rainfall in Kilifi County

Table 5: Intra-annual variability of rainfall in Kilifi County

Months	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Octo	Nov	Dec
Mean	8.1	6.7	38.5	153.9	313.8	138.6	88.9	60.4	44.0	83.5	65.8	29.8
STDEV.P	18.0	21.6	46.5	94.6	127.4	75.8	50.4	46.8	41.5	87.8	56.7	32.0
CV(%)	45.3	30.8	82.8	162.6	246.4	182.8	176.3	129.1	106.0	95.1	116.1	93.1

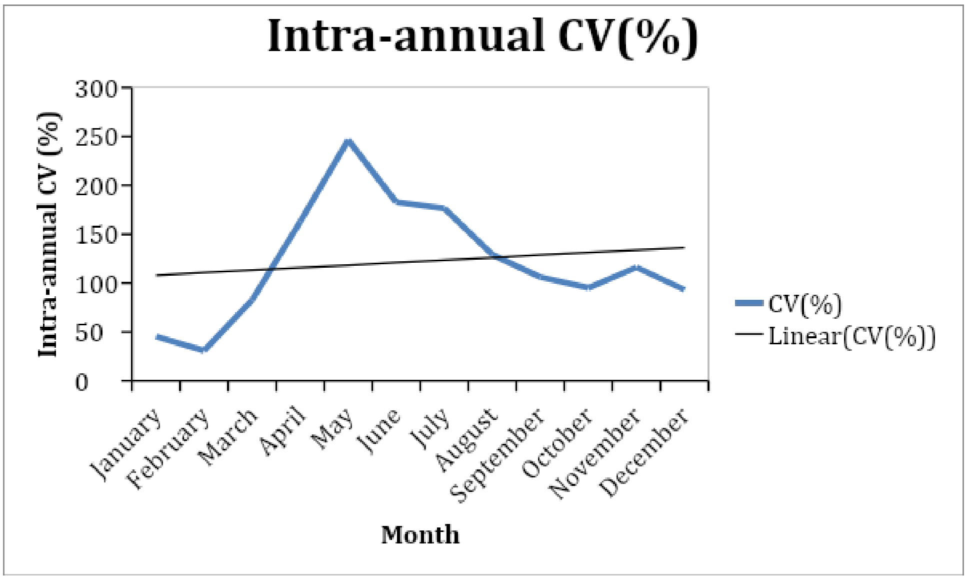

Figure 18: Bar graph showing monthly mean, STDEV.P and the percentage CV for rainfall in Kilifi County.

From the results in table 5 and figure18, indicates that all months have high intra-annual CV (more than 60%) in annual rainfall apart from months of January (45.3%) and February (30.8%) respectively. The months with the high CV (%) are the months of April, May June and July. The month with the highest CV (percentage) is May (246.4%) followed by June (182.8%) and July (176.3%).

The months with low percentage CV include; May (41%), June (55%), July (57%) and April (62%) respectively. The month with the lowest CV is the month of May.

From Table 5 and figure 18**,** it is observed that between the periods of 1962 to 2018, the month with the highest variability is February followed by January. While the months with the lowest variability in the mean monthly rainfall, is May followed by June.

The above results are supported by Kenya Meteorological report of May 2019, which states that, the county recorded average monthly rainfall (May) of 4.8mm which was below 80% long term mean at that time of the year. For instance Chakama in Magharini received 10.4mm while Mwarakaya in Kilifi sub-county received 10.4mm.

However, Mcsweeney et al. (2007) states that, amount of recorded rainfall in entire Kenya from 1960 has shown statistical trend although this trend is insignificant. Although, most climatic models predicts an increase in 1-day (up to 25mm) and 5-day (3 to 32mm) rainfall annual maxima by the 2090s.

Therefore, communities in Kilifi County should be encouraged to implement rainwater harvesting to enable them store the little rainwater available during long and short rains instead of losing it through surface runoff. This water can be later used during times of droughts hence help people in the County to adjust well to climate change events like floods and droughts.

4.4 Level of adoption of existing RWHT in Kilifi County

This was determined through the following steps below;

4.4.1 Water harvesting techniques practiced by households in Kilifi County

Household heads were asked to point out the water harvesting techniques practiced by the households and the outcomes were tabulated in table 6.

Table 6: Table showing RWHT mentioned by household heads.

RWHT mentioned by households respondents in Kilifi county	Total/Number of adopted RWHT in Kilifi county	Percentage (%)
Rooftop water tanks	12000	92.6
Water pans/ponds	450	3.5
Runoff terraces	400	3.0
Negarims/ Zai pits	90	0.7
Dams, Sand/ sub-surface dams/rock dams/earthen dams	20	0.2
Total	12960	100

Table 6 shows that majority (92.6%) of Households in Kilifi County have implemented rooftop RWHT, followed by water pans/ponds (3.5%). Majority adopted water tanks since tanks are seen as the best storage facilities for high quality water especially for drinking, relatively affordable and many NGOs, banks (KCB & Equity) county government have been supporting them in buying them.

Gateri et al., (2016) used rooftops to calculate harvestable volume of water, in determining the potential of RWH at the coast, and she recommended that if rooftop water harvesting is well adopted it could assist in meeting the minimum water requirement during the dry seasons at the coastal zone of Kenya.

In addition, studies by Makau (2014) and Kimani, et al. (2015) revealed that, the wide spread use of rooftop tanks by most households in most rural area is related to the fact that most organizations and Non- governmental organization (NGOs) supports them to buy them. Furthermore, rooftop water tanks are easy to implement by many households in rural areas and hence their wider use.

Many NGOs have been supporting many Rooftop water tank use in the rural areas of Kenya since they are seen as the best storage facilities for high quality water especially for drinking (Nelly, 2010).

The second widely adopted WHT is the use of water pans/ponds (3.5%). This was attributed to the fact that water pans/ponds are somehow easy to construct and is suitable to the natural landscape of the area especially in Ganze and Magharini sub counties. In addition, pans/ponds provide enough water for small-scale farming and livestock or domestic use in the dry season. Many Similar researches reported that water pans/ponds store water for a bigger number of people, since there is no restriction of water withdrawal to the people involved in the pans development.

Despite the low adoption of water pans/ponds, Ahmed et al., (2013) stated that the potential of water pans/ponds to store a larger amount of water is very high thus making it suitable for storing water that can be used by thousands of people, animals, and irrigating vegetable gardens, and tree nurseries.

Implementation of other technologies like terracing (3%), Negarims/Zaipits (0.7%) and Dams, Sand / sub-surface dams/rock dams, /earthen dams (0.2%) is low in this area. This is due to the technical expertise needed and the high construction cost. Dams, Sand/ sub-surface dams/rock dams are the least adopted technology because of their complexity in their construction, which is further worsened by lack of enough technical expertise, within the community .

Black, et al. (2012) found that the technology needed to construct Sand/ sub-surface dams/rock dams is more complex, thus, engineering skills are required. Mati (2006) reported that because of high construction costs for earth dams and other dams, usually construction of such dams is in most cases facilitated by donors. Nevertheless, there are some cases where communities mobilize themselves seek for funding and construct earth dams.

4.4.2 Volume of water harvested by Rooftop technology

Household heads were asked to indicate the volume of water harvested by rooftop water tanks used. Table 7 presents the responses.

Table 7: Volume of water harvested using Rooftop technology (tanks)

Volume of water harvested	Number of Household heads	Percentage of respondents
Less than 400 litres	130	33.8
401-1000litres	120	31.1
1001-5000litre	100	26.0
5001-10,000litres	20	5.2
More than 10000litres	15	3.9
Total	385	100

The result shows that the majority (33.8%) of the households harvest less than 400litres, 120 (31.1 %) respondents harvest 400L-1000litres, 100(26.0%) harvest 1001L-5000litre, while 35 (9.1%) harvest 5001L to more than 10,000L. Results indicates that over 60% of the households do not harvest and store enough water that can take them throughout the dry seasons, since most of them have capacity to store less than 1000 litres. The major use of rainwater harvested by rooftop is for domestic use.

From these results, it could be concluded that more effort is needed in encouraging more households to invest in larger tanks that can store larger volumes (more than 1000L) of rainwater. The water that is harvested is utilized in dry seasons for cattle, small-scale irrigation and sometimes for home use. Hence, saving time, which would otherwise be spend in walking longer distances in search of water, and the time saved could be used in profitable and constructive work.

Lack of storage tanks with larger capacities and poor quality roofing materials makes rooftop technology an unsuitable RWHT especially for drinking or domestic use. This technology stores water of good quality and is commonly adopted at schools and homesteads.

4.4.3 Willingness of the household heads to adopt rainwater harvesting Technologies (RWHT)

Family heads were asked to indicate if they were ready to implement rainwater harvesting technologies to reduce water scarcity or not willing. Table 8 presents the responses obtained.

Table 8: Willingness to implement rainwater harvesting Technologies (RWHT)

Extent	No. of household heads	Percentage
Not willing (scale of 0-1)	25	6.5
Willing (scale of 2-3)	250	64.9
Strongly willing (scale of 4-5)	110	28.6
Total	385	100

Table 8 shows that the largest proportion (93.5%) of household heads was willing to adopt RWHT. Most of the households who were ready to adopt RWHT did not suffer from water shortage, and most likely they either reside around the forested areas like in Kilifi North and south and along the Indian Ocean where they experience some moderate rainfall or live in the urban areas within the county where there is piped water supplies.

Furthermore, a larger proportion of household heads interviewed were willing to implement many other RWHT as a community apart from the dominant rooftop RWH. This research also revealed that implementation of most RWHT especially pans and dams were mostly funded by various development partners and this has led to development of a dependency syndrome and unsustainability of these projects in the county.

Magut et al., (2014) noted that many communities in ASALs are willing to mobilize themselves and undertake RWH projects whenever governments or other development partners bring projects to them. Furthermore, for those projects that are funded by donors the community members are willing to be involved right from earlier stages of project implement especially in the planning and decision making since this make them to own up these projects and hence enhance sustainability of these.

Otti, et al., (2013) reported that community develops awareness and self-confidence when they are involved in project implementation. Community involvement makes members of these communities to evaluate their problems and on how to solve them.

4.5 Household socio-economic factors that affect the implementation of RWH technologies and their significance

The results are discussed in the sub-sequent sub-sections below.

4.5.1. Distance to water source

The Family heads were asked to indicate the distances travelled to their nearest sources of water. Table 9 presents the responses obtained.

Table 9: Distance to water source

Distance in Km	No. of household heads	Percent (%)
0-2	131	35.0
3-7	239	62.1
8-10	15	2.9
Total	385	100.0

Table 9 indicates that majority of the households (62.1%) in the county cover a distance of 3-7 Km in search of water. The longer the distance covered to the water source shows a likelihood of huge water insecurity to meet the higher demand for water in the county for farming, livestock and for domestic use.

Logit model result showed that the odds ratio of distance from the household to nearby water source from Table 10 is 7.502. This shows that an increase in the distance covered by one more kilometer leads to an increase in the level of adoption of RWHT by more than seven units.

This observation is in agreement with a report done by ASDSP Kilifi (2014), which concluded that many people in Kilifi county walk for distance that is more than 4km in search of water for domestic, faming and livestock use.

Table 10: Logit Model output on factors that influence adoption of RWHTs

No.	Variable	Exp (β) (odds ratio)
1.	Distance from the home to the nearest source of water	7.502
2.	Earnings of the family head	6.509
3.	Family size	5.909
4.	Household house roofing material	5.257
5.	Education level of household head	4.611
6.	Marriage status of household respondent	4.589
7.	Training information on rainwater harvesting	2.674
8.	Gender of family head	2.506
9.	Age of family head	1.874
10.	Membership to a social group (social capital)	1.821
11.	Family land size and ownership rights	1.755
12.	Livelihood of household head	0.815

4.5.2 Age of household heads

The Family heads were supposed to tick the age bracket of the household head from the choices given. Table11 presents the distribution of household heads by age groups

Table 11: The distribution of household heads' Age

The respondents' age (years)	No. of household heads	Percentage (%)
Below 35	100	26
36-45	120	31.1
46-55	130	33.8
56-65	20	5.2
Above 65	15	3.9
Total	385	100.0

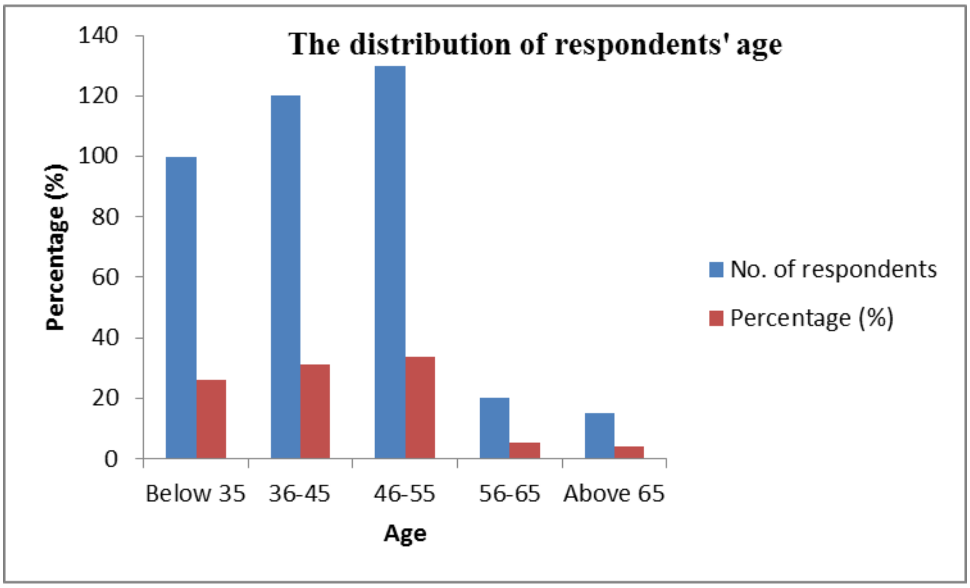

Figure 19: The distribution of household heads' Age.

Table 11 and indicates that the majority of the family heads (33.8%), fell in the age bracket of 46-55 years. This shows that many of the household respondents (130) are in the age of 46-55years, this age is the suitable age for construction, or implementing RWHT since this work requires more energy and effective decision-making.

A result of the significance of age of the household heads from Table 10 is 1.874. This shows that age has a statistically negative influence on the degree of adoption of RWH technologies. i.e., elderly people are unlikely to embrace RWHT than middle-aged ones. This means that when a person adds a year to his/her age the probability of adoption reduces by over 1. Likewise, the chance of absorbing and applying new knowledge is higher in young members of a household unlike the elderly ones. Middle-aged People are mostly selective in choosing the various RWHT unlike other age groups. People in this age group understand the problems of the various technologies since most of them get access to information.

These results are in agreement with results obtained by Ahmed et al., (2015) and (Lloyd, 2015) who concluded that persons involved in RWH projects are the age bracket of 45-55 years.

Mbogo (2014) stated that a person intensifies the adoption of RWHT in the household, as he/she grows older up to 55 years then reduces as he/she becomes elderly. This can be attributed to farmer understanding his/her agricultural undertakings, that other researchers have established to be important in the implementation of the RWH technologies.

4.5.3 Gender of Household Head

The family heads were asked to specify gender of the household head from among choices given. Table 12 shows the gender distribution of household heads.

Table 12: Gender distribution of household heads

Gender of respondent	No. of household heads	Percentage (%)
Female	231	55
Male	154	45
Total	385	100.0

Majority of the family heads (55%) were women as compared to 45% male. this is because women are often more likely to be found at home and most affected by water scarcity. Therefore, more women will be willing to involve themselves in water and sanitation related issues than men. Culturally, it is the role of women to deal with issues of water in every household. The significance of gender to adoption of RWHT from Table 10 was 2.506 implying that the more the women are actively involved in the RWH projects the greater the impact since gender has a positive effect on the implementation of RWH technologies.

However since the majority of the household in the county have women as their heads, this may not have much impact on the level of adoption of RWHT because many of the women in the county have limited rights to land ownership.

This result tends to disagree with several studies in ASAL areas including that done by Lloyd (2015) that reported higher respondents for male than female meaning that a man will be more willing to embrace RWHT at 3.5 times the odds of a woman. He attributed this observation to the unfairness against countryside women in taking over land or having protected land rights.

4.5.4 Literacy Level/ Education level of household heads

The household heads were asked to indicate their highest academic qualifications of the household head. Table 13 presents the distribution of household heads by highest academic qualifications attained.

Table 13: Family heads' academic qualification

Family heads' academic Qualification level	No. of family heads	Percentage (%)
No Education	25	6.5
Primary	200	51.9
Secondary	130	33.8
Tertiary	10	2.6
University	20	5.2
Total	385	100.0

Table 13 indicates that the majority of all the family heads (51.9 %) had achieved primary education level. Highest education of the household head affects adoption of RWHT positively, because the level of education is usually important in making decisions about the adoption of new technologies. Level of Education influences the level of taking risks and hence affects the levels of investment.

Significance of the level of education to adoption of RWHT of household head is 4.611 (Table 10) indicating that the higher the level of education the higher the probability of adoption of RWHT by 4.611.This means that increase in the level of education by one unit has a probability of adoption of RWHT of more than 4. Therefore, highly educated household heads adopt RWHT more likely than those with lower education levels.

The above outcomes agree with the studies done by Tesfaye (2001), Florence (2013), Ibrahim (2013), Mbogo (2014), Lloyd (2015), and Kattel (2015) who all indicated that the education level affects positively the adoption of RWHT.

4.5.5 Livelihoods/occupation of household head

The family heads were required to specify the main livelihoods of the households. Table 14 presents the main sources of livelihoods of the respondents.

Table 14: Main sources of livelihood for the households

No.	Livelihood	No. of household heads	Percentage (%)
1.	Livestock herding	15	4.0
2.	Own farm labor	85	22.0
3.	Employed (Salaried	36	9.3
4.	Waged labor	142	36.9
5.	Petty trading	59	15.4
6.	Merchant/Trader	6	1.5
7.	Firewood/Charcoal	35	9.0
8.	Fishing	4	1.0
9.	Others	3	0.9
	Total		100.0

Majority (36.9%), of the household heads depends on waged labor as a means of livelihood.

From the logical analysis, results indicate that the odds ratio of occupation is 0.815 (Table 10). This means that the impact of livelihood on implementation of RWH technologies is slightly significantly. This means that if a household head is involves himself/herself with a better livelihood that has higher monetary returns; the probability of that person adopting RWHT is almost one. This result is in agreement with a study done by Mati (2006) that concluded that occupation has little significant impact on the adoption of RWHT.

4.5.6 Family heads marital status

The family heads were required to state the state of marriage. Table 15 presents the responses obtained.

Table 15: Marriage status of the household head

Marriage status	No. of household heads	Percentage (%)
Married	308	80.2
Single	40	10.1
Divorced	10	2.7
Widow/widower	27	7.0
Total	385	100

The majority (80.1%) of the household heads were married. The adoption of RWHT is affected positively by the marital status of the household heads. From table 10 the marital status odd ratio was 4.589 implying that the probability of marred person to adopt RWHT is more than young and single persons. This could be because most of the single persons do not have rights to own their land and are usually not involved in making decisions hence they cannot decide on the RWH technique to be adopted (Ahmed et al., 2013).

4.5.7 Household size and labor availability

Household heads were required to point out the number of people within their household. Table 16 shows the distribution of household sizes.

Table 16: Size of household

Size of households	No. of households	Proportion (%)
Below 3	50	13
3-5	95	24.7
6-8	200	51.9
Over 8	40	10.4
Total	385	100.0

Majority (51.9%) of the households in Kilifi County had an average number of 6-8 members.

Logit model results (Table 10) shows that the odds ratio of household size was 5.909. Family size affects the water used per household. The larger the family, the greater the water consumption and demand and hence larger families are likely to embrace RWHT as an additional source of water than small families.

Furthermore, larger number of household members would offer higher family labour in constructing water-harvesting structures if required. This makes hence makes implementation of water harvesting technologies easier (Magut, et al., 2014).

4.5.8 Income of Household head

Family heads were asked to indicate their major source of revenue for the family head. Table 17 presents the responses obtained.

Table 17: Major source of revenue for the family head

Major source of income	Percentage (%)
Farming	33.8
Casual labor	24.4
Petty trading e.g. Sale of firewood	21.7
Permanent jobs	7.8
Remittances	6.7
Sale of Livestock / livestock products and personal assets	5.6
Total	100

The majority (33.8%) of household heads had farming as a source of income (Table 17). Logit model results show that the odds ratio of household income was 6.509 (Table 10) implying that a rise in the income of the household head increases the possibility of adopting RWHT by 6.509. Farming is the leading source of income for most households within the County, hence ownership of land is very important to household's welfare because it offers direct benefit to individuals in the households.

Therefore the greater the income of the household head, the higher the probability of adopting RWHT. The higher the household income the greater the investment in agronomic technologies and the greater the capability to take risks that come with its adoption as noted by Kimani et al. (2015).

Consequently, expanding sources of income for households in Kilifi County could boost adoption of RWHT and reduce water insecurity. More than seventy percent of the population lives below the poverty line hence cannot meet the expense of building or even buy ready-made tanks for RWH (CIDP, 2018). However, enhancing the adoption of RWHT will increase the income hence reduce the level of poverty in Kilifi County.

4.5.9 Roofing material and adoption of Rainwater Harvesting Technologies (RWHT)

Household respondents were asked to indicate the type of roofing materials they used for constructing their homes. Table 18 presents the responses obtained.

Table 18: Distribution of main roofing material used in Kilifi County

Roofing material	No. of household heads	Percentage (%)
corrugated Iron sheets	154	40
Tiles	47	12
Makuti	184	48
Total	385	100

The majority (48%) of households in Kilifi tese Makuti as roofing materials as shown in Table 18 above. The odds ratio from Table 10 is 5.257 implying that roofing material is very important in determining rooftops for RWH. Rooftops help in collecting drinking or domestic water and water for irrigation purposes. This observation agrees with that of Gateri et al. (2016) who stated that considering cleaner water, and preventing ingress from thatched roofs and putting into considerations that thatched roofs are avoided due to the high cost of having a high pitched roof, corrugated iron sheets are considered for RWH in Kilifi County.

The main limitation of Makuti roofs is the presence of soot and rotten particles of the Makuti making their way into the water hence making it unfit for domestic use. Since a significant number of households own Makuti thatched houses this affects the adoption of RWHT negatively leading to the low adoption of rainwater harvesting and especially rooftop RWH that is the easiest and cheaper technology for RWH.

4.5.10 Household land tenure

The household heads were asked to indicate household head's land ownership rights. Table19 presents the responses obtained.

Table 19: Household land ownership/ land tenure

Land ownership	No. of household heads	Percentage (%)
Private land	56	28.0
Family land	137	68.5
Leasehold	3	1.5
Freehold	4	2.0
Total	385	100

Table 19, shows that the majority (68.5%) of the household heads own family land. This mode of land tenure fosters low investment in RWH due to fear of losing the project due to land redistribution (Bekele and Drake, 2003).

Majority of the small-scale farming household heads own about 3.44 Ha of land, while large scale farming household heads own 30.4 Ha of land and only about 20% of all landowners have genuine title deeds (KILIFI CIDP, 2018). Logit results (table 10) indicate that the odds ratio is 1.755. This indicates that land ownership, which is secure, can rise the likelihood of embracing RWHT by 1.755.

Therefore, a right to land ownership dictates the type of developments on this land. Now that rainwater harvesting is one of the investments on the household land, it is thus, negatively affected by lack of legal land ownership documents among many households in Kilifi County.

4.5.11 social capital

The family heads were required to specify whether they belonged to any social group or not. Table 20 presents the findings of responses on membership to social groups.

Table 20: Household social capital

Social capital	Percentage(%) household heads
Belonging to social group	40
Do not belong to any social group	60

Majority of the household heads (60%) do not belong to any social group while only 40% below to some social group. Table 10 indicates that the odds ratio for social capital is 1.521, implying that involvement of a family in social groups could most likely increase the possibility of embracing RWHT by 1.521. Household heads that belong to social groups like groups of women and self-support groups and others who are more likely to implement RWH technologies than those who do not belong to any social group.

UNICEF (2016) noted that adoption of RWHT is highly affected by poverty, and since many households within Kilifi County, live below poverty line and many do not belong to any social group, it is difficult for them to adopt RWHT due to inadequate capital and lack of access to credits. Consequently, they cannot invest in RWHT that requires bigger capital and it is difficult for them to access help from both governments since governments invest most in community/ social projects than individual projects. Household heads who are members of social groups or group organizations, have higher chances of accessing credits and therefore, are likely to invest in RWH projects.

In order to enhance sustainability, accountability, and ownership of many of the RWH projects in the County, these projects are thus executed through social groups and associations. This increases the adoption of RWHTs by those who belong to such groups/organizations as noted by Abtew & Setegn (2014) that if a community is highly connected it experiences faster and easier transfer of information.

4.5.12 Technical and Extension support

Family heads were asked to point out the number of trainings received in the past three years. Table 21 presents the responses obtained.

Table 21: Trainings received in the Past three years.

Number of trainings received in the last 3years	No. of household heads	Percentage (%)
0	200	51.9
1-3	100	26.0
4-6	60	15.6
7-9	25	6.5
Total	385	100

The majority (51.9%) of the household heads did not receive any training or extension services in the past three years. Table 10 indicates that the odds ratio of sensitization on RWH is 2.674 suggesting that if families are trained on rainwater harvesting, the probability of them adopting RWHTs could be increased by 2.674 as compared to those who are not aware.

This rises an urgent need for agricultural extension officers and water technical officers in the county to offer trainings to households on RWH technologies including construction of RWH systems, proper sizing of the systems, and management, proper selection of building materials and proper site selection for installation of RWH systems.

Households should also be trained on other essential technical aspects including choice of gutters and fixation methods, taps fixing, construction of tank valves, and project operation to enhance sustainability of water harvesting systems. This observation agrees with those of Makau et al. (2014) who noted that unsustainability of RWH projects could be due to lack of training programmes on issues of water extraction methods, and health matters among others.

Mbogo (2014) reported that households' ability to adopt RWHT could be enhanced by sensitizing them on RWH technologies, inputs, sources of credits, and the borrowing of agricultural equipment. Furthermore, the adoption of RWHT can be increased by allowing households to participate in on-farm demonstrations and trials for comparison and further learning (Mbogo (2014).

4.6 KEY INFORMANTS AND FGDs

This research gathered information/knowledge from key informants and FGDs concerning various aspects of RWH, water management and efforts in place for alleviating water shortages in Kilifi County.

From key informants and FGDs, it was evident that there exists persistent variation in the rainfall experienced in Kilifi County and especially in the seasonal rainfall. Many of the representatives reported that they have experienced a rise in temperatures both at night and at daytime.

From key informants and FGDs it was revealed that each of these organizations carries out various distinct activities, but overall they supplement each other in providing essential services that improve water security in the Kilifi. However, the high level of poverty in the county is a major constraint to adoption of RWHT in Kilifi County.

It was revealed that there exists water shortages in county and women and children are the most affected as they search for this scarce resource. Children and women walk for longer distances of 3-7km looking for water and waste a lot of time, which could be spent on other productive undertakings like trading and agri-business.

From key informants and FGDs, it was noted that many households are willing to mobilize themselves, their assets as a communities rather than individuals in terms of funds, labour, time, managing and implementing RWH.

Moreover, in as much as females are willing to adopt rainwater harvesting, the males are the ones who should make decisions in most communities since they are the landowners and this affects negatively the adoption of RWHT.

In addition, it was noted that land tenure is a constraint that makes investment in RWHT by development partners and ministries difficult thus leading to water and food insecurity in the county. This is because any community project should be constructed on community land but majority of the lands are privately owned.

From key informants and FGDs also noted that although a number of RWH systems have been successful, the rate of adoption is still low, hence has made minimum impact. Furthermore, there exists an information gap on the potential of RWH in the county. Thus, there is need for advocacy "to enhance more adoption of RWH both at the policy and local level.

High cost of constructing RWHT is another limiting factor, an alternative water source should be considered and assess the priority sequence. Alternative water sources should be compared in terms of cost to the RWHT and the risks involved. The quality of harvested water as well as operational and maintenance costs should be looked at and more priority given to a water source with good water quality, cheaper to develop and maintain, easier to obtain, and with low risks.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

This chapter presents major conclusions of the study and also makes recommendations and suggestions for future studies.

5.1 CONCLUSION

The overall objective of this study was to determine the adoption of the existing rainwater harvesting technologies as a coping mechanism to climate variability in Kilifi County.

The results from the study show that there exists high variability in both annual and seasonal rainfall experienced in Kilifi County. This analyses show that both minimum and maximum temperatures are rising equally in all seasons in Kilifi County and this agree with global observations.

From the results, it is evident that there is water scarcity in Kilifi county due to long distances travelled in search for water. Results show that most of the communities in Kilifi county have adopted roof tanks for RWH because they are easily accessible and they provide water that is relatively clean.

Many of the households were cognizant of the existing rainwater harvesting technologies in their locality. Some of them have been sensitized about RWHT by agricultural Extension Officers, and from local Radio Programmes. However, by the fact that a number of RWH systems have been successful, the rate of adoption is still low, hence has made minimum impact. Therefore, there exists a training or extension services gap on the importance of households adopting rainwater harvesting in the county.

Results also indicated most households are cognizant of the fact that there is climate variability; hence, most households are willing to mobilize themselves and harvesting surface runoff as a community but not as an individual.

Results also indicated most households do not belong to social groups hence they are unable to access credit from financial facilities. Consequently, they cannot invest in RWHT that requires bigger capital and it is difficult for them to access help from both governments since governments invest most in community/ social projects than individual projects

The results also shows that for Kilifi county to enhance the adoption of RWHT by households it requires combined efforts from all the stake holders in the water sector. Since some of the RWHT requires a large amount of capital to invest of which most of the households may not raise.

5.2 STUDY LIMITATIONS

The main limitation for the research was that the some of the experts (key informants) that were addressed were very busy and were not able to find time for answering a questionnaire.

The research involved acquiring information about opinions, attitudes and experiences of the household respondents on why they have not adopted RWHT, how extension services and other economic factors influenced them in adopting rain harvesting technologies, and this may result in false information being presented by the respondents.

5.3 RECOMMENDATIONS

Founded on observations and challenges encountered during this study, and the results of the findings from the investigation in Kilifi County the following recommendations were made.

5.3.1 Recommendations to the National and County Governments and Development partners

Government agencies need to take the frontline in promoting the adoption of RWH at the local level. Both governments need to ensure advocacy and lobbying on RWH is consistent and persistent, for instance, any initiative should take a longer period until the local people finally and successfully adopts it.

The adoption of rooftop and surface runoff harvesting should be enhanced to act as an alternative source of water during dry seasons.

This research revealed that implementation of most RWHT especially pans and dams were mostly funded by various development partners and this has led to development of a dependency syndrome and unsustainability of these projects in the county. Therefore, to ensure sustainability of RWH projects, governments should ensure that implementation of RWHT should be community demand driven where communities are encouraged to mobilize themselves and initiate the construction of water pans or encourage them to seek for their own funding either by getting micro-finance credits in order to solve their water problems.

RWH should be mainstreamed into all sectorial development plans for the county like through the County Integrated Development Plans (CIDP).

Relevant agencies in both governments should offer training and sensitization to farmers, develop and propagate rainwater harvesting and storage technologies that are more effective and affordable and also formulate alternative policy instruments and social institutions that promote the implementation of RWH and storage practices.

Recommendation is made to both national and county government (Ministry of agriculture and water) to facilitate or help farmers to access more simple materials on long-term credit basis or at lower cost in the market especially for roof water tanks.

Governments should develop and implement integrated policies and programs that promote educational attainment, enhance family income, membership to social and economic group, and access to water in order to enhance farmer awareness to climate change, adaptive capacity, and build local resilience at the household level.

5.3.2 Recommendations to the community

Recommendation is made to the community in the region, to mobilize themselves and form social groups. This will help them to put together all the existing local resources, and local creativities, and also enable them to access credits from financial facilities and also access financial assistance from the both governments and development partners to be able to adopt RWHT and unravel the problems of water insecurity, and improve project sustainability.

Women are highly encouraged to actively involve themselves in decision making concerning community water resources since they are the most affected with water shortage.

5.4 Suggestions for future research

From the research results, the following subsequent areas are proposed for further studies;

Research should be carried out on the issues that affect the embracing of RWH techniques amongst households in other areas of the Country.

A study need to be done to determine the most suitable RWH technology in Kilifi County.

Research need to be carried out to establish the most sustainable revenue making activities that could be sustained by rain water harvested in Kilifi County.

Research should be carried out to determine whether adoption of RWH by farmers would increase their level of household income or not.

Study should be conducted to determine the quality, accessibility, construction and maintenance costs and the risks involved with rooftop harvested water in Kilifi County to help the county policy makers to either invest in RWHT as a supplementary to tap water in providing drinking water to the communities in the county or not. So that more priority is given to a water source with good water quality, cheaper to develop and maintain, easier to obtain, and with low risks.

A study to be done to find out the potential of other inexistent rainwater harvesting techniques in the region. These may include; digging of sand or earth dams along the roads to harvesting road runoff especially in urban centers, flood based irrigation especially in lowland flooding areas, and construction of concrete tanks to be used for storage instead of plastic tanks.

In addition, research should be done to establish the effectiveness of traditional technologies and how they can be incorporated in the recent technologies to help agriculturalists and pastoralists to cope with the advance effects of climatic changes and variability in various environments in the ASALs regions.

REFERENCES

Abdelfadeeel, I.A.I., 2012. Investigation of Rainwater Harvesting Techniques in Yatta District, Kenya Master of Science (Research Methods) Jomo Kenyatta University.

Abtew, A.M.M.W. & Setegn, S.G., 2014. *Nile River Basin: Ecohydrological Challenges, Climate Change and Hydro politics*,

Adom Dickson, Emad Kamil Hussein and Joe Adu Agyem 2018. Theoretical and Conceptual Framework : Mandatory Ingredients Engineering. *International Journal of Scientific Research*, 7(January). Available at: https: https://www.researchgate.net/publication/322204158.

Ahmad, Deshan Tang, Tian Fang Wang, Mei Wang, and Bakhtawar Wagan, 2015. Precipitation Trends over Time Using Mann-Kendall and Spearman ' s rho Precipitation Trends over Time Using Mann-Kendall and Spearman ' s rho Tests in Swat River Basin , Pakistan https://www.researchgate.net/publication/27172286. *Advances in meteorology*, 2015(January).

Ahmed, Ijaz, Deshan Tang, Tian Fang Wang, Mei Wang, and Bakhtawar Wagan, 2013. Evaluation of types and factors influencing adoption of rainwater harvesting techniques in yatta district, kenya 1. *International Journal of Education and Research*, 1(6), pp.1–14.

Andang'o, H. A., J. O. Ouma, N.J.M. and A.O.O., 2016. Investigating the Homogeneity of Monthly Rainfall Records in Kenya. J. Meteorol. Relat. Sci. vol 9 pg 48-54. http:// dx.doi.org/10.20987/jmrs.4.05.2016. , (June).

Aroka, N., 2010. Rainwater Harvesting in Rural Kenya Reliability in a Variable and Changing Climate.

Aroka, N., 2010. Rainwater Harvesting in Rural Kenya Reliability in a Variable and Changing Climate. , p.45.

Arun Mondal, Sananda Kundu, Anirban Mukhopadhyay., 2012. Rainfall trend analysis by Mann-Kendall test : a case study of North-Eastern part of Cuttack district, Orissa Rainfall Trend Analysis by Mann-Kenall Test., (January). International Journal of Geology, Earth and Environmental SciencesISSN: 2277-2081 (Online) An Online International Journal Available at http://www.cibtech.org/jgee.htm2012 Vol. 2 (1) January-April,pp.70-78/

ATPS, 2013. Indigenous Rain Water Harvesting Practices for Climate Adaptation and Food Security in Dry Areas : The Case of Bahi District. , (22), pp.1–24.

Bancy M. Mati, Maimbo Black and Alex Oduor, 2006. Promoting rainwater harvesting eastern and southern Africa Promoting rainwater harvesting in eastern and southern Africa. The RELMA experience

Behnassi M., Syomiti Muteng'e M., Ramachandran, G., Shelat, K.N. (Eds.), 2014. *Vulnerability of Agriculture, Water, and Fisheries to Climate Change: Toward Sustainable Adaptation Strategies*,

Berger, M., 2011. Rainwater Harvesting in Kenya. Faculty of Natural Sciences of the University of Berne. Centre for Development and Environment (CDE), Institute of Geography (GIUB).

Bordage, G., 2009. Medical education research Conceptual frameworks to illuminate and magnify.Department of Medical Education, College of Medicine, University of Illinois at Chicago, Chicago, Illinois, USA. , pp.312–319.

C. W. Recha &G. L. Makokha &P. S. Traore & C. Shisanya., &T. Lodoun&A. Sako, 2011. Determination of seasonal rainfall variability, onset, and cessation in semi- arid Tharaka district, Kenya.Researchgate.

Creswell JW., (2007), Qualitative Inquiry and Research Design: Choosing Among Five Approaches: International Student Edition. Thousand Oaks, California: Sage Publications; 2007.

Ebrahim, Y., 2018. Chapter 3 (Research design) Part 2 (Research design stage 1 , 2 & 3) Section 2 methodology textbook on asse ... , 3(June).

FAO, 2012. Coping with water scarcity. An action framework for agriculture and food security.

Fidell, 2013. Introduction to Logistic Regression. APACHE II Score and Mortality in Sepsis. Pp.1–24.

Gateri, Magdalene Wanjiku, Opere Alfred Owuor and Gitau Wilson, 2016. Domestic Rainwater Harvesting in Kilifi, Taita-Taveta and Mombasa Counties. J. Meteorol. Related. Sci. vol 9 issue 2 pg 2-10. http://dx.doi.org/10.20987/jmrs.1.08.2016. , 9(2), pp.2–10.

George, K. V, Pillai, K.V. & Mathew, J., 2015. Studies on Water Resource Management: Approaches and Strategies. *International Journal of Advanced Research*, 3(11), pp.781–791.

Gomoro, G., Tekalign, S. & Reddy, R.U., 2014. Climate Variability And Its Local Perception And Adaptation Measures In Weliso Woreda , Ethiopia , East Africa. , 3(11).

IPCC, 2014a. Climate Change 2014 Synthesis Report Summary Chapter for Policymakers.

IPCC, 2014b. Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change[Field, C.B., V. , (February 2015).

Ishaku, H.T., Majid, M.R. & Johar, F., 2012. Rainwater Harvesting: An Alternative to Safe Water Supply in Nigerian Rural Communities. *Water Resources Management*, 26(2), pp.295–305.

Israel, G.D., 1992. Determining Sample Size 1. , (November), pp.1–5.

Joshua Black, Maimbo Black, Alex Oduor, K.C. and M.N., 2012. Rainwater harvesting inventory of Kenya. *ICRAF*, Technical.

Kabir, S., 2018. Methods of data collection. , (July 2016). Basic Guidelines for Research: An Introductory Approach for All Disciplines, Edition: First, Chapter: 9, Publisher: Book Zone Publication, Chittagong-4203, Bangladesh, pp.201-275. Researchgate.

Kattel, R., 2015. Rainwater Harvesting and Rural Livelihoods in Nepal. , 4(10), p.7196.

KILIFI CIDP, 2018. County Government of Kilifi County Integrated Development Plan. , I(Volume I).

Kimani, M.W., Gitau, A.N. & Ndunge, D., 2015. Rainwater Harvesting Technologies in Makueni County , Kenya. , 5(2), pp.39–49.

Lee .H. and Kang K (2015), "Interpolation of Missing Precipitation Data Using Kernel Estimations for Hydrologic Modelling," Advances in Meteorology, vol. 2015, pp.1-12, Art. No.935868

Linda Ajuang Ogallo, Gilbert Ouma and Philip Omondi, 2017. Changes in Past and Present Rainfall and Surface Temperature Over Lower Jubba, Somalia. Vol 1, issue 2, pp. 39-52. *Journal of Climate Change and Sustainability, 1:4 Volume 1, Issue 2 July, 2017*, 1(2), pp.39–52. Institute of Climate Change and Adaptation, University of Nairobi. IGAD Climate Prediction and Application Centre

Lindoso, D.P., 2018. Harvesting Water for Living with Drought : Insights from the Brazilian Human Coexistence with Semi-Aridity Approach towards Achieving the Sustainable Development Goals.

Lloyd, 2015. Determinants of rainwater harvesting technology (RWHT) adoption for home gardening in Msinga , KwaZulu-Natal , South Africa. , 41(1), pp.33–40.

Magut, R., Kipkorir, E.C., and Daudi, F., 2014. Community Participation in Surface Water Harvesting in Marigat Division, Kenya. *Ethiopian Journal of Environmental Studies & Management 7 Suppl.: 850 – 858, 2014. ISSN:1998-0507*, (2007), pp.850–858.

Makau. W. Kimani, A. N. Gitau and D. Ndunge, 2015. Rain Water Harvesting for Enhanced Household Water , Food and Nutritional Security : Case Study of Kitui West , Lower Yatta and Matinyani Districts , Kenya. *Journal of Environment and Earth Science,* 4(14), pp.62–69.

Manuel Berger, 2011. *Rainwater Harvesting in Kenya-How Do Institutions and Policies Hinder or Promote Rainwater Harvesting?*

Mbogo, E.M., 2014. Factors Influencing Adoption of Rain Water Harvesting Technologies Among Households in Mbeere South Subcounty, Kenya.

Mburu, B.K., Biu, J. & Muriuki, J.N., 2015. Climate change adaptation strategies by small-scale farmers in Yatta District , Kenya. , 9(9), pp.712–722.

Mcsweeney, C., New, M. & Lizcano, G., 2007. UNDP Climate Change Country Profiles. , pp.1–26.

Memba, F., 2015. Effect of Progressive Lending Mechanism on Access to Finance in Rural Kenya : A Survey of Masaba North District Abstract : *The International Journal of Humanities & Social Studies*, 3(1), pp.313–318.

MoALF. 2016.Climate Risk Profile for Kilifi County. Kenya County Climate Risk Profile Series. The Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi, Kenya.

Mogaka, H. et al., 2006. *Climate Variability and Water Resources Degradation in Kenya*, Monica K. Kansiime, Stephen K. Wambugu and Chris A. Shisanya et al.,., 2013. Perceived and Actual Rainfall Trends and Variability in Eastern Uganda : Implications for Community Preparedness and Response. , 3(8). School of Agriculture and Enterprise Development, Department of Agribusiness Management and Trade, Kenyatta University

Mugerwa, N., 2007. Rainwater harvesting and rural livelihood improvement in banana growing areas of Uganda.

Muthama, N. J ,W.B. Masieyi, R. E, Okoola and A. O. Opere ,J. R. Mukabana, W Nyakwada, S. Aura and B. A. Chanzu & M.M. Manene ,2012. Survey on the Utilization of Weather Information and Products for Selected Districts in Kenya Survey on the Utilization of Weather Information and Products for Selected Districts in Kenya. *J. Meteorol. Rel. Sci., 6, 51 –58 (2012)*, (November 2011).

Muthama Nzioka John, Manene M.Moses and Ndetei Cornelius Joseph, 2014. Simulation of Decadal Precipitation over Nairobi in Kenya, 13(June 2008), pp.43–54. Department of Meteorology, University of Nairobi, Kenya; School of Mathematics, University of Nairobi, Kenya, P.O.Box 30197-00100 Nairobi, Kenya, Email: jmuthama@uonbi.ac.ke. Research gate.

Mutimba, S. & Wanyoike, R., 2013. Towards a coherent and cost-effective policy response to climate change in Kenya: Country Report. , p.60.

Mwanthi, A.M., 2015. Investigating Linkages between the Subtropical Indian Ocean Dipole Mode and East Africa Rainfall during October to December

Nathaniel Mason, Denali Nalamalapu & Jan Corfee-Morlot, 2019. Climate Change Is Hurting Africa’s Water Sector, but Investing in Water Can Pay Off

Ngigi, S.N., 2009. *Climate Change Adaptation Strategies: Water Resources Management Options for Smallholder Farming Systems in Sub-Saharan*

Africa,

NWMP, 2013. The National Water Master Plan 2030 October 2013 japan international cooperation agency nippon koei co., ltd. , 1(October).

Odhiambo., S., 2016. Investigating the Relationship between Rainfall Variability and Flow Characteristics of Nyando Basin.

Okumu, O.F., 2013. Small-scale farmers' perceptions and adaptation measures to climate change in Kitui County, Kenya.

Otti, V. I., & Ezenwaji, E.E., 2013. Enhancing community driven initiative in Rainwater Harvesting in Nigeria. *International journal of Engineering and Technology*, 1(3), pp.73–79.

Ouma, J.O., 2015. Assessing the Potential Effects of Climate Variability and Change on Livestock in the Arid Lands of Kenya ?University of Nairobi.

Pohlert, T., 2018. Non-Parametric Trend Tests and Change-Point Detection. , pp.1–18.

Rockström, J., 2002. Potential of Rainwater Harvesting to Reduce Pressure on Freshwater Resources By :

Rodr´ıguez, G., 2007. Logit Models for Binary Data. , (September 2007).

Techo, V.P., 2016. Research Methods-Quantitative , Qualitative , and Mixed methods Doctorate in Business Administration (DBA) Assignment submitted by : Techo Vincent Powoh Cource: Facilitator : , (July).

Timo Salmi, Anu Määttä, Pia Anttila, Tuija Ruoho-Airola &Toni Amnel., 2002a. *Detecting Trend of Annual Values of Atmospheric Pollutants by the Mnn-Kendall Test and Sen's Slope Estimates*, Helsinki, Finland: Published by Finnish Meteorological Institute Vuorikatu 24, P.O. Box 503 FIN-00101 Helsinki, Finlan.

Timo Salmi, Anu Määttä, Pia Anttila, Tuija Ruoho-Airola &Toni Amnel., 2002b. *Detecting Trends of Annual Values of Atmospheric Pollutants by the MANN-KENDALL Test and SEN'S Slope Estimates*, Meteorologiska Institutet Finnish Meteorological Institute Helsinki 2002.

Trochim, W. M. K. 2006. The Qualitative Debate. Research Methods Knowledge Base. http://www.socialresearchmethods.net/kb/qualmeth.php

Tuva, M.T., 2016. Climate Variability and Change Signals in Mombasa and Kilifi Counties. , (May).

UNDP, 2015. Sustainable Development Goals

UNEP, 2012. Report of the United Nations Environment Programme (UNEP). , (May), pp.1–9.

UNICEF, 2016. Kilifi County SMART Survey Report. , (November).

Viatcheslav V. Kharin and Francis W. Zwiers, Xuebin Zhang & Gabriele C. Hegerl, 2007. Changes in Temperature and Precipitation Extremes in the IPCC Ensemble of Global. , pp.1419–1444. Journal of Climate, Volume 20.

APPENDICES

Appendix 1: Authority Letter to Carry out Research Work

P.O. BOX 49720

Nairobi.

The Deputy County Commissioner 12/06/2018.

Malindi Sub County

P.O. Box 36

Kilifi.

Dear Sir/Madam,

RE: PERMISSION TO CARRY OUT ACADEMIC RESEARCH

I am a postgraduate student undertaking a Master of Science Degree in Climate Change in the Department of Meteorology at the University of Nairobi. I am conducting a research study entitled "Assessing the adoption of rain water harvesting technologies by households in Kilifi County".

The purpose of this letter is to request permission to interview households on key issues of this study using the attached copies of questionnaires. The information obtained will strictly be used for academic purpose and shall be treated with utmost confidentiality.

Thank You,

Yours faithfully,

JANET TULULA

L50/82344/2015

Appendix 2: Population Projections by Constituency/Sub-County

Constituency	2009 (Census)			2012 (Projections)			2015 (Projections)			2017 (Projections)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Kilifi North	99324	108263	207587	109004	118814	227818	119628	130394	250022	131287	143102	274390
Kilifi South	82109	89498	171607	90111	98220	188332	98893	107793	206687	108532	118299	226831
Ganze	65868	71796	137664	72287	78793	151081	79332	86472	165805	87064	94900	181965
Malindi	77853	84859	162712	85440	93129	178570	93767	102206	195974	102906	112167	215073
Magarini	84805	92436	177241	93070	101445	194515	102141	111332	213473	112095	122182	234278
Kaloleni	74516	81223	155739	81778	89139	170917	89748	97826	187575	98495	107361	205857
Rabai	46500	50685	97185	51031	55624	106656	56005	61046	117051	61464	66995	128459
Total	530975	578760	1109735	582724	635167	1217892	639518	697071	1336590	701846	765009	1466856

Source: Kenya National Bureau of Statistics, Kilifi office 2013

Appendix 3: Research Questionnaire for Households

Instructions

The purpose of this questionnaire is to obtain information on adoption of Rain Water Harvesting Technologies (RWHT).

Please fill the relevant boxes and blank spaces.

PART A: BACKGROUND INFORMATION AND DEMOGRAPHIC DATA

1. Gender (a) Male [ ] (b) Female [ ]

2. Please indicate your age.

(a) Below 35 [ ] (b) 36 – 45 [ ] (c) 46 – 55 [ ] (d) 56 – 65 [ ] (e) above 65 [ ]

3. County_________________

4. Marital status (a) Single [ ] (b) Married [ ] (c) Widowed [ ] (d) Divorced [ ] (e) Separated

5. What was the highest level of education you completed?

(a) None [ ] (b) Primary [ ] (c) Secondary [ ] (d) College [ ]

(e) University [ ]

6. Are you the main household provider? (a) Yes [ ] (b) No [ ]

7. Indicate the number of dependants in your household.

(a) Male [ ] (b) Female [ ]

8. The size of the community/population__________________

9. Indicate the size of your land holding (In ha/acres)______

10. What three main economic activities form the main source of your income (in order of importance)? ___________________ __________________ ____________________

11. Which enterprises do you have on your farm, which require water consumption?

11. On average, how much water do you use per day?

PART B: QUESTIONS ON RAINWATER HARVESTING

1. What is the main source of water that you use in your household? (Please select one answer only)

a) Tapped [ ]
b) Rainwater [ ]
c) Spring [ ]
d) River [ ]
e) Borehole [ ]
f) Pond/water pan [ ]
g) Dams/sand dams [ ]
h) Others (specify) [ ]

2. How far are you from the main source of water?

>1km [ ] 1km [ ] 2km [ ] 3-4km [ ] 5km [ ] 5-10km [ ]

3. Is this source permanent or temporal?

Permanent [ ] temporal [ ]

4. How often does it rain in the area?

None [ ] very rare [ ] rare [ ] Often [ ] frequent [ ] very frequently [ ]

5. In your own opinion, how can you assess the amount of rainfall received?

Very low [ ] low [ ] sufficient [ ] heavy [ ] very heavy [ ]

6. Do you experience water shortage?

Yes [ ] NO [ ]

(b) If yes, for how long?

Days [ ] Weeks [ ] Months [ ] Years [ ]

(c) Indicate month(s) of the year in which water shortage is usually severe in this area (please tick the month or months reported)

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

(d) How do you cope with periods of water shortage? Please explain with respect to water for;

i) Domestic use

ii) Livestock needs

iii) Agricultural activities

7. Do you experienced floods?

Yes [ ]   NO [ ]

(b) If yes, when and for how long?

(c) Which month(s) of the year are floods usually severe in this area (please tick the month or months reported)

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

(d). How do you capture the excess rainwater?

Don't capture [   ] Ground water recharge [   ] Rainwater/floodwater harvesting [   ]

8. Do you understand the term rainwater harvesting?

YES [   ]   NO [   ]

9. Have you ever been involved in rainwater harvesting?

YES [   ]   NO [   ]

If no, (go to question 10)

If yes, (please select all that apply)

a) Yes, I use it in my house [   ]

b) Yes, I have been involved in rainwater harvesting projects

c) Yes, have the knowledge, but have not implemented [   ]

d) No, never had experience but I am interested [   ]

e) No, I can't think that it can be useful [   ]

If yes, what methods do you use? (Please select all that apply)

a) Bucket [   ]

b) Water tanks [   ]

c) Water pans/farm ponds [   ]

d) Micro catchments [   ]

e) Zai pits [   ]

f) Terraces [   ]

g) Dams/sand dams/rock dams [   ]

h) Others (specify) [   ]

If yes, is roof water harvesting carried out?

(a) Yes [ ] (b) No [ ]

If yes, please indicate the capacity of water in litres, which can be held by your water storage containers

(a) Less than 100lires [ ] (b) 100-500 litres [ ] (c) 501-1000litres [ ] (e) 1001-5000litres [ ] (f) more than 5000litres [ ]

10. What is the type of roof of the house?

(a) Iron sheets [ ]   (b) shrubs [ ]   (c) grass [ ]

11. Do you think you have been harvesting rain/flood water efficiently?

Yes [   ]   No [   ]

If yes, what percentage?

0-30% [ ]   40-70% [ ]   70-100% [ ]

If YES, what are the challenges faced?

a) Inadequate practical knowledge and skills [   ]

b) Lack of funds [   ]

c) Land tenure [   ]

d) Topography [   ]

e) Soil types [   ]

f) Others Specify [   ]

12. If no, are you willing/interested in undertaking rain/Flood water harvesting?

a) Interested [   ]   b) Not interested [   ]

If interested, what do you think has hindered you from undertaking rainwater/floodwater harvesting? (Please select all that apply)

a) Lack of know how / knowledge i.e. I don't know how to go about it [   ]

b) Too expensive to install [   ]

c) I live in a house or flat with no outside space to install a water butt or tank [   ]

d) I live in a property belonging to someone else who won't install one [   ]

e) No suitable downpipes on my property [   ]

f) I do not know how to install one [   ]

g) Do not believe that I will save any money [   ]

h) I do not believe that the products are reliable enough [   ]

i) The water quality is not good enough [   ]

j) I do not believe that there are any benefits to the environment [   ]

k) Other (please specify) [   ]

13. What are your concerns with regard to harvested rainwater?

A) Quality, please specify

Very poor [   ] Poor [   ] bad [   ] not bad [   ] good [   ] better [   ] best [   ] I don't know [   ]

B) Quantity, especially during the long rains (AMJ season)please specify

Very low [   ] low [   ] high [   ] very high [   ]

Quantity, especially during the short rains (OND season) please specify

Very low [   ] low [   ] high [   ] very high [   ]

14. What do you consider as advantages of rainwater?

15. Does the place where you live currently have any form of rainwater harvesting technology that specifically collects rainwater?

Yes [ ] No [ ]

If yes, which one? (Please select one answer only)

a) Bucket [ ]

b) Water tanks [ ]

c) Water pans/farm ponds [ ]

d) Micro catchments [ ]

e) Zaipits [ ]

f) Terraces [ ]

g) Dams/sand dams/rock dams [ ]

h) Rock catchments [ ]

i) Others (specify) [ ]

If tanks, what capacity?

a) One or a few water butts or small tank (max total capacity 1,000 litres)[ ]

b) Several water butts or tanks (capacity between 1,000 and 10,000 litres)[ ]

c) Large tank or tanks (capacity in excess of 10,000 litres)[ ]

d) Do not know [ ]

e) Other (please specify) [ ]

What do you use the harvested water for? (Please select all that apply).

a) Domestic use [ ]

b) For livestock [ ]

c) Watering the kitchen garden /small scale irrigation [ ]

d) Commercial use [ ]

e) Others (please specify) [ ]

16. Do you get any assistance from local/national/international partners including private sector, companies, NGOs or Research institutions or national government /county government agencies involved in rainwater harvesting in the area?

Yes [ ] No [ ]

If yes, name them

If yes, what form of assistance do they offer?

a) Educational sponsorship [ ]
b) Funding rainwater harvesting projects [ ]
c) Trainings [ ]

17. In your own opinion, do you think they have done enough to increase the availability of water in the area?

Very poor [ ] poor [ ] good [ ] very good [ ] excellent [ ]

18. How can you rate the level of rainwater harvesting in the area?

1-20% [ ] 30-50%[ ] 50-80%[ ] 100%[ ]

18. In your own opinion, what do you think should be done to encourage more communities/families to engage in rainwater harvesting?

19. As a community or a person, have you ever been trained on rainwater harvesting issues?

Yes [ ] No [ ]

If yes, by who?

If no, are you interested?

Yes [ ] No [ ]

PART C: QUESTIONS ON CLIMATE CHANGE/CLIMATE VARIABITY

1. Do you understand the term climate change or climate variability?

Yes [ ] No [ ]

2. In your own opinion what are your perceptions on climate change and climate variability issues?

Yes, climate change/ climate variability is real (go to question 2) [ ]
No, climate change/ climate variability is not real [ ]

3. If yes, what are some of the indicators of climate change/climate variability experienced in the area? (Please select all that apply)

a) The temperatures are increasing [ ]
b) Heavier rainfall causing flooding [ ]
c) Extreme drought is increasing [ ]
d) Rivers drying up [ ]
e) More frequent heat waves [ ]
f) Warmer temperatures affect human health [ ]
g) Change in rainy seasons [ ]

3. What strategies have you as an individual/community undertaken to adapt to above changes?

4. Has these changes affected your cost of living?

a) Lowered the cost of living [ ]

b) Increased the cost of living [

5. Have you ever been trained on climate variability?

6. If yes, by who?

7. If no are you willing to be trained?

8. Apart from training, which other help would you require to enable fights the impacts of climate change?

Thank you very much for your time!

This survey will only be used for the purposes of research for an Open University course. Your details are completely confidential and will not be used for any other purpose

Appendix 4: Questionnaire Designed For the Key Informants and Institutions

Sample No……………………Sub-Location………………

Name of Organization/Institution …………………..…………………

What is the main source of water that you use in the institution? (Please select one answer only)

a) Tapped [ ]

b) Rainwater [ ]

c) Spring [ ]

d) River [ ]

e) Borehole [ ]

f) Pond/water pan [ ]

g) Dams/sand dams [ ]

h) Others (specify) [ ]

2. How far are you from the main source of water?

3. Is this source permanent or temporal?

a) Permanent [ ] b) temporal [ ]

4. How often does it rain in the area?

None [ ] very rare [ ] rare [ ] Often [ ] frequent [ ] very frequently [ ]

5. **In your own opinion, how can you assess the amount of rainfall received?**

Very low [ ] low [ ] sufficient [ ] heavy [ ] very heavy [ ]

6**. Do you experience water shortage/scarcity?**

Yes [ ] NO [ ]

(b) If yes, when and for how long?

(c) Which month(s) of the year is water shortage usually severe in this area (please tick the month or months reported)

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

(d) How do you cope with periods of water shortage? Please explain with respect to water for;

a) Domestic use

b) Livestock needs

c)Agricultural activities

7. Do you experience floods?

Yes [ ] NO [ ]

(b) If yes, when and for how long?

(c) Which month(s) of the year are floods usually severe in this area (please tick the month or months reported)

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

(d). How do you capture the excess rainwater?

Don't capture [ ] Ground water recharge [ ] Rainwater/floodwater harvesting [ ]

8. Have you ever been involved in rainwater harvesting?

a) YES [ ]   b) NO [ ]

If no, (go to question 9)

If yes, (please select all that apply)

a) Yes, I use it in my house [ ]

b) Yes, I have been involved in projects where rainwater harvesting played a role. [ ]

c) Yes, I am interested in rainwater harvesting [ ]

d) Yes, have the knowledge, but have not implemented [ ]

e) No, never had experience but I am interested [ ]

f) No, I can't think that it can be useful [ ]

If yes, what methods do you use? (Please select all that apply)

a) Bucket [ ]

b) Water tanks [ ]

c) Water pans/farm ponds [ ]

d) Micro catchments [ ]

e) Zaipits [ ]

f) Terraces [ ]

g) Dams/sand dams/rock dams [ ]

h) Others (specify) [ ]

What do you use harvested water for?

a) Domestic [ ]

b) Livestock [ ]

c) Small-scale irrigation [ ]

Do you think you have been harvesting the rain/flood water efficiently?

Yes [ ]   No [ ]

If yes or no at what percentage?

0-30% [ ] 40-70% [ ] 70-100% [ ]

If No, what are the challenges faced.

a) Inadequate practical knowledge and skills [ ]

b) Inadequate funds+ land tenure [ ]

c) Inadequate funds+ technical knowledge [ ]

d) Inadequate funds+ topography + climate change [ ]

e) High costs + Soil types [ ]

Are you willing to scale up rain/floodwater harvesting in the area

Yes [ ] No [ ]

1. Main causes of persistent water shortages in the sub county

Deliberate in order of importance the root causes of persistent water shortages in this

Locality giving the reasons why?

…………………………………………………………………………………………

…………………………………………………………………………………………

What do people do in this locality to get water in case the water shortage has persisted for long?

…………………………………………………………………………………………

…………………………………………………………………………………………

In what way do you think these causes can be addressed?

…………………………………………………………………………………………

…………………………………………………………………………………………

2. Adoption of small-scale water harvesting and saving technologies

What are the commonly used water harvesting and saving technologies in this area?

a) Bucket [ ]

b) Water tanks [ ]

c) Water pans/farm ponds [ ]

d) Micro catchments [ ]

e) Zaipits [ ]

f) Terraces [ ]

g) Dams/sand dams/rock dams [ ]

h) Others (specify) [ ]

Why are they preferred to the rest?

…………………………………………………………………………………………

…………………………………………………………………………………………

How would you rate the importance of various water harvesting technologies practiced in this locality?

No.	Water saving technology	Popularity (Importance rating)				
		5	**4**	**3**	**2**	**1**
1.	Roof water tanks					
2.	Water pans/ponds					
3.	Runoff terraces					
4.	Shallow wells					
5.	Negarims/ Zai pits					
6.	Boreholes					
7.	Dams/sand dams/rock dams					

KEY: 5: very high; 4: high; 3: fairly high; 2: low; 1: very low

What do you think should be done to improve the adoption rate of the water Harvesting structures in this locality?

………………………………………………………………………………………

…………………………………………………………………………………………

3. Factors that hinder investing in small scale water harvesting and saving technologies

What factors do you think hinder the investment of small scale water harvesting structures in this locality?

…………………………………………………………………………………………

…………………………………………………………………………………………

What role do you think you can play as an individual or organization to reduce the factors mentioned above?

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

4. Climate Change /Climate variability

In your own 0pinion, do you understand the term climate change or climate variability?

Yes [ ] No [ ]

What are your perceptions on climate change and climate variability issues?

a) Yes, climate change/ climate variability is real [ ]

b) No, climate change/ climate variability is not real [ ]

If yes, what are some of the indicators of climate change/climate variability experienced in the area? (Please select all that apply)

a) The temperatures are increasing. [ ]

b) Heavier rainfall that cause flooding. [ ]

c) Extreme drought is increasing. [ ]

d) Rivers drying up [ ]

e) More frequent heat waves. [ ]

f) Warmer temperatures affect human health. [ ]

g) Change in rainy seasons. [ ]

What strategies have you as an Organization/ Institution, undertaken to adapt to above changes

……………………………………………………………………………………

……………………………………………………………………………………

Has these changes affected your cost of living?

Yes [ ] No [ ]

If yes, in which way?

Have you ever been trained/ capacity built on climate variability?

Yes [ ] No [ ]

If yes, by who?

What steps have you as an organization taken to enhance community's resilience to climate change?

………………………………………………………………………………………

………………………………………………………………………………………

…………

Thank you very much for your time!

This survey will only be used for the purposes of research for an Open University course. Your details are completely confidential and will not be used for any other purpose.