ASSESSMENT OF RAIN WATER HARVESTING TECHNOLOGIES FOR IMPROVED FOOD SECURITY IN KAUWI SUB-LOCATION, KITUI COUNTY

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DECLARATION

I recognize that plagiarism is a fault and I therefore declare that this project is my original work and has not been presented in any other institution for any academic award.

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ABSTRACT

Water is an essential natural resource, vital for any development to take place. However, not more than one percent of the water is freely available for human needs including agricultural production in the entire world. Arid and semi-arid lands globally are facing water scarcity challenges. Rain-fed agricultural system is the major farming method in these areas, but this has been challenged greatly by aridity and climatic uncertainty. Kitui County is an ASAL where farmers are experiencing little annual rainfall averagely as well as varying temporal and spatial rainfall supply hence the need to evaluate use of rain water harvesting technologies in the area. The main aim of this study was to assess rain water harvesting technologies for enhanced security of food in Kauwi sub-location, Kitui County. Specifically, the study aimed at studying the extent of utilization of the rain water harvesting technologies, factors that influence utilization of rain water harvesting technologies and exploring farmers' perception of effectiveness of rain water harvesting technologies in Kauwi sub-location, Kitui County. The study adopted a survey design. Random sampling was used to identify the villages and systematic sampling applied in selecting the households to be interviewed. Data was collected through personal observation and administering interview schedules to a sample size of 160 households. From the logistic regression model, Zai pits variation was explained at 45% and cases correctly predicted at 93.1% where age $p<0.05$, $B=0.11$ and land size, $p<0.05$, $B=0.56$ were factors that significantly influenced its utilization. This study has generated information to be used by the farmers to help in prioritizing factors that influence decision on utilizing rain water harvesting technologies. The ministry of agriculture can use this information as a guideline for designing agricultural developments strategies. The Policy makers can use this information to develop agricultural policies.

TABLE OF CONTENTS

DECLARATION ii
ACKNOWLEDGEMENT iii
ABSTRACT iv
TABLE OF CONTENTS v
LIST OF TABLES viii
LIST OF FIGURES ix
ACRONYMS AND ABBREVIATIONS x
DEFINITION OF TERMS xi
CHAPTER ONE 1
1.0 INTRODUCTION 1
1.1 Background of the Study 1
1.2 Problem Statement 3
1.3 Objectives of the Study 4
1.3.1 Specific Objectives 4
1.3.2 Research Questions 4
1.4 Justification of the Study 5
1.5 Significance of the Study 5
1.6 Scope and Delimitation of the Study 5
CHAPTER TWO 6
2.0 LITRATURE REVIEW 6
2.1 Introduction 6
2.2 Rain Water Harvesting 6
2.3 Rain Water Harvesting Technologies 7
2.4 Extent of Utilization of Rain Water Harvesting Technologies 7
2.4.1 In Situ Rain Water Harvesting 7
2.4.2 Macro Catchments 8
2.4.3 Micro Catchments 9
2.4.4 Rooftop Catchments 10
2.5 Factor Influencing Utilization of Rain Water Harvesting Technologies 10
2.6 Perceived Effectiveness of Utilization of Rain Water Harvesting Technologies 12

2.7 Conceptual Framework 13
2.8 Knowledge Gap.. 16
CHAPTER THREE 17
3.0 METHODOLOGY 17
3.1 Introduction 17
3.2 Study Area... 17
3.2.1 Map of Study Area 18
3.2.2 Climate of Study Area 18
3.2.3 Social Economic Activity... 19
3.3 Study Approach.. 19
3.3.1 Research Design 19
3.3.2 Target Population 19
3.3.3 Sampling Procedure.. 20
3.4 Data Collection Instruments.. 20
3.4.1 Interview Schedules.. 20
3.4.2 Validity and Reliability of Research Instruments.. 21
3.5 Data Collection Process 21
3.6 Data Analysis 21
3.6.1 Logit Model 22
3.7 Ethical Considerations... 25
CHAPTER FOUR... `26
4.0 RESULTS 26
4.1 Introduction 26
4.2.1 Demographic Characteristics of Respondents in Kauwi Sub-Location 26
4.2 Existing and Utilized Rain Water Harvesting Technologies 27
4.3 Extent of Utilization of Rain Water Harvesting Technologies 29
4.4 Influential Factors of the Utilization of Rain Water Harvesting Technologies in Kauwi... 29
4.5 Farmers’ Perception of Rain Water Harvesting Technologies... 35
4.6 Effectiveness of Water Harvesting Technologies 35
CHAPTER FIVE 37
5.0 DISCUSSION 37

5.1 Extent of Utilization 37
5.2 Influential Factors of the Utilization of Rain Water Harvesting Technologies in the Kauwi Sub-Location 38
5.3 Farmers' Perception on Effectiveness of RWHTs 41
CHAPTER SIX 44
6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 44
6.1 Introduction 44
6.2 Summary 44
6.3 Conclusions 45
6.4 Recommendations for Further Research 46
REFERENCES 47
APPENDICES 55
Appendix 1: Household Survey Interview Schedule 55
Appendix 2: Work Plan 66
Appendix 3: Budget 67

LIST OF TABLES

Table 3.1: Kauwi Sub-Location Villages.. 20
Table 3.2: Operationalization of Variables.. 23
Table 3.3: Logistic Variable Description.. 24
Table 4.1: Demographic Characteristics of Household Heads in Kauwi Sub-Location............... 27
Table 4.2: Use of RWHT by Farmers in Kauwi Sub-Location 28
Table 4.3: Extent of Utilization of Rain Water Harvesting Technologies in the Kauwi Sub-Location Kitui County 29
Table 4.4: Logistic Model for Factors Influencing Utilization of RWHSTs in Kauwi 34

LIST OF FIGURES

Figure 2.1: Conceptual Framework 15

Figure 3.1: Map of Study 18

ACRONYMS AND ABBREVIATIONS

ASARs	Arid and semi-arid regions
SSA	Sub Saharan Africa
IPCC	Intergovernmental Panel on Climate change
ASALS	Arid and Semi-arid Lands
SDGs	Sustainable Development Goals
RWH	Rain Water Harvesting
RWHT	Rain Water Harvesting Technology
FAO	Food and Agricultural Organization
UNDP	United Nation Development Program
CVEWE	Climate Variability and Extreme Weather Events
KNBS	Kenya National Bureau of Statistics
GoK	Government of Kenya

DEFINITION OF TERMS

Smallholder farmers- farmers who produce agricultural production for local consumption but the can sale the surplus

Rain water harvesting- collection and storage of rain water rather than letting it run-off for later use in the agricultural fields

Rain water harvesting technology- is the various types of techniques used for collecting and storing rain water.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Water is an essential natural resource, vital for any development to take place. However, studies indicate not more than one percent of the water is freely available for social needs including agricultural production in the entire world (Boretti and Rosa 2019). FAO (2011) indicated that the demand for water had increased worldwide rapidly, causing a gap amid provision and fulfilling the various human needs, and real supply and access to best water quality, mostly in low to medium-income countries. Climatic variation, factors including social and economic, agricultural variations and demographic variations are a major cause of the increased demand (Fewkes, 2012; Lee *et al*, 2016). The change in climate is a risk that puts extreme pressure on hydrological systems and water resources that is by now stressed. Climate change effects are now evident since temperature and variation in rainfall are greater than before and intensified over time (Kahinda *et al*, 2010). Expected impacts of climate change include: changes in the frequency, intensity and spatial distribution of precipitation; increased or decreased amounts of precipitation; increased evaporation due to increasing temperatures; increased or decreased runoff; increased or decreased ground water recharge rates; rise in sea level in coastal areas; increase in floods and droughts; and increased variability of water resources (IPCC, 2007).

Arid and semi-arid regions worldwide are facing water scarcity challenges, mutually for drinking and for domestic, industrial, commercial and agricultural purposes. Rain-fed is the most common farming practice in ASARs however; it has been challenged by aridity and the uncertain climate. The main aspect limiting agricultural production is water (Luvai *et al*, 2014). Farmers are met by rainfall that is low on average annually and changing rainfall distribution both temporally and spatially (Luvai *et al*, 2014).

The IPCC (2007) indicated that Sub-Saharan Africa is largely impacted by climate change compared to other continents due to anthropogenic activities. Climate change is impacting Sub-Saharan Africa (SSA) mostly as a result of anthropogenic activities compared to any other continent as its economy largely relies on weather sensitive crop production and livestock production systems (Ndungu *et al*, 2017). These impacts are also the reason for the low adaptation capacity of the Sub-Saharan Africa countries to climate variability and climate change. Climate-change-induced agricultural drought commonly means a prolonged period without precipitation sufficient to meet crop water requirements (Ndungu *et al*, 2017). This causes a reduction in soil water content and thereby leads to plant water deficits. It is mainly a result of a variable supply of rainfall across seasons, poor water holding capacity of soil and improper management of water resources (Amede, 2009).

Sub Saharan Africa's Arid and Semi-arid Lands are inhabited by the poorest and most vulnerable population in the region. Among the characteristics of such land is scarce water, low output agriculturally and degrading lands. Due to diminishing resources and scarcity of water, it has resulted into insecure provision in food and clash among communities (Jaetzold *et al*, 2007). It is becoming difficult to manage the change in climate there is widespread recurring drought, inequality in distributing land and the extreme dependence on rain-fed agriculture (Vohland and Barry, 2009).

Kenya with 80% of its land being ASAL largely depends on its land and water resources to meet the needed necessities for its speedy rise in population (Kirbride and Grahn, 2008). The arid and semi-arid areas of Kenya are characterized by insufficient water for household use and for crop and livestock production (Jaetzold *et al*, 2007). Due to low rainfall and its irregularity and variability in distribution, low use of fertilizer and poor overall crop management, smallholder farmers obtain very low yields on average (Jaetzold *et al*., 2007).

Kitui County, located in the lowlands of South Eastern Kenya, and is home to 995,267 people (KNBS, 2011). The population has been growing rapidly. The region encounters severe challenges of water scarcity, lower water supply due to recurrent droughts, many rivers have become seasonal and some completely drying. The challenge has been worsened by increased frequencies in deforestation which has resulted in reducing the water catchment volume. As the climate variability increases and population raises, water shortage increases. The county's water demand will increasingly exceed freshwater sources. With expansion in agriculture due to increase in population, upstream catchment degradation will continue thus impacting the already limited available water.

About 88% of the county's inhabitants rely highly rely on rainfed farming practices. Inadequate rain and on other times rains failing results into unreliable agricultural production and little surplus for sale to bring more income resulting to food insecurity (Igbadun 2008). Fast population growth places massive pressure on natural and environmental resources such as forests, water, and land (United Nations Development Program, UNDP, 2010).

The impact of water resources degradation at global level is also felt at local levels including in Kitui. There is increased stiff competition for a better portion of fresh water for domestic, agriculture, industrial and environmental habitat. Several suggestions are being made by stakeholders relying on water for various purposes on how they can maximize production with minimum available water (Jothiprakash and Sathe, 2009). Rain water has been found to be an alternative that is cheap source of water (Luvai *et al*, 2014). Rain water harvesting is a practice that has been in use for long, it is well established worldwide (Dean *et al*, 2012). When rain water harvesting is applied in the right environment, it can provide convenient, cheap and a source that is sustainable for water (Dean *et al,* 2012). A big population of people has shown interest and is participating in rainwater harvesting. According to Lee and Kim 2012, rain water harvesting is a modest, low cost technique which needs little specific expertise and knowledge though it is not as low cost. It offers a lot of potential benefits, (Otti and Ezenwaji, 2013).
Kauwi, an arid and semi-arid land in Kitui has its small holder farmers trying to maximize on production by utilizing rain water harvesting technologies. This study will focus on the extent of utilization of the technologies, the factors influencing utilization of these technologies and perceived effectiveness of these rain water harvesting technologies in the study area.

1.2 Problem Statement

According to Luvai *et al*, 2014 Kitui County has climate that is arid and semi-arid experiencing very little and undependable rainfall. There is increased climate variability and extreme weather events (CVEWE) for instance; precipitation in the form of rain is predicted to be highly affected in the County. Recurring famine and season after season spells of dryness have appeared as the main causes of insecure food availability and skirmishes in the community. The communities in these regions are expected to be extremely affected as water scarcity continues to be a challenge.

There is commendable effort in promoting rain water harvesting technologies so as to increase communities' resilience to recurring drought and enhance food security.

Rainwater harvesting have potential benefits to rural communities. The benefits of adopting rainwater have been identified (Otti and Ezenwaji, 2013). Despite the known benefits of rain water harvesting technologies, Kitui County is slowly adopting this technology (Ibrahim 2013). Factors that affect household's tendency to investment and utilization in rainwater harvesting technologies remain critical for future development planning, hence the focus of this study (Dean *et al,* 2012). In the ASALS, there is successful testing of various rain water harvesting technologies. This study therefore sought to document the existing rain water technologies in Kitui County, to assess the extent of utilization, assess the factors influencing utilization of these techniques and finally ascertain how the community perceives rain water harvesting technology.

1.3 Objectives of the Study

The main objective of the study was to assess rain water harvesting technologies for improved food security in Kauwi Sub-location in South Eastern Kenya, Kitui County.

1.3.1 Specific Objectives

i. To assess the extent of utilization of the rain water harvesting technologies among small holder farmers in Kauwi Sub-location, Kitui County.
ii. To assess factors that influence utilization of rain water harvesting technologies of small holder farmers in Kauwi Sub-location, Kitui County.
iii. To evaluate small holder farmers perception of effectiveness of rain water harvesting technologies in Kauwi Sub-location, Kitui County.

1.3.2 Research Questions

i. What is the extent of utilization of rain water harvesting technologies by smallholder farmers in Kauwi Sub-location, Kitui County?
ii. What are the factors that influence utilization of rain water harvesting technologies of smallholder farmers in Kauwi Sub-location, Kitui County?
iii. How do smallholder farmers perceive specific rain water harvesting technologies in terms of their effectiveness in Kauwi Sub-location, Kitui County?

1.4 Justification of the Study

Water is an essential need used for human in many aspects of life including agriculture, domestic, industrial and livestock use. It's availability for particular needs are depleting due to climate change and increasing population hence increasing requirements for water. In order to achieve some of the key Sustainable Development Goals (SDGs) including: 1 Ending poverty and all its aspects, 2 Ending hunger, hence achieving food safety and raising nutrition and sustaining agriculture that is sustainable, 13 Ensuring that quick action is taken to fight change in climate and its effects and 15 Guard, reestablish and support terrestrial ecosystems' sustainable use, managing forests sustainably, fighting desertification and stop and reverse degraded land and stop damages to the biodiversity. There is need to improve and bring up small-scale rain-fed agriculture so as to increase food safety, eliminate malnourishment and achieve the first millennium development goal (Kahinda *et al*., 2010). Rainwater harvesting is enumerated among the exact adaptation actions and ought to be familiarized to community so to enable them in handling water scarcity and disasters during floods. The collected water will be useful for cover of needs, ground water recharging hence increasing ground water storage (Aladenola and Adeboye, 2010; Kahinda *et al*., 2010).

1.5 Significance of the Study

This study will generate information that will help farmers to ensure that decision they make on capitalizing on rain water harvesting technologies have been prioritized upon the factors such as access to credit, education level, years in farming among others. The information will act as guideline to the ministry of agriculture in formulating the strategies and policies in agriculture in rain water harvesting technologies. Additionally, policy makers will also benefit as they will use the information in developing policies and strategies to encourage community members to adopt rain water harvesting technologies. Finally, the study will add to the empirical literature relating to rain water harvesting thus increasing the acceptability of the study by the researchers in society.

1.6 Scope and Delimitation of the Study

The study was conducted in Kauwi sub-location, Kitui County. It dedicated concern on rain water harvesting technologies for improved safety of food among households of the area of study.

CHAPTER TWO

2.0 LITRATURE REVIEW

2.1 Introduction

This chapter gives a brief overview of rain water harvesting technologies and factors influencing utilization of the technologies.

2.2 Rain Water Harvesting

Rain water harvesting is defined as the collection storage and conserving local surface run off for various purposes (Lee and Kim, 2012; Wanyonyi, 2002). The rain water can be used for portable and non-portable uses including domestic, commercial, institutional, and industrial purposes. In some places, it can be used for agriculture, livestock and ground water recharge purposes.

Unlike other sources of water such as surface water bodies, shallow wells, boreholes, water vendors, rain water is least patronized, (Otti and Ezenwaji, 2013). This is because of low water tariffs making it less economical to install rainwater mechanism, lack of incentives to include RWH in building designs and lack of mandatory regulation to enforce rainwater harvesting systems. The advantages of rain water harvesting outweigh that of all other sources of water; there is a large number of catchment surfaces to harvest ran water, no distance or little distance need to be covered to collect the rain water , saves on cost by reducing volume of water purchased, it employs simple inexpensive technique, to the government, it reduces the burden for new investment to replace aging systems and adding water supply infrastructure and also reduces cost on each development as the technique can easily be retrofitted to existing structure, to the environment, it reduces flooding and erosion. Its disadvantage is that, there poor quality of water from roofs for domestic purpose especially during the onset of rain, poor construction techniques for harvesting and the finance associated with the project, (Ezenwaji *et al*, 2017).

According to Otti and Ezenwaji, (2013) water harvesting is a simple and low-cost technique that requires no expertise and knowledge to adopt. It has been in practice for over 5000 BC in Iraq (Falkenmark *et al*, 2001), 3000 BC in the Middle East (Barron 2009), 2000 BC in the Negev desert in Israel, Africa, and India (Fewkes 2012).

In rain water harvesting when appropriate technology is used, the rain water can be valuable and necessary water resource. It has the potentials to argument safe water supply with no or little disturbance to the environment, (Ishaku *et al,* 2012).

2.3 Rain Water Harvesting Technologies

According to Barron, (2009), Rain Water Harvesting consists of variety of technologies, advanced to traditional ones and from expensive ones to cheap ones. This depends on the area of application and the space it covers. RWH usually has three major components; catchment area where rainfall is collected from, storage equipment where to store water and a target system, what usage the water will be used for or what the water will serve (Fewkes 2012).

In literature, the classification of rain water harvesting technologies varies depending with the focus of the researcher. FAO, 1991 classified it into micro catchment, macro catchment and flood water harvesting. It classified it according to catchment size and the runoff transfer distance. Hatibu and Mahoo, (1999) classified RWH based on; Runoff generation process which they further classified it into runoff-based system and in-situ run off based system was further classified into storage within soil structures and storage structures; size of the catchment which includes macro catchment and micro catchment and finally, classified based on the type of storage. For crop production, they classified into different types determined by distance between catchment area (CA) and cropped basin utilization area. This classification includes: in-situ rain water harvesting, micro catchment and macro catchments rain water harvesting systems. Kimani, Gitau and Ndunge, (2015) in Mati *et al*, (2007) classified rain water harvesting technologies into: Macro catchments, micro catchments and rooftop rain water harvesting.

2.4 Extent of Utilization of Rain Water Harvesting Technologies

2.4.1 In Situ Rain Water Harvesting

In Ethiopia, an experiment lasting 3 years was carried out in areas experiencing drought such as Wollo region. From the results, it was evident that where technologies as tied ridging, open ridging and sub-soiling, the water content in the root zone improved by 24%, 15% and 3% consecutively when likened to traditional tillage during the cropping season, (McHugh *et al* 2007). In the semi-arid region of Ethiopia, a study revealed that a lot of water is lost as runoff during rainy season, tied ridges reduced the runoff by about 60% thereby improving soil water content by at least 13% (Araya and Stroosnijder, 2010).

Funakawa *et al* 2018, conducted a field trial in central Tanzania to assess how ripping and tie-ridges in situ rain water harvesting technologies when incorporated with organic and inorganic fertilizers helped in preventing serious periods of deficiency of moisture in the soil for sorghum yield performance. They found out that tie-ridges kept a significant water amount of 577 and 457 m^3 ha^{-1}, that prevented the sorghum by the maximum of 95% and 37% for the above-average rainfall and below-average rainfall season, respectively.

Naba *et al* 2020 used four treatments and replicated them three times in an experiment using Randomized Complete Block Design. These treatments include in-situ rain water harvesting technologies including; Control, Targa, Tie-ridge and *Zai* pits. The results revealed that the yield of maize grain and components as biomass of the dry matter, and length of the cob were highly significant ($p<0.05$) on Targa. Targa and tied ridges had significantly higher content of moisture throughout the dry period during the whole season of crop growing.

2.4.2 Macro Catchments

2.4.2.1 Earth Dams and Water Ponds or Pans

According to Biazin *et al*, (2012), the technologies have positive response both for crops and water productivity responses in semiarid areas. A study by Kahinda *et al*, (2007) in Zimbabwe, found out that macro catchment system increased water productivity from 1.75kg/m^3 to 2.3kg/m^3 by mitigating intra seasonal dry seasons. In Kenya, Barron and Okatch, 2005 found out that hand dug dams with fertilization increased the rainwater use efficiency of maize from 2kg/m^3 when not irrigated and fertilized to 4.1kg/m^3 with irrigation during season with low rains.

A study by Mzirai and Tumbo (2010) revealed that macro-catchment RWH systems increases water use efficiency up to more than 20 kg ha-1 mm-1 when compared to rain-fed system where water use efficiency can hardly reach 3 kg ha-1 mm-1. They also proved that by receiving more than 70 mm of additional runoff, farmers can manage the water and capitalize on higher value crop. This is one-way poverty is reduced as farmers can produce even for sell in the market.

Fox and Rockstorm, (2003) conducted a study in Burkina Faso and found out that 75% of water was lost by seepage and 5% through of harvested dam water. A similar study in Kenya by Okatch and Baron (2005) revealed that 57% of water was lost by seeping and 12% evaporating. Makurira *et al,* (2007) indicated that during conveyance to the field, much water was lost hence lowering the irrigation efficiency of macro dams. To overcome the challenge of seepage and evaporation low cost drip system can be used; a study in semi-arid of Zimbabwe by Maisiri *et al*, (2005) revealed that more than 50% of water can be saved by use of drip system.

2.4.3 Micro Catchments

Biazin *et al*. (2011) found out that there was promising water and crop productivity where there are micro catchment rain water harvesting techniques. Abudulkadir and Schultz (2005) set up a field experiment where they were to study growth of trees species used for multiple purpose intercropped with grass in plots with micro catchments. The findings revealed that there was31% more moisture during the wet season and in dry season, 24% more moisture compared to plots without the technologies. Dry matter yielded 32% more on 100 m^2 than 25m^2 plot as it showed a higher dependence on area of the micro catchment. There is a maximum level of soil around bunds and trenches in semi-arids. The trenches and bunds concentrate little available rainfall into green water flow paths, (Makurira *et al*, 2009). A study by Kabore and Reij, (2004) concluded that *Zai* pits can be used to rehabilitate land where nothing was grown previously. This expands land for agricultural purposes.

Aydrous *et al*, (2015) conducted a study to evaluate the efficiency in retaining runoff and the content of moisture in the soil of four different micro catchment rain water harvesting techniques. They also determined which of the rain water harvesting technique is suitable. The techniques included pits, deep ditches, V-shaped dikes and semi-circular bunds. There was high soil moisture content in the techniques when equated to the control, especially during months towards the end of the rainy season. For example, there was increased percentage of moisture content in soil in October in the semicircular, V-shaped, pits and deep ditch micro catchments as paralleled to the control was about 92.8%, 127.2%, 78.3% and 68.3% for the 2010-2011 season and 92.8%, 109.0%, 81.1% and 43.2% for 2011-2012 season, correspondingly. These treatments improved soil moisture content as compared to the control by about 5199.0%, 6399.0%, 4799.0% and

3699.0% and by about 8685.7%, 13328.6%, 7328.6% and 4900.0%, correspondingly during April for both seasons. This was attributed to the ability of the technique to collect, store and hold more surface runoff and reduce evaporation.

Kumar *et al*, (2013) conducted a field experiment for apple production under rain fed state where micro-catchment rain water harvesting and conservation methods would affect its moisture content. The techniques employed included; full moon, half moon, trench, cup and plate and no water harvesting (control). The results showed that vegetative growth of apple trees was subjected by rain water harvesting techniques in rain-fed conditions. High average mean plant height, trunk cross sectional area, canopy bulk and yearly shoot growth were recorded in complete moon water harvesting system then next was by incomplete half-moon system and minimum in control. The full moon water harvesting system increased the plant height (31.25 %), Tree cross section area, TCSA (33.58 %), canopy bulk (75.94 %) and yearly shoot growth (22.14 %) over control treatment. The full moon water harvesting system showed better performance compared to half-moon owing to even availability and distribution of moisture in the soil around the root zone that is active and trans-located to all other tree parts hence increasing its vegetative growth.

2.4.4 Rooftop Catchments

In a study by Adunga *et al*, (2018) revealed that rooftop rain water harvesting has the potential of reducing scarce water supply in Addis Ababa. The sources that supply water currently are vulnerable to the lengthy dry months and climate change. RWH could decrease the vulnerability of the water supply in urban areas. Moreover, RWH will ease the stress on the groundwater water resources as water directly collected from the roofs will be used and the surplus saved. That which has been recharged to the ground shall be used during dry periods.

2.5 Factor Influencing Utilization of Rain Water Harvesting Technologies

From the already conducted research, there is numerous perceptions in the correlation between farmers' demographic status and their choice to adopt or not adopt water and land conservation technologies. Siraj and Beyene, (2017) conducted research in Gursum District in Ethiopia on the determinants of RWHT. They selected 150 households, 105 adopters and 45 non adopters based on the proportion of users and non-users. The results showed that farming experience, education level of sampled household heads, family size, labor availability mean land holding and external support were statistically significant and had a positive potential relationship to adoption while distance to the market was negatively significant related to adoption since as distance to the market increased, access to necessary tools for construction of RWHT technologies reduced.

Teshome *et al*, (2015) conducted a detailed farm survey in three water sheds on the drivers of different stages on the adoption of soil and water conservation (SWC) technologies in the north-western highlands of Ethiopia. They used a simple descriptive statistic and an ordered probit model in analyzing the drivers of diverse phases of adoption of SWC. It was evident from results that some socio-economic and institutional factors affect the three adoption stages, initial, actual and final adoption stages of SWC in different ways. The labor used in the farm, the parcel size, the possessed tools, teachings in SWC, programs present in SWC, social capital, distribution of labor schemes and perception of erosion problems have an influence that is significant and positive on actual and final phases of adoption of SWC. Moreover, tenure security, cultivated sizes of land, slopes of the parcels and the perceptions of the importance of SWC related positively to the final step of adoption of SWC. They recommended to the policy makers that they needed to consider factors affecting adoption of SWC. These factors include; profitability, security of tenure, social capital, technical support, and resource endowments (e.g., tools and labor) while planning and implementing SWC policies and development programs.

Cheserek *et al*, (2013) in Keiyo district of Kenya examined the factors influencing farmers' decision to adopting rainwater harvesting techniques. This study categorized social economic factors into household variables as age, gender and education level and economic variables such as wealth status, social status. The study found out that adoption rate by female headed households was low, those with high level of education that is above primary level have positive attitude toward adoption compared to those who had not attended school. Households with young household heads adopted rainwater harvesting technologies, they were enthusiastic about adopting the technology, financial endowment of rich and in between-income household motivated them to taking credit and spend in RWHT. Members who belonged to a social institution were found to adopt RWHT as they could access information during group meetings about the technologies and its advantages. Households with positive perception on rain water harvesting were found to adopt the technology while those with undesirable perception avoided utilizing the technology. Among the factors that were found to negatively influence the utilization of RWHT were; poor endowment of both capital and human resource, lack of access to credit and negative perception.

Llyod James, (2015) examined the factors influencing adoption of rain water harvesting technologies in Msinga, South Africa. He used questionnaire to gather data from 180 households. In order to evaluate the different factors, he used the binary logistic regression to evaluate the different factors influencing adoption. From his findings, the study showed that 126 of the house-holds selected had at-least adopted at least one form of RWHT. Factors such as gender, education, household income, social capital, contact with extension agent, security of land and farmers' perception had a significant positive effect on adoption while age was not significant. He concluded that it is important that policy makers and private sector target young farmers while promoting adoption, there is need for effort to reduce gender gap in adoption, farmers need to be educated on RWHT and farmers contact to extension officers should be increased as it positively influences rain water harvesting technology adoption.

Ahmed *et al*, (2013) assessed the factors prompting adoption of rainwater harvesting technologies amid households of Yatta district (Kenya). Logistic regression model was used to evaluate different factors influencing adoption elements of rainwater harvesting technologies. They found out that a good number of farmers knew of a diverse WHT, where roof WH (45%) and dams (36.1%) were rated highest. House-holds were willing to adopt them within their local setting. Factors that positively influenced the adoption included education level of household head, awareness of water harvesting techniques, age and the experience of water shortage. The study established that for effective application and successive adoption of rainwater harvesting technologies, technical knowledge and skills, capital, availability of raw materials and support from necessary organizations would be required by farmers. Furthermore, it is important that farmers get mobilized and trained on the use of rainwater harvesting technologies. Additionally, they need to be informed on the possible socioeconomic profits of adopting RWHT.

2.6 Perceived Effectiveness of Utilization of Rain Water Harvesting Technologies

Aydrous *et al*, (2015) conducted a study to evaluate the efficiency of four different micro catchment rain water harvesting techniques in retaining surface runoff and soil moisture content and to determine which of the rain water harvesting technique is suitable. The techniques included pits, deep ditches, V-shaped dikes and semi-circular bunds. The techniques had a significantly higher means of soil moisture content when it was compared to the control, especially in the months near the end of the rainy season. For example, during October the percentage of increase in soil moisture content in the semicircular, V-shaped, pits and deep ditch micro catchments as paralleled to the control was about 92.8%, 127.2%, 78.3% and 68.3% for the 2010-2011 season and 92.8%, 109.0%, 81.1% and 43.2% for 2011-2012 season, correspondingly. Whereas during April for both seasons, these treatments improved soil moisture content as compared to the control by about 5199.0%, 6399.0%, 4799.0% and 3699.0% and by about 8685.7%, 13328.6%, 7328.6% and 4900.0%, correspondingly. This was attributed to the ability of the technique to collect, store and hold more surface runoff and reduce evaporation.

A study by Mzirai and Tumbo, (2010) found out that macro-catchment RWH systems increases water use efficiency up to more than 20 kg ha-1 mm-1 when compared to system that large depends on rain only where water use efficiency can barely reach 3 kg ha-1 mm-1. They also proved that by receiving more than 70 mm of additional runoff, farmers can manage the water and capitalize on higher value crop. This is one-way poverty is reduced as farmers can produce even for sell in the market.

A study in Kenya by Okatch and Baron, (2005) revealed that seepage accounted for 57% and evaporation 12% hence less water efficiency reducing the effectiveness of macro catchment rain water harvesting technology. Makurira*et al*, (2007) indicated that much water was lost during conveyance from dams to individual fields thus lowering the irrigation efficiency of micro dams. To overcome the challenge of seepage and evaporation low cost drip system can be used; a study in semi-arid of Zimbabwe by Maisiri *et al*, (2005) revealed that more than 50% of water can be saved by use of drip system.

2.7 Conceptual Framework

This is a basic structure that contains certain mental blocks that represent the observational and the logical or unnaturally aspects of a process or system being perceived, (Bogdan and Biklen, 2003). The interconnection of these blocks concludes the framework for certain probable results. The framework involves both dependent and independent variables. In this case, dependent variable is the utilization of the technology while independent variables are the factors influencing utilization, social economic, ecological and technical factors.

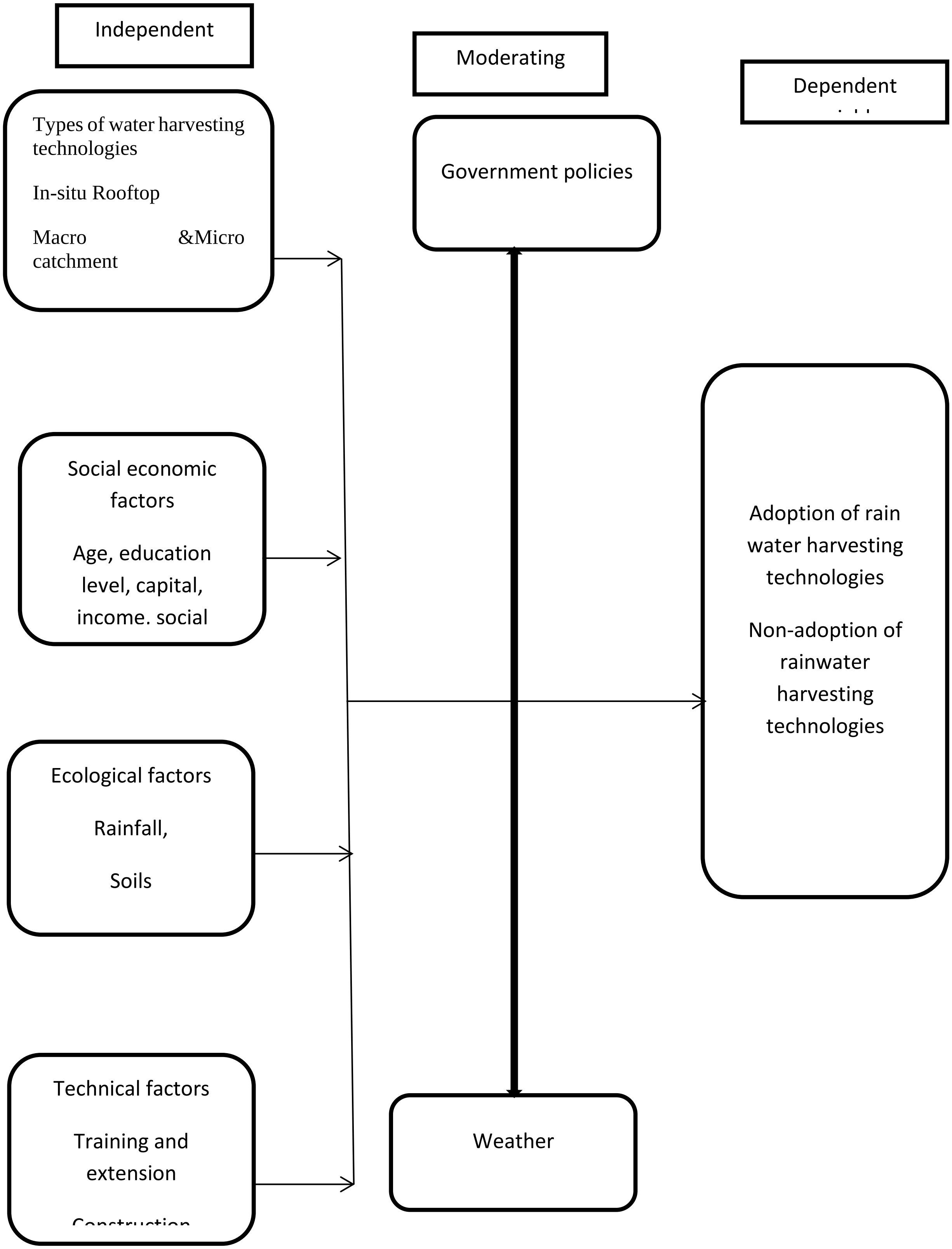

Figure 2.1: Conceptual Framework

Source: *Mbogo Muchagi, 2014*

2.8 Knowledge Gap

From the literature, it is clear that rain water harvesting technologies can improve crop production hence increasing food security in the arid and semi-arid lands especially the micro and macro catchments water harvesting technologies. From the various field experiments discussed above, it is not clear on the extent to which these technologies have been used by the community. This study will focus on the extent to determine if they have been used to a great extent or low extent. From the literature, the technologies have been found to increase on productivity in agriculture. It is however not clear what factors influence the utilization of the various technologies hence the focus of this study to determine them.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

This chapter explains the research methodology that was used in the study.

3.2 Study Area

Kitui County is located about 160km away from the east of Nairobi City with an area of 30,496.4 km^2 this comprising 6,369 km^2 of Tsavo East National Park. There are seven other counties neighboring Kitui. They include: towards the north are Tharaka Nithi and Meru, north west is Embu, Machakos and Makueni counties to the west to the south is Taita taveta county finally to the east and south east is Tana river county. It is in the location of latitudes between 0° 10‶ and 3° 0‶ south and longitudes 37° 50‶ and 39° 0‶ east (GoK, 2009). The County experiences two rainy seasons, the long rains occurring in March/April while the short rains occur in November/December (Luvai *et al*, 2014). It has a low-lying topography with arid and semi-arid climate and rainfall distribution that is erratic and unreliable. There are several highlands namely, Migwani, Mumoni, Kitui Central, Mui, Mutitu Hills and Yatta plateau which receive relatively high rainfall compared with lowlands of Nguni, Kyuso and Tseikuru. Its topography can be divided into hilly rugged uplands and lowlands. Its general land scape is flat with plain towards the east and north east whose altitude is as low as 400m its altitude ranges between 400 and 1800m above the sea level (GoK, 2009). The soils are well drained, moderately deep to very deep, dark reddish brown to dark yellowish brown, friable to firm, sandy clay to clay with high moisture storing capacity and low nutrient availability, (Kibunja *et al* 2010). In most places, they have topsoil of loamy sand to sandy loam.

3.2.1 Map of Study Area

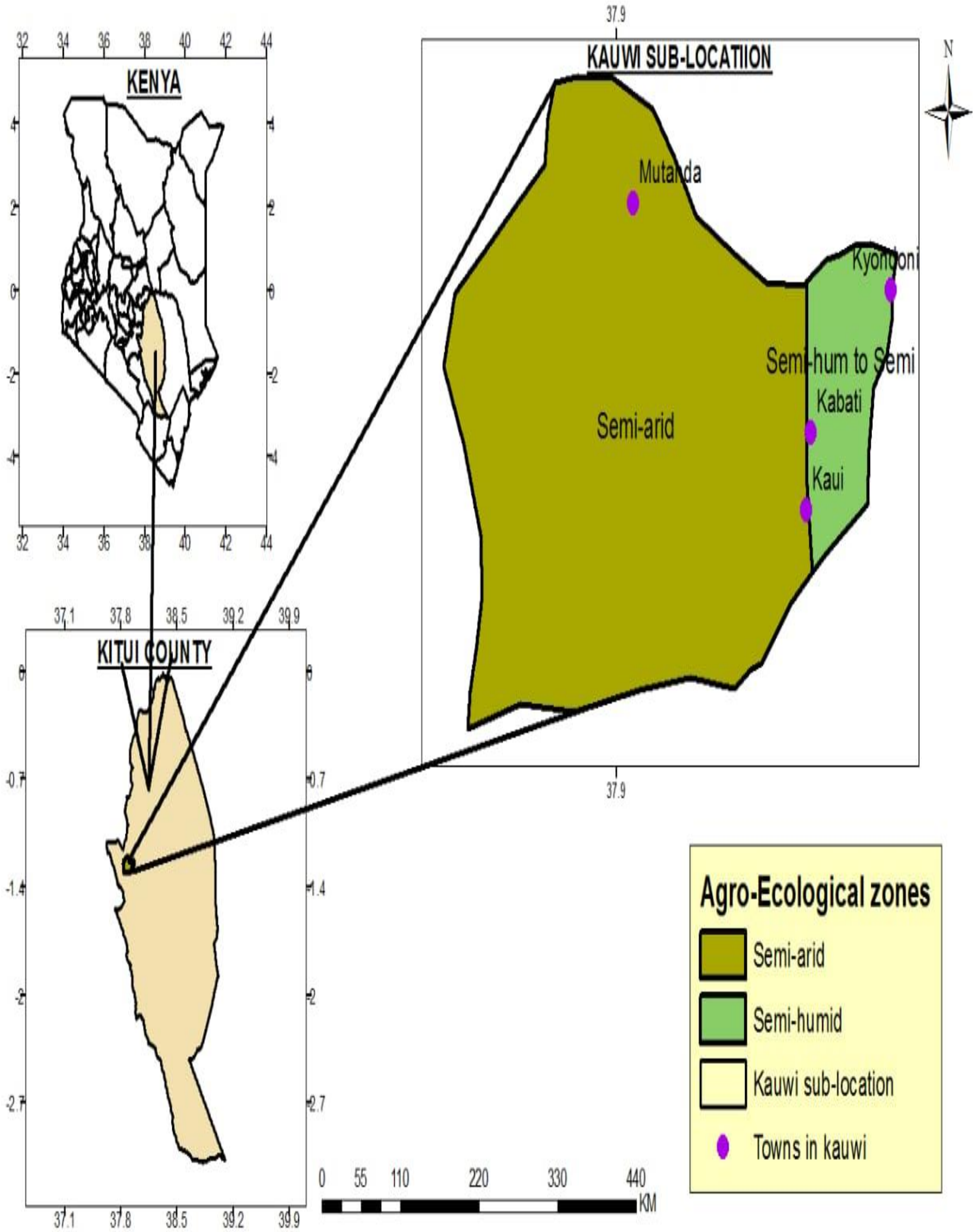

Figure 3.2: Map of Study

Source: ILRI

3.2.2 Climate of Study Area

The climate of Kitui County is arid and Semi-Arid with unreliable rainfall. This climate is in two climatic zones, arid and semi-arid but most of the County being categorized as arid, (Luvai *et al*., 2014). The County's temperatures are high throughout the year, ranging from 14°C to 34°C (GoK, 2009). September and October to January and February are the hot months usually 26°C and 34°C are the maximum mean annual temperatures while the minimum mean annual temperature ranges between 14°C and 22°C. The coldest month is July with temperatures falling to as low as 14°C while the hottest month is that of September with temperature rising as high as 34°C (GoK, 2009). The rate of evaporation is high as the temperatures are high throughout the year. The rainfall pattern is bi-modal with two rainy seasons annually. The long rains come in the months of March to May. These are commonly very erratic and unreliable (Luvai *et al*, 2014). The short rains forming the second rainy season occur between October and December and are more reliable. The other part of the year is dry (Luvai *et al*, 2014). The annual rainfall ranges between 250mm-1050 mm per annum with long rains being 40% reliable while short rains 66% reliable (GoK, 2009). It is difficult to predict rainfall yearly. Seasonal rivers during the periods of rain are the major sources of surface water but after the rains, they dry up.

3.2.3 Social Economic Activity

The community's main economic activity is mixed crop and livestock production. This production system is determined on the agro-ecological zones. Arable farming is the main activity where they grow crops such pigeon, maize, millet, cow peas, green gram, sorghum. They plant cash crops for commercial purpose such as green grams, cotton, coffee sunflower. They rear livestock, goats, sheep, donkeys, chicken and bees (GoK, 2009).

3.3 Study Approach

3.3.1 Research Design

This study adopted a descriptive research design. The design used in the study was a description of variables as they were without any form of manipulating them. The designs helped in identifying factors that influence utilization of rain harvesting technologies in Kitui County. The design accommodated large sample sizes, 160 households and was able to give the general results.

3.3.2 Target Population

The target population was 1600 households. To get a representative sample size of 160 households, 10% of the total population (1600 households) of the study area was sampled; this is according to the established formula of determining sample size, where 10% is the appropriate sample size (Mugenda and Mugenda, 1999).

3.3.3 Sampling Procedure

Kauwi Sub- Location was clustered into 23 villages that were all homogenous and 50% of the villages were then randomly selected by writing down names of all villages on 23 different pieces of papers, then mixing them and picking 12 pieces of named villages for the purpose of the study (Table 3.1). The sample size was obtained proportionately according to the number of households of each village. A point to start collecting data was selected conveniently from the nearest market and the tenth respondent was selected systematically from each village as a study sample for the purpose of being interviewed. The households were obtained from the Kenya National Bureau of Statistics.

Table 3.1: Kauwi Sub-Location Villages

No.	Village	Households	Sample size
1	Kavwata	130	13
2	Ngungu	110	11
3	Kauwi	210	21
4	Kitote B	110	11
5	Mumbuni	120	12
6	Kitote A	130	13
7	Kamukuyu	130	13
8	Nzewani	130	13
9	Kwa Nyingi	130	13
10	Mathayo	130	13
11	KasueA	140	14
12	Kiteeti	130	13
	Total	1600	160

3.4 Data Collection Instruments

Personal observations and household survey interview schedules were adopted for this study.

3.4.1 Interview Schedules

The interview schedule was the key instrument in collecting data for this study. This was used purposely for collecting quantitative and qualitative primary data. This was divided into main areas of investigation.

3.4.2 Validity and Reliability of Research Instruments

The validity is the level to which the research instrument measures what it should measure. The research instrument was confirmed in terms of content by reading thoroughly on related literature and the instrument was also sent to experts in the field of study to review and hence determine the validity.

The research instrument is reliable when it is capable of yielding consistent and stable results after several trials. The researcher checked the reliability of the interview schedule by use of test and retest technique to determine its consistency by administering the same research instrument to the same sample identified for this purpose at different points in time, that was May 2019 and May 2018.

3.5 Data Collection Process

It was essential that the researcher got all the essential documents such as the introduction letter from the University before starting data collection. This was to provide an enabling environment to the researcher from the field and sample interview schedule to help in familiarizing the target population what to expect. People sampled in the study area were also reached to explain the purpose of the study. After the clearance, the researcher personally commenced the process of interviewing sampled respondents.

3.6 Data Analysis

The study will employ both descriptive and econometric model to study the relationship between the change variable and the outcome variables. The Statistical Package for Social Sciences (SPSS) will be used to generate descriptive statistics such as frequency and percentages so as to enable the presentation of the quantitative data in form of tables and graphs based on the major research questions.

To analyze the extent and the perceived effectiveness on rain water harvesting technologies, a Likert scale will be employed. Farmers' perceived effectiveness was put into statements where the respondents had to choose that best describes according to them, least effective, less effective, greatly effective and of greatest effectiveness. For the extent of utilization, all technologies will be noted and a Likert scale of statements as lowest extent, low extent, moderate extent, great extent and greatest extent.

The econometric model will be employed to assess the variables empirically. The econometric model to be employed will be logistic regression model which will be used to analyze factors influencing adoption of rain water harvesting technologies. This model will be chosen because it is simple in estimation hence lends itself to a meaningful interpretation, (Pindyck and Rubinfeld, 1998) and it is also the standard method of analysis when the outcome variable is dichotomous, in this case adoption and non-adoption, (Hosmer and Lemeshow, 2000).

3.6.1 Logit Model

$$Pi = F(\alpha + \beta xi) = \frac{1}{1+e^{-\alpha+\beta xi}}$$

$$Pi = \left[1 + e^{-(\alpha+\beta xi)}\right] = 1$$

Where $\alpha+\beta x_i = \log\left[\frac{P_i}{1-P_i}\right]$

And $\frac{P_i}{1-P_i}$ is the likelihood ratio, whose log gives the odds that a technique is adopted.

Where: α is the constant of the equation

β is the intercept term

The regression can be expressed as

$\text{Log}(p_i/(1-p_i)) = \alpha + \beta 0 + \beta 1 * x1 + \ldots + \beta_n * x_n$

Where, i denotes i th farmer, (1……364); Pi the probability of adoption by the farmers, and (1-Pi) is the probability of non-adoption. Where α is the intercept term, and β_1, β_2, β_3... β_n will be the coefficients associated with each explanatory variable X_1, X_2, X_3... X_n

This table is to help in summarizing how data of each objective was collected

Table 3.2: Operationalization of Variables

	Objective	**Variables**	**Data collection method**	**Method of analysis**
1	Assess extent of utilization of RWHT	Extent	Interview schedule	Descriptive statistics
2	Assessing factors influencing utilization of RWHT	Age, education level, membership to farmers' group, labour source, number of farming years, training	Interview schedule	Logistic Regression
3	Evaluating community's perception on Effectiveness of RWHT	effectiveness	Interview schedule	Descriptive statistics

Table 3.3: Logistic Variable Description

Independent variables	Measurement type
Use of Zai pits, grass strips, trash lines, sand dams, contour bunds, earth dams, rooftops, boreholes, fruit trees, exotic trees, and indigenous trees **Dependent variables** Gender of Household head	Binary (1= yes,0=no) 1= male, 0= female
Age of Household head	Numeric (years)
Education level of Household head	Ordered categorical (1=None, 2, primary, 3=secondary, 4=tertiary)
Occupation of Household head	Ordered categorical (1=full time farmer, 2=business, 3=casual labour, 4=formal employment, 5=other)
House hold size	Numeric (number of inhabitants in household)
Labour source	Ordered categorical (1=family, 2= hired, 3=other)
Land size	Numeric (acres)
Years of farming	Numeric (years)
Type of soil	Ordered categorical (1=clay, 2= sand, 3=loam, 4=others)
Sales surplus	Numeric (Kshs)
Off-farm income	Numeric (Kshs)
Access to credit	Binary (1= yes, 0= no)
Loan borrowed last year	Numeric (Kshs)
Amount of credit without loan	Numeric (Kshs)

3.7 Ethical Considerations

Mugenda Mugenda, (2003) defined ethics as that branch of philosophy that deals with one's conduct and serves as a guide to one's behavior. The researcher sought prior permission from the local administration; the sub chief and the village elders and South Eastern Kenya University to collect data. They provided adequate information and clear explanation on the purpose of the study to the respondents. They then sought for their voluntary consent to participate. The dignity of the respondents was maintained by letting them to speak for themselves and addressing them properly. The researcher ensured that there was no any form of either physical or physiological harassment to the respondent. The researcher politely and cautiously requested the respondent to only provide the relevant information which was treated with great confidentiality.

CHAPTER FOUR `

4.0 RESULTS

4.1 Introduction

Here, the findings of the study were presented.

4.2.1 Demographic Characteristics of Respondents in Kauwi Sub-Location

The demographic characteristics of the respondents presented in this section include gender, education, age, marital status, and occupation, sources of labor and income distribution of the households that participated in this study.

A total of 160 respondents were sampled from Kauwi sub-location. The results indicated that 79.9% of the household heads were males, while only 28.1% were females (Table 4.1). Majority of the heads of households were monogamously married 46.9% whereas 11.3% were single, 15.0% polygamously married, 10.0% divorced and 16.8% widowed. In addition, the results showed that most of the household heads were full time farmers 37.5%, 18.8% were business people, 28.1% casual laborers, and 15.6% had formal employment.

Further, data presented in Table 4.1 indicated that 48.1% of the respondents obtained their sources of labor from members of the family, 33.1% hired labor and 18.8% obtained labor from other sources. The results showed that 11.3% of the household heads had no education at all, 25.0% had primary level of education, 40.0% had secondary level of education, 13.1% had college level of education and 10.6% had university degrees. From the results, it was evident that most of the household heads had secondary level of education.

Table 4.4: Demographic Characteristics of Household Heads in Kauwi Sub-Location

Demography	Value	Percentage (%)
Gender	Male	71.9
	Female	28.1
Marital status	Single	11.3
	Monogamously Married	46.9
	Polygamous married	15.0
	Divorced/ separated	10.0
	Widowed	16.8
Occupation	Fulltime farmer	37.5
	Business person	18.8
	Casual laborer	28.1
	Formal employment	15.6
Source of labor	Family labor	48.1
	Hired labor	33.1
	Others	18.8
Level of education	None	11.3
	Primary	25.0
	Secondary	40.0
	Tertiary	23.7
Group membership	No	78.87
	Yes	21.13
Title deed ownership	No	68.42
	Yes	31.58
Credit Access	No	44.65
	Yes	55.35

4.2 Existing and Utilized Rain Water Harvesting Technologies

Data presented in Table 4.2 indicated the rain water harvesting technologies that have been in agricultural use in Kauwi Sub Location in Kitui County. The results indicated that 81.6% of the households were using *Fanya Juu* Terraces, 9.4% *Zai* pits and 3.1% *Negarim* rain water harvesting technologies. Grass strips were used by 28.5% of the households. Only 6.3% of the households used trash lines while sand dam technology was used by 6.3% of the households. Of the sampled households, 18.4% used contour bunds, 6.3% earth dams, 9.4% water pans, 0.6% rock catchments, 31.6% rooftops and 6.3% boreholes (Table 4.2).

Table 4.5: Use of RWHT by Farmers in Kauwi Sub-Location

RWHST	Used technology (%)		Total (%)
	No	Yes	
Fanya juu	18.4	81.6	100
Zai pit	90.6	9.4	100
Negarim	96.9	3.1	100
Grass strips	71.5	28.5	100
Stone lines	100	0	100
Trash lines	93.7	6.3	100
Sand dam	84.8	15.2	100
Contour band	81.6	18.4	100
Earth dam	93.7	6.3	100
Water pan	90.6	9.4	100
Rock dam	99.4	0.6	100
Roof top	68.4	31.6	100
Bore hole	93.7	6.3	100
Fruit tree	50	50	100
Exotic trees	60	40	100
Indigenous trees	30	70	100
Semi-circular bunds	100	0	100

Values are arranged as percentages

4.3 Extent of Utilization of Rain Water Harvesting Technologies

The results in Table 4.3 indicated that the households had utilized *Fanya Juu/chini* terraces at 60%, which was to a moderate extent. *Zai* and *Negarims* had been used to lowest and low extent of 42.9% and 50% respectively. For grass strips, 34.1% and trash-lines, 42.9% were used by the households a moderate extent while 28.6% used trash-line to a low extent. For sand dams, 60.9% earth dam, 60.7%, water pans, 63.6% and rock catchments 33.3%, households utilized them to a low extent. For those who used exotic trees to a moderate extent were 41.8%.

Table 4.6: Extent of Utilization of Rain Water Harvesting Technologies in the Kauwi Sub-Location Kitui County

	Extent of use in %					
RWHST	Lowest extent	Low extent	Moderate extent	Great extent	Greatest extent	Total (%)
Fanya juu/chini	4.6	33.8	60.8	0.8	0	100
Zai pit	42.9	35.7	14.3	7.1	0	100
Negarim	0	50	50	0	0	100
Grass strips	27.3	38.6	34.1	0	0	100
Trashlines	28.6	28.6	42.9	0	0	100
Sand dam	21.7	60.9	17.4	0	0	100
Contour band	100	0	0	0	0	100
Earth dam	10.7	60.7	28.6	0	0	100
Water pan	9.1	63.6	27.3	0	0	100
Rock dam	20	33.3	46.7	0	0	100
Fruit tree	44.4	22.2	33.3	0	0	100
Exotic trees	34.3	41.8	20.9	1.5	1.5	100
Indigenous trees	40	50	10	0	0	100
Semi-circular bunds	10	40	40	0	0	100

4.4 Influential Factors of the Utilization of Rain Water Harvesting Technologies in Kauwi

This study aimed at studying how different factors influenced individual rain water harvesting technologies in Kauwi Sub-Location. The significance level was at 5% and 1 % significance level.

The most significant rain water harvesting technologies included earth dams 60%, rooftops 58%, trashlines 48%, sand dams 46% and Zai pits 45% rain water harvesting technologies. This was because they had large Nagel kerke value compared to the rest of the technologies.

From the study area, earth dams were the most significant rain water harvesting technologies where 60% of the variation of its utilization was explained by the outcome variables. The variables that significantly influenced the utilization of this technology at 5% level of significance included labour source ($p<0.05$, B=2.66) and access to credit ($p<0.05$, B=5.44). Among the factors that positively influenced utilization of this technology include education ($p>0.1$, B= 0.25), occupation ($p>0.1$, B= 0.29), household size ($p>0.1$, B= 0.50) land size ($p>0.1$, B= 0.58) and the type of soil ($p>0.1$, B= 2.20). Age ($p>0.1$, B= -0.16) is the only factor that negatively influenced the utilization of this technology.

Rooftop rain water harvesting technology was the second most significant rain water harvesting technology where 58% variation of its utilization was explained by the predictor variables. Occupation of household head ($p<0.01$, B=0.93), years involved in farming ($p<0.01$, B=-0.11), type of soil ($p<0.01$, B=-1.17) and off farm income ($p<0.01$, B=0.00) were the most significant factors at 1% significant level. Age of the household ($p>0.1$, B= 0.05), education level ($p>0.1$, B= 0.18), and household size ($p<1.0$, B=0.40) were among the factors that positively influenced the utilization of this technology. Access to credit ($p>0.1$, B= -0.62) influenced the utilization of this technology negatively.

From the table 4.4, trash lines were the third most significant rain water harvesting technology where 48% (Nagelkerke R^2=0.48) of the variation of the utilization of this technology was explained by the outcome variables and 92.1% of the cases were correctly predicted. At 5% significant level, only one predictor variables influenced its utilization, the type of soil ($p<0.05$, B=-2.27).

The variation of utilization sand dam rain water harvesting technology as explained by the predictor variables was 46%. The predictor variables that were significant at 5% level of significance included gender ($p<0.05$, B=-2.31), household size ($p<0.05$, B=-0.43), land size here and elsewhere ($p<0.05$, B=-1.06) and type of soil ($p<0.05$, B=-0.99).

For the *Zai* pits rain water harvesting technologies, the factors that significantly influenced utilization at 5% significance level was age ($p<0.05$, B=-0.11) and land size here and elsewhere ($p<0.05$, B = 0.56) owned by the household head. The results indicated that 45% of the variation of the utilization of the *zai* pits technology was explained by the predictor variables (Nagelkerke R^2=0.45) and 91.1% were correctly classified cases.

From the table 4.4, contour bunds are rain water harvesting technologies whose variation as explained by the predictor variables was 31% (Nagel Kerke R^2=0.31) and whose cases were correctly classified at 88.3%. Soil type at ($p<0.05$, B=-1.02) was the only factor that significantly influenced its utilization at 5% significant level. Gender ($p>0.1$, B= 0.28), age ($p>0.1$, B= 0.02), occupation ($p>0.1$, B= 0.49), land size ($p>0.1$, B= 0.11), access to credit ($p>0.1$, B= 1.24), and household size ($p>0.1$, B= 0.18) are among the factors that positively influenced he utilization of this technology. The factors that negatively influenced the utilization of this technology include education level ($p>0.1$, B= -069), labour source ($p>0.1$, B= -0.96) and yeas in farming ($p>0.1$, B= -0.03).

Trees aid in improving on ground water recharge and in soil conservation by avoiding soil erosion as it holds soil particles together. From the table 4.4, 27% (Nagel kerke R^2=0.255), of the variation of utilization of the fruit tree was explained by the model is and only 68.8% of its cases were correctly classified. Among the factors, those that significantly influenced the utilization of fruit trees at 5% level of significance included labour source ($p<0.05$, B= 0.80), land size here ($p<0.05$, B= 0.23) and the type of soil ($p<0.05$, B= -0.80). Gender ($p>1.0$, B= 0.18), Education level ($p>1.0$, B= 0.45) house hold size ($p>1.0$, B=0.07) and access to credit ($p>1.0$, B= 0.59) were among the factors that influenced positively the utilization of the technology.

From the table 4.4, 33% (Nagel Kerke R^2=0.33) of the variation of the utilization of the utilization of exotic trees was explained by the predictor variables and 67.7% of its cases were correctly classified. Factors such as gender ($p>1.0$, B= -0.41), age ($p>1.0$, B= -0.02), occupation ($p>1.0$, B= 0.32) and household size ($p>1.0$, B=-0.12) negatively influenced the utilization of this technology.

Those that positively influenced the utilization of this technology include education level ($p>1.0$, B= 0.55), labour source ($p>1.0$, B= 0.55 and years involved in farming ($p>1.0$, B= 0.01.

For indigenous trees, 30% of the variation of utilization of this technology was explained by the predictor variables and 76% of its cases were correctly classified. The factor that significantly influenced the utilization of this technology at 5% significant level was labour source($p<0.05$, B= 2.03).The factors that positively influenced the utilization of this technology include type of soil ($p>1.0$, B= 1.00), years involved in farming ($p>1.0$, B= 0.01) and land size here ($p>1.0$, B= 0.26) Those that negatively influenced the utilization of this technology include gender ($p>1.0$, B=-0.59), education level ($p>1.0$, B= -0.26), occupation ($p>1.0$, B= -0.29) and household size ($p>1.0$, B= -0.15).

Table 4.7: Logistic Model for Factors Influencing Utilization of RWHSTs in Kauwi

Parameters	Zai	Grass strips	Trash line	Sand dam	contour bund	Earth Dam	rooftop	Fruit tree	exotic tree	indigenous trees
Gender of household head	-0.96	0.02	1.63	-2.31**	0.28	-4.19	2.49***	0.18	-0.41	-0.59
Age house hold head	-0.11**	-0.01	-0.00	-0.04	0.02	-0.16+	0.05	-0.01	-0.02	-0.04+
Education level household head	-0.72	0.14	1.20	0.21	-0.69	0.25	0.18	0.45*	0.55+	-0.26
Occupation of household head	0.45	-0.37	-0.07	-0.40	0.49	0.29	0.93***	-0.01	-0.37	-0.29
House hold size	-0.03	-0.05	0.35	-0.43**	0.18	0.50	0.40	0.07	-0.12	-0.15
Labour source	-0.35	-0.08	-1.89	0.71	-0.96	2.66*	2.16**	0.80**	0.55	2.03*
Land size here and else	0.56**	0.08	-0.01	0.43^{+}	0.11	0.07	-0.25	-0.04	0.02	-0.02
Land size here	-0.50^{+}	0.02	0.21	-1.06**	-0.17	0.58	0.45*	0.23**	-0.28+	0.26
Years in farming	0.02	-0.02	-0.05	0.07^{+}	-0.03	-0.05	-0.11***	-0.02	0.01	0.01
Type of soil	-0.24	-0.83**	-2.27**	-0.99**	-1.02**	2.20	-1.17***	-0.80**	-0.14	1.00
Sale of surplus	0.00	0.00	0.00	0.00	0.00+	0.00	0.00	0.00	0.00	0.00
Off farm income	0.00	0.00	0.00	0.00	0.00	0.00	0.00***	0.00	0.00	0.00
Access to credit	-1.19	0.71	-0.54	0.08*	1.24	5.44**	-0.62	0.59	-0.97+	0.18
Loan borrowed last year	0.00^{+}	0.00	0.00	0.00	0.00**	0.00	0.00	0.00	0.00	0.00
Amount of credit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Constant	4.89	2.41	1.92	7.09*	0.96	-5.61	-7.04***	-0.89	1.64	2.44
Percentage correct	93.1	77.3	96.1	92.2	88.3	94.5	81.3	68.8	67.7	76
Hosmer	0.19	0.12	0.98	0.67	0.39	1	0.69	0.80	0.57	0.94
Nagelkerke	0.45	0.25	0.48	0.46	0.31	0.60	0.58	0.27	0.33	0.30

*Significance values are as follows: 0 - 0.001 '***', 0.001 - 0.01 '**', 0.01 - 0.05 '*', 0.05 - 0.1 '+', 0.1 - 1.0 (not significant, no symbol), R Core Team (2017).*

Values in the table are the B odds.

4.5 Farmers' Perception of Rain Water Harvesting Technologies

This was the last objective of the study. This section entailed finding out the community's perception of rain water harvesting technologies. This involved assessing the effectiveness of usage of RWHTs in Kauwi Sub Location.

4.6 Effectiveness of Water Harvesting Technologies

Table 4.5 indicate that 40.3% of the households who had utilized *Fanya Juu/chini* water harvesting technology found it to be effective, 34.1% and 25.6% perceived it to be more effective and most effective, respectively. In addition, the results revealed that grass strips, trash lines, rock catchment and rooftops were also perceived as most effective technologies by 4.4%, 10%, and 40% of households respectively. *Negarims* and earth dams were largely perceived as least effective RWHTs by 20% and 6.9 % of households respectively. Sand dams were viewed by 12.5% of the households to be effective, 100% indicated that contour dam was less effective, 58.6% of the households who participated in this study found that earth dam was effective, 10% of the households who used the water pans technology found it to be less effective.

Table 4.5: Effectiveness of Water Harvesting Technologies

RWHST	Effectiveness					Total
	Least effective	Less effective	Effective	More effective	Most effective	
Fanya juu/ Fanya chini	0	0	40.3	34.1	25.6	100
Zai pit	0	7.1	50	28.6	14.3	100
Negarim	20	20	20	40	0	100
Grass strips	4.4	2.2	64.4	24.4	4.4	100
Trash lines	20	10	50	10	10	100
Sand dam	12.5	0	50	33.3	4.2	100
Contour band	0	100	0	0	0	100
Earth dam	6.9	0	58.6	27.6	6.9	100
Water pan	0	10	80	10	0	100
Rock dam	0	6.7	40	13.3	40	100
Roof top	100	0	0	0	0	100
Fruit tree	0	10	60	10	20	100
Exotic trees	0	0	70	20	10	100
Indigenous trees	0	10	60	20	10	100
Semi-circular bunds	0	10	50	20	20	100

CHAPTER FIVE

5.0 DISCUSSION

5.1 Extent of Utilization

From the results in table 4.3, *Fanya juu* / *chini* terraces had been used to a moderate extent at 60.8% and to a low extent at 33.8%. The great extent was ascribed to the fact that the technology has been in practiced in Kenya since the early 1970s. Therefore, most small holder farmers had knowledge about it. Since the technology had lasted for several decades, a big number of households were already practicing it. This agrees with the study by Falkon and Barron, (2009) and Critley *et al*, (1991) who established that the technologies had been introduced on the slopes of Machakos and Kitui in the early 1970 hence increasing its familiarity hence great extent of its utilization.

Zai pits had been used to a lowest extent at 42.9% and *Negarims* to a low extent at 50%.as of table 4.3. The two technologies were still new among the small holder farmers in the study area. Therefore, households were still familiarizing themselves with the two technologies. Due to the fact the technologies were still new hence low extent of its utilization. This agreed with the study by Black *et al, (*2012) who found the two technologies to have been introduced recently in Kenya hence the small holder farmers were still familiarizing themselves with the technology.

Communally owned rain water harvesting technologies were used to a low extent by the community as of table 4.3. Earth dams at 60%, water pans at 63.6% and rock catchments at 33.3%. This could be attributed to the fact that the technologies were communally managed and therefore meant for communal purposes. Where communal management accepted the technologies to be used for agricultural purposes, small holder farmers found out that channeling the water to crop field incurred additional costs. Additionally, a lot of water was lost through seepage and evaporation hence not economical. This resulted to the low extent of utilizing the technologies. This was in line with studies by Fox and Rockstorm, (2010) who conducted a study in Burkina Faso and found out that seepage accounted for 75% loss of water and evaporation 5% of harvested water. A similar study in Kenya by Okatch and Baron, (2005) found that seepage accounted for 57% and evaporation 12%. Makurira *et al*, (2007) found that much water was lost during conveyance from dams to individual fields thus lowering the efficiency of these technologies hence low extent of utilization.

Trash-line is a traditional and local technology where crop residues are placed on soil surface to reduce surface flow. In the study area, as of table 4.3, the technology was used to a great extent at 42.9%. This was credited to the fact that the materials meant for its installation were readily available. These were crop residues of the previous crops in the field that had been harvested. This finding was in line with that of Muriu *et al,* (2017) who found that the technology was simple and easily understood hence its great extent of utilization. However, 28.6% of the households used this technology to the lowest extent. This was because they reared livestock and hence the crop residue would rather be used as animal feed.

Grass strips were used to a great extent at 34.1%, as of table4.3. Smallholder farmers believed accessing the materials for installation of this technology was easy. They borrowed among themselves from those who already had planted the grass along the contours. The households also learned from one another about the technology as it was simple and easily understood. These findings agreed with Muriu *et al, (*2017) in Tharaka-Nthi County where she found that the technology was easily understood by the community and required little knowledge and was less resource intensive.

5.2 Influential Factors of the Utilization of Rain Water Harvesting Technologies in the Kauwi Sub-Location

From the study area, earth dams were the most significant rain water harvesting technologies where 60% of the variation of its utilization was explained by the outcome variables. The variables that significantly influenced the utilization of this technology at 5% level of significance included labour source ($p<0.05$, B=2.66) and access to credit ($p<0.05$, B=5.44). This technology is labour and cost intensive during its initial construction face and maintenance face. Both family and hired labour increased the chances for utilizing this technology. This is because there was more labour made work easier and there was shared responsibility. Access to credit made it possible for the households to access the funds necessary for purchasing of installation materials. This was in line with Mangisoni *et al,* (2019) who found that access to credit enabled small holder farmers to access finance that would later be used to buy installation materials and pay for labour in the initial face and the maintenance face of the RWHTs.

Rooftop rain water harvesting technology was the second most significant rain water harvesting technology where 58% variation of its utilization was explained by the predictor variables. Occupation of household head ($p<0.01$, B=0.93), years involved in farming ($p<0.01$, B=-0.11), type of soil ($p<0.01$, B=-1.17) and off farm income ($p<0.01$, B=0.00) were the most significant factors at 1% significant level. It was very much unexpected that male was more likely to utilize this technology. Most female were responsible in utilizing rooftop rain water harvesting technologies as they were responsible in collecting water for domestic and livestock use. However, this could be due to the fact that the males were the decision makers and responsible for making various households' decisions. This finding was contrary to that of Ibrahim, 2013 who found females to be highly associated with rooftop rain water harvesting technology. Those who were employed were more likely to utilize this technology compare to the unemployed. Employed persons could earn additional income that would be used in buying storage tanks for rooftop rain water harvesting. On the other hand, employed persons were less likely to practice rooftop rain water harvesting to fulfil agricultural needs since the income earned could enable them in purchasing the needed agricultural products. This finding agreed with that of Cheserek *et al* 2013 who found out that employed persons would afford storage tanks for rooftop rain water harvesting technologies.

From the table 4.4, trash lines were the third most significant rain water harvesting technology where 48% (Nagelkerke R^2=0.48) of the variation of the utilization of this technology was explained by the outcome variables and 92.1% of the cases were correctly predicted. At 5% significant level, only one predictor variables influenced its utilization, the type of soil ($p<0.05$, B=-2.27). Trash line involved pilling crop residues along contours in order to control erosion and help in improving water infiltrating into the soil. However, clay had high infiltration rate due to its high infiltration rate no erosion would be experienced due to run off thus this negatively influenced utilization of trash lines in the study area.

The variation of utilization of sand dam rain water harvesting technology as explained by the predictor variables was 46%. The predictor variables that were significant at 5% level of significance included gender ($p<0.05$, B=-2.31), household size ($p<0.05$, B=-0.43), land size here and elsewhere ($p<0.05$, B=-1.06) and type of soil ($p<0.05$, B=-0.99). This was very much unexpected considering the fact that males have been assumed to be household heads who are associated with making final decisions at household level. This study was contrary to Mekonnen, (2017) who found that male were the final decision makers at household level and would therefore influence their decision into utilizing this RWHT. A unit increase in land size reduced the probability of utilization of this technology. A unit increase in land size resulted in decreasing odds in utilization of sand dam RWHT. This could be attributed to the fact that households who had large parcels of land could grow diverse types of crops. Diversifying the crops increased their chances of getting more produce since they believed that incase one crop failed then at least one of the many would not fail. Those who had small parcels were likely to use this technology in order to maximize on the produce. This finding was in line with that by Mangisoni *et al*, (2019) who found that households with small parcels of land were more likely to utilize rain water harvesting technologies in order to make maximum use of their minimal available land. Clay soil type is difficult to rupture when compared to sand soil. Small holder farmers prefer the soil that easily ruptures for construction of rain water harvesting technologies. This finding was in line with that by Mekonnen, (2017) who found out that small holder farmers preferred to install rain water harvesting technologies in soils that were easy to rupture while installing the technologies.

For the *Zai* pits rain water harvesting technologies, the factors that influenced utilization was age ($p<0.05$, B=-0.11) and land size here and elsewhere ($p<0.05$, B = 0.56) owned by the household head. The results indicated that 45% of the variation of the utilization of the *zai* pits technology was explained by the predictor variables (Nagelkerke R^2=0.45) and 91.1% were correctly classified cases. A unit increase in age meant decrease in the odds of utilization of this technology. This was ascribed to the fact that, with increasing age, the people became less energetic. For technologies that needed much energy in its construction then meant that older people would shun away from such hence decreasing in odds of its utilization. This study agreed with that by Tesfaye, 2015 where he found that older people are less likely to adopt new technologies since they have little energy needed for the construction of such technologies. Land size here and elsewhere influenced the utilization of *Zai* pits. Where, in every unit increase inland size, the odds of utilizing his technology increase. This was so much unexpected as people with large parcels were found to diversify on what they were growing in the crop field. They expected not to lose from the various crops grown in the farm. If one failed then the other would not. This was contrary to findings by Mangisoni *et al*, (2019) who found that households with small parcels of land were more likely to utilize rain water harvesting technologies in order to make maximum use of their minimal available land.

Trees aid in improving on ground water recharge and in soil conservation by reducing runoff as it holds soil particles together Jennie, (2016). Factors that significantly influenced the utilization of fruit trees at 5% level of significance were labour source ($p<0.05$and B= 0.80), land size ($p<0.05$, B= 0.23) and the type of soil ($p<0.05$, B= -0.80). A unit increase in labour source increased the odds of utilizing trees as RWHT. Where both family and hired labor was involved there was an increase in the likelihood of utilizing the fruit tree rain water harvesting technology. An initial stage was labour intensive and availability of labour influenced utilization of the technology. This was in line with studies by Llyod, (2015) who established that availability of labour influences the utilization of the rain water harvesting technologies. A unit increase in land size increased the likelihood of utilizing tree RWHT. This is ascribed to the fact that smallholder farmers with small parcels having not learned about the advantage s of trees and feel planting trees is not benefiting when compared to planting crops. Those with large parcels therefore will prefer to plant the trees since they can diversify with other crops on the large parcel. As land size increased, it increased the likelihood of utilizing trees as a RWHT. The farmers believed there was extra land for growing crops besides that of food crops. This disagreed to study by Mangisoni *et al*, (2019) who found out that farmers with small parcels were more likely to adopt the technologies compared to those with large parcels in order to maximize the produce from the land.

5.3 Farmers' Perception on Effectiveness of RWHTs

Fanyajuu/chini rain water harvesting technology was said to be effective, 32.5%. The household heads reported that the technology was effective especially when it came to conserving soil moisture and soil when it was rainy season. By enhancing conserving soil moisture and soil, the crops that were planted along the terraces had enhanced growth and hence increased crop yields.

This agreed with a study by Saiz *et al,* (2016) that found that *fanya juu/chini* terraces were effective since they preserved valuable topsoil and promoted the growth of plants leading to organic matter levels being enhanced. Additionally, the terraces had enhanced crop yields by 25% in East Africa increasing food productivity. The farmers who felt the technology was not effective because of the very high primary cost of constructing terraces. This cost exceeded the profits to be realized in one growing season.

The household heads that had utilized either *Zai* or *Negarim* or both of the technologies had found them to be effective at 50% and most effective at 40% for the two respectively. The *zai* pits had crop growth that was enhanced and when the rains disappeared while the crop was growing, the crop withstood the dry season. This growth was attributed to the fact the *zai* pits had hold moisture in it that enhanced crop growth. This result agreed with a study by Aydrous *et al*, (2015) who conducted a study to evaluate the efficiency of micro catchment such as *Zai* pits rain water harvesting techniques in retaining surface runoff and soil moisture content. The techniques had a significantly higher means of soil moisture content when it was compared to the control, especially in the months near the end of the rainy season.

Negarims were less effective at 20% and *Zai* pits are found to be least effective at 7.1% in the study. This was attributed to the fact that the technologies have been recently introduced in Kenya and are still gaining popularity. The small holder farmers have therefore not learned on the advantage s of using these technologies on improving crop growth. This was in line with studies by, Black *et al,* (2012) who found out that the technologies were still new and hence farmers were still familiarizing themselves the technology.

Grass strips were found to be effective at 64.4% and trash-lines at 50% in the study area. The respondents said that the technologies were easily understood as they learned from one another by seeing. For grass strips, one could easily borrow from the neighbor seedlings to plant on one’s land as a soil conservation measure but also conserving moisture This agreed with studies by (Muriu *et al,* (2017) who found out that grass strips are simple technologies requiring little knowledge and less resource intensive by farmers to install it. Trash-lines were also readily available especially after harvesting season; the trash would be collected and placed along the contours as a soil and water conservation measure during the rainy season. After the rainy seasons, crops that were planted near the grass-strips and along the trash-lines were more productive compared to those that were far from them. This agreed to findings of Muriu *et al,* (2017) conducted a study in Tharaka Nithi County who found out that the technology was less resource intensive and required little knowledge by the farmer to install. From the study area, 20% of the respondents however, responded that the trash-lines were not effective since the materials for making them were used as animal feeds and farmers would rather use the residue as animal feed as opposed to making the trash-line.

Earth dams were found to be effective, 58.6% (table 4.5) and water pans were supposed to be effective, 80% (table 4.5) the respondents agreed that this technology increased crop production in the field compared to when the technology was not used. This attributed to the fact that when rains disappeared, water from this technology would be channeled to the crop field to aid lowering risks of crop production as a result of inadequate soil moisture. This agreed with studies by Barron and Okatch, (2005) found out that hand dug dams (earth dams) with fertilization increased the rainwater use efficiency of maize from 2kg/m^3 when not irrigated and fertilized to 4.1kg/m^3 with irrigation during season with low rains. Other households found the technologies not effective, 6.9% for earth dams and less effective, 10% for water pans. They said the technology required additional costs into channeling water to agricultural fields and that a good amount of water was lost through seepage. This agreed with studies by Fox $ Rockstrom, (2010) in Burkina Faso that found out these technologies to be greatly affected by seepage and evaporation which accounted for water loss at 75% and evaporation accounted for water loss at 5%. A similar study in Kenya by Baron and Okatch, (2007) found that seepage accounted for 57% and evaporation 12% water loss.

Sand dams were found to be effective, 50%. The technology saved a huge amount of water beneath the sand and the water would be channeled to the field for irrigation purposes hence increasing crop productivity compared to when compared to where there were no sand dams. This agreed with a study by Mzirai and Tumbo, (2010) who in a field experiment found out the technology increases water efficiency up-to more than 20 kg ha^{-1} mm^{-1} when compared to rain-fed system where water use efficiency can hardly reach 3 kg ha^{-1} mm^{-1}. A few households, 12.5% found the technology to be least effective. They complained that the technology needed additional costs to channeling water into the agricultural field.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter aims at summarizing, concluding and gives recommendations of the study based on the objectives of the study.

6.2 Summary

Water demand has been increasing worldwide rapidly, causing a gap amid provision and fulfilling the various human needs, and real supply and access to best water quality, mostly in low to medium-income countries. Climatic variation, factors, including social and economic, agricultural variations and demographic variations are a major cause of the increased demand. The change in climate is a risk that puts extreme pressure on hydrological systems and water resources that is by now stressed. Agricultural production largely relies on rainfed production in the Kauwi sub-location, Kitui County. The rain fall distribution is erratic and unreliable in the area causing agricultural production to have minimal or no produce at all when the rainfall comes in a short while.

Rain water harvesting is a technique that is low-cost requiring little or no specific expertise and knowledge. Harvesting of rain water is therefore needed to supplement the inadequate rainfall water that becomes insufficient especially in semi-arid and arid regions. It offers a lot of potential benefits. When appropriate technology is applied in the right place, rain water can be a valuable water resource that can provide convenient, inexpensive and sustainable water for arid and semi-arid lands such as Kauwi Sub-Location in Kitui County.

From the findings, it was evident that most respondents were male headed households 40.25%. The big population was composed of full-time farmers at 73.45%. The population highly relied on hired labour, that is 30.28% of the households, 82.57% had attained a primary level of education with 68.42% of the households not having land title deeds and 55.34% having access to credit. Additionally, the analysis findings showed that technologies that were assumed to be simple and community being familiar with were used to high extent such *fanya juu/chini* at 60.8%, trash lines at 42.9% and grass strips at 34.1% whereas those technologies that were still gaining popularity in the study area were used to a low extent such as *zai* pits 42.9% and *negarims* 50%.

Logistic estimation model technique was employed to assess the utilization of RWHTs. The results from the model indicated that different technologies were statistically significantly influenced by different factors except for the type of soil that influenced all the technologies. The variation of the technologies as explained by the outcome variables was for *Zai* pits 45% and correctly classified at 93.1%, grass strips 25% and correctly classified at 77.3%, trash lines 48% and correctly classified at 96.1%, sand dams 46% and correctly classified at 92.2%, earth dams 60% and correctly classified at 94.5%, rooftops 58% and correctly classified at 81.3%, fruit trees 27% and correctly classified at 68.8%, exotic trees 33% and correctly classified at 68.8% and indigenous tree 30% and correctly classified at 76%.

6.3 Conclusions

On the extent of utilization of the rain water harvesting technologies, the study established that technologies such as *zai* pits and *negarims* had not been utilized extensively. These was due to the fact that they were still new in Kenya at large and in the study area hence were still gaining popularity. There is need for awareness creation about these technologies so to enhance its familiarity in the region hence its utilization among the smallholder farmers.

The study found out that different technologies were statistically significantly influenced by different factors differently except for the type of soil that statistically significantly influenced all the rain water harvesting technologies. It was evident that clay type of soil decreased the likelihood of utilizing all rain water harvesting technologies. Small holder farmers preferred soil type that was easy to dig into for the purpose of constructing these technologies with ease. A unit increase in education level resulted to an increased likelihood in utilization of the rain water harvesting technologies. A higher education level meant more awareness and more knowledge on the advantages of the rain water harvesting technologies hence the positive influence.

The technologies that were simple to install such as grass strips and trash lines were perceived to be effective and those that had loses of water while conveying them to the field were perceived less effective such as sand dams and earth dams where water was lost through seepage and evaporation.

6.4 Recommendations for Further Research

Other research topics that were recommended after the findings are;

i. Analysis on the effect of extension and training of farmers on agricultural productivity in dry regions.
ii. Effect of farmer’s level of education on rain water harvesting and utilization should be conducted so as to ascertain the extent of water utilization and agricultural productivity.

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APPENDICES

Appendix 1: Household Survey Interview Schedule

Kindly respond to all the questions honestly and faithfully as they apply to your farm. The intended study is purely for research purpose and therefore your responses will be treated with strict ***confidentiality****. Answering all the questions will be greatly appreciated.*

Thanks in advance.

Enumerator's Name: ______________________ Date of interview: _______/____/____

Time when the interview started: ___________ End: ___________________________

Sub-County: __________________Ward: ______________ Location: _________________

Sub-Location_____________ Village: ____________________

Coordinates: N_______________________________S____________________________

	Name of the Respondent? Preferably the household head_______		
	Contact (Mobile)		
	ID No.		
	What is the gender of the respondent_________	1=male, 2=female	
	How old is the respondent_______		In years
	How do you relate with the household head? ___________	1=Household head, 2=Spouse of the household head, 3=Grown up child, 4=Relative, 5=Others (Specify)	If the answer is **2** go to **4**
1.	What is the name of household head (**main decision maker on farm operations**) _____________		

2.	What is the gender of the Household head_____	1=male, 2=female	
3.	How old is the household head____		In years
4.	What is the marital status of the household head ________________	1= Single 2=Monogamously married 3=Polygamously married, 4= Divorced/ separated 5= Widowed	
5.	What is type of household______	1=Male headed 2=Female headed 3=De jure female headed (widow, never married, divorced), 4=De facto female headed (husband absent) 5= Not yet married, 6=Polygamous	
6.	What is the education level of household head_____	1=none, 2=primary, 3=secondary, 4=College 5=University 6=Others (specify)	
7.	What is the main occupation of the household head __	1=full-time farmer, 2=Business 3=Casual labourer 4= Formal employment 5=Others (specify)	
8.	Main occupation of the Spouse? _____	1=full-time farmer, 2=Business 3=Casual labourer	

		4= Formal employment 5=Others (specify)	
9.	How many members are of these household (Including respondent)? Male(s)____ female(s)____		
10.	From the above, how many are actively involved in day to day farming? Male(s)____ female(s)____		Indicate the number by gender
11.	Who is the **Major** labour source in the farm? ______	1=family labour, 2=hired labour, 3=other (specify)	
12.	Do you belong to any farmers' group?	0=No, 1=Yes	
13.	If so, is your group registered?	0=No, 1=Yes	
14.	How do you pay your membership fee/contributions payment?	1=Always pays on time; 2=Never pays on time; 3=Rarely pays; 4= Never pays	
15.	For how long have you been a member? _____		Indicate the years
16.	Does the group hold regular meetings? _____		If No go to 17
17.	How often do you meet as a group?_______	1= Weekly; 2= Fortnightly; 3= Monthly;	

		4= Quarter yearly	
18.	Do you attend meetings? _______	0=No, 1=Yes	
19.	Do you have a role you play in your group? _______	0= None; 1= Chairperson; 2= secretary or treasurer	
	How big is your total land size **owned (here and elsewhere)________.**		(In acres)
20.	How big is the total land size **owned (here)_**		(In acres)
21.	For how has this household been involved in farming on this piece of land?(years) ___		Give the number of year e.g. 10
22.	What size of your land is/was: a) Allocated family land? .... b) Inherited? .... c) Purchased? ...... d) Rented in?		
23.	how is the nature of your land	1=steep 2=slanting 3=flat	
24.	What type of soil is in your land	1=clay 2=sand 3=loam	
25.	In what state was your land when you obtained this land?	1=Virgin land/pasture, 2=Land under fallow, 3=Already under cultivation,	

		4=Others (Please specify)	
26.	Do you have land ownership title Deed to this piece of land?	1=Yes, 2=No	If yes go to 25
27.	If not how do you relate with the title deed holder ……	1=Landlord, 2=Parent, 3=Community 4=Others (specify)	
28.	What size of land is under **crops** (in the current season) (acreage)? _______		(In acres)
29.	What size of land is under **pasture** (in the current season) (acreage)? _______		(In acres)
30.	What size of land is under fallow (in the current season) (acreage)? _______		(In acres)
31.	What is the size of land under irrigation throughout the year? (acreage) ________		(In acres)
32.	What is the land size under irrigation during dry spells? (acreage)_________		(In acres)
33.	Do you have any part rented out of your land?	Yes=1, 2=No	If No go to 33
34.	If yes what size(acreage) _______		(In acres)
35.	How much is your approximate annual income earned from farm produce (surplus sold) _______		Indicate the amount
36.	How much is your approximate off farm annual income _________		Indicate the amount
37.	Are you able access to credit?	Yes=1, 2=No	If No go to 37

38.	What is the total amount of credit you can access if you do not have any debt? _______		Amount (Ksh)
39.	What was the amount of loan you borrowed in the past one year? __________		Amount (Ksh)
40.	Is there any significant changes in weather patterns you have noticed over the years in relation to agricultural water availability?_	0=no, 1=yes	
41.	If so, which are these changes you have observed? a) Has the number of seasons without enough rainfall increased _______ b) Is there Rainfall increase _______ c) Is there Rainfall decreased _______ d) Is there Flooding _______ e) Does Rain starts later than expected f) Does rain Starts later and ends early___- g) Is there Shorter periods of rainfall_____ h) Is there Higher temperature _______ i) Is there Lower temperatures _______ j) Is there Long inter-seasonal dry spells __ k) Does Rain starts earlier than expected ____ l) Is there Low overall amounts of rainfall_____	0=No such Change; 1=Increased in frequency 2=Decrease in frequency	

	Others (specify) ______		
42.	What is your type of farming activity?	1) Livestock (2) Crop (3) Mixed (4) Others (Specify)	

1. **Training and utilization of rain water harvesting and conservationTechnologies**

			(codes provided below)							
Rainwater harvesting and **conservation Technology**	**<u>Ownership</u>** <u>1= Self</u>	**<u>Trained</u>** 1=YE	**<u>Use</u>** 1=YES	If YES at what **size**of	**<u>Abandoned</u>** 1=YES	Time used (Yrs.)	If**NO** indicate	if**YES**<u>in trained</u> or <u>in use</u>	Slope of the land 1= Steep	Soil type 1= Loam 2= Clay
1= *Fanya*Juu and										
2= *Zai* pits										
3= *N egarim* pits										
4= Grass strip										
5= Stone terraces										
6=Trash lines										
7= Sand dams										
8= Semi/circular										
9= Contour										
10= Earth dams										
11=Water pans										
12= Rock										
13= Rooftop										
14= borehole										
15=Agro-forestry *(No.of*										
a.Fruit trees										
b. Exotic trees										
c. Indigenous										
16 a. Others 1										
b. Others 2										
c. Others 3										

Codes forreasonofnoteverused
1=neverheardofit
2= lackofknowledge and skills
3=lack ofcapital
4=labor constraints
5=shortageof land
6=Feed to livestock

Codes forhow thefarmerlearnt
1=Extension agent showed

43. Kindly rate the perceived effectiveness and the extent of use of the technology in the community *(Regardless of whether you use the technology)*

NB: First rate the effectiveness followed by the extent of use; for effectiveness circle the scale 5 being most effective and 1 being least effective; for extent indicate by circling whether low (L), Medium (M) or High (H), I do not know (0),

44. From the above water harvesting technologies briefly describe them in terms of viability or durability, requirements in terms of resources, the order in which you prefer them and finally, its ability to store water for critical periods. (*Only for those who have the specific technologies on their farm*)

Rainwater harvesting and **conservation Technology**	**Effectiveness (5,4,3,2,1)** 5= Most effective	**Extent of use (L,M,H,0)**
1= *Fanya*Juu and Chini terraces		
2= *Zai* pits		
3= *Negarim* pits		
4= Grass strip		
5= Stone terraces		
6=Trash lines		
7= Sand dams		
8= Semi/circular bunds		
9= Contour bunds		
10= Earth dams		
11=Water pans		
12= Rock catchments		
13= Rooftop		
14= borehole		
15=Agro-forestry *(No. on cultivated land)*		
a.Fruit trees		
b. Exotic trees		
c. Indigenous trees		
16 a. Others 1 (Specify)		
b. Others 2 (Specify)		
c. Others 3 (Specify)		

RWHT	Durability: (1,2,3,4,5) 1= lowest 5= highest	Viability: (1,2,3,4,5) 1= lowest 5= highest	Labour requirement (1,2,3,4,5) 1= Highest 5= Lowest	Capital Investment (1,2,3,4,5) 1= Highest 5= Lowest	Sufficiency of water for use during dry spells (1,2,3,4,5) 1= lowest 5= highest
1= *Fanya* Juu and Chini terraces					
2= *Zai* pits					
3= *Negarim* pits					
4= Grass strip					
5= Stone terraces					
6=Trash lines					
7= Sand dams					
8= Semi/circular bunds					
9= Contour bunds					
10= Earth dams					
11=Water pans					
12= Rock catchments					
13= Rooftop					
14= borehole					

15=Agro-forestry *(No. on cultivated land)*					
a. Fruit trees					
b. Exotic trees					
c. Indigenous trees					
16 a. Others 1 (Specify)					
b. Others 2 (Specify)					
c. Others 3 (Specify)					

44. Do you have training and extension services provided to you by the agricultural extension officers on rain water harvesting technologies? (Tick appropriately)

(a) yes [ ] (b) No [ ]

45. If yes please explain the following information about the trainings and extension services conducted.

i) Method of training used

1. Demonstration [ ] 2. Workshop/seminar [ ] 3. Other [ ]

46. How many times have you been trained in the last 12 months on rain water harvesting technologies? ______________

Appendix 2: Work Plan

Duration: September 2018-February 2020								
	2018			**2019-2021**			**2022**	
Activity	**May - June**	**July-September**	**October-December**	**January-September 2019**	**September 2019-March 2020**	**April 2021-December 2021**	**January**	**February -March**
Proposal development	■							
Research proposal revision, defence and submission		■						
Testing instruments for data collection.			■					
Actual data collection				■				
Data analysis, interpretation and reporting					■			
Seminar						■		
Submission of the research report							■	
Thesis defence								■

and Publication								

Appendix 3: Budget

Serial	**Item**	**Unit**	**Cost**
1	Printing questionnaire	160	5000
2	Stationary	Pens, note books, pencils	2000
3	Internet and Airtime		5000
4	Transport	2 way	10000
5	Research Assistants	3	25000
6	Flash drive	1	2000
7	Publications	2	22000
8	Breakfast and Lunch	3	5000
9	Printing Thesis for examination	1	2000
10	Printing final Thesis	3	8000
	Total		**76,000**