RAINFALL VARIABILITY AND USE OF RAINWATER HARVESTING AS AN ADAPTATION STRATEGY TO CLIMATE CHANGE IN BARINGO COUNTY, KENYA

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A Research Thesis presented to Institute of Postgraduate Studie in Partial Fulfillment of the Requirements for the Doctor of Philosophy Degree in Environmental Geography of Kabarak University

KABARAK UNIVERSITY

NOVEMBER, 2016

DECLARATION

This research thesis is my original work and to the best of my knowledge, it has not been submitted for examination in any other university, either in part or as a whole.

Signed…………………………….Date………………………………………

GDES/M/1198/09/13

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RECOMMENDATION

To the Institute of Postgraduate Studies:

The research thesis entitled **"Rainfall Variability and Use of Rainwater Harvesting as an Adaptation Strategy to Climate Change in Baringo County, Kenya"** written by Ednah Chemutai Koskei, is presented to the Institute of Postgraduate Studies of Kabarak University. We have reviewed the research thesis and recommend it to be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Environmental Geography.

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ACKNOWLEDGEMENT

I give honour and glory to God for the gifts he has deposited in me throughout the entire study period. Many people have contributed and supported in different ways, in my study at Kabarak University towards this research. To all of them, I wish to extend my sincere gratitude. I am grateful to Kabarak University Institute of postgraduate studies and School of Science, Engineering and Technology for offering me a study opportunity. My whole hearted thanks should go to my supervisors: Prof. Jackson John Kitetu, Department of Environmental Science, Kabarak University and Dr. Charles Wambongo Recha, Department of Geography, Egerton University for their guidance, encouragement and thoughtful comments that made this work a success. I appreciate the invaluable insights provided by them. For his encouragement from the beginning up to end of the research, I am greatly honoured to thank and to express my gratitude to Prof. Kennedy Ondimu (Egerton University). I would like to acknowledge all the respondents who took their time off their busy work schedules to respond to my interview questions. Last but not least, I owe much gratitude to my parents, family members, brothers, sisters, friends and colleagues for their encouragement and moral support. Most notably, I owe the greatest debt to my husband and children for their strong emotional support and constant encouragement and, for their long patience that helped me remain focused throughout the study period.

DEDICATION

To young ladies whose work inspired me with confidence in pursuance of my studies.

ABSTRACT

Climate change is acknowledged in Kenya hence innovations that may help to increase the availability of water are of major importance. The purpose of this study was to assess rainfall variability and use of rainwater harvesting technologies as an adaptation strategy to climate change in Baringo County Kenya. The specific objectives of the study were to: (i) analyze rainfall trends in agro-ecological zones: Lower Midlands 5 (LM 5), Inner Lowland (IL 6) and Lower highland (LH 2); (ii) establish the effects of rainfall variability on access to domestic water; (iii) determine adoption of rainwater harvesting technologies (RWHT) as an adaptation strategy to climate variability; (iv) determine variations in adoption of rainwater harvesting technologies (RWHT) among households by agro ecological zones and; (v) Assess constraints to use of rainwater harvesting technologies (RWHT) at household level. The study utilized three data sets: daily rainfall data (1981 -2010), household survey (N=376) and interviews with key informants. To analyze rainfall variability, the study used rainfall anomaly index to establish rainfall trends for the period on record. To determine adoption of rainwater harvesting technologies, percentage of adopters was calculated while correlation analysis was used to establish the effects of rainfall variability on access to domestic water. Chi- square was used to determine variations in adoption of rainwater harvesting technologies and adoption constraints. Constraints of use of rainwater harvesting technologies were also summarized by use of percentages. In Baringo County, total annual rainfall varied in the three agro-ecological zones. Annual rainfall in LH2 showed an increasing trend whereas in LM5 and IL6, it showed decreasing trends. Only few households (29 %) in Baringo County have no access to domestic water. There was no statistically significant relationship between perceived rainfall amount and access to water. About half of the households (50 %) in Baringo County have adopted RWHTs in their households. Various rainwater harvesting technologies (RWHTs) are used within Baringo County including Roof top Rainwater harvesting technologies (i.e.; storage tanks and wells) and Surface runoff RWHT (i.e.; water pans and dams). Adoption of RWHT significantly varied among the three agro-ecological zones. More than half of the households have adopted RWHT in LH2 while in LM5 and IL6, less than half of the households have adopted. In Baringo, adoption of RWHT has been constrained by lack of finances, inadequate rainwater harvesting structures, rainfall variability, illiteracy, lack of technical skills and knowledge on RWHT, age, source of income and education level of the household head. Lack of finances is the main barrier to adoption. There are government officers and NGO’s in Baringo supporting adaptation through training and implementing some RWHT. There is need for increase of awareness of climate change and development of appropriate mitigation measures. Ways of promoting the adoption of RWHTs such as capacity building and training, provision of adequate rainwater harvesting structures and financial capital, diversifying sources of income, poverty alleviation through enhancement of income generation activities, increasing educational attainments, targeting older people and equipping people with technical knowhow and skills on rainwater harvesting technologies are recommended.

Key word: Climate change; Climate variability; rainwater harvesting; access to water

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ABBREVIATIONS AND ACRONYMS

ACDI	African Climate and Development Initiative
ADB	African Development Bank
AEZ	Agro-ecological zone
ASALs	Arid and Semi-Arid Lands
CARE	Christian Action Research and Education
DTU	Development Technology Unit
ENSO	El Nino Southern Oscillation
EU	European Union
FAO	Food Agricultural Organization
GoK	Government of Kenya
IFAD	International Fund and Agriculture and Development
IPCC	Intergovernmental Panel on Climate change
ITCZ	Inter Tropical Convergence Zone
JMP	Joint Monitoring Programme
KARI	Kenya Agricultural Research Institute
KNBS	Kenya National Bureau of Statistics
KRA	Kenya Rainwater Association
KWAHO	Kenya Water for Health Organization
MALDM	Ministry of Agriculture, Livestock Development and Marketing
M.a.s.l	meters above sea level
MDG	Millennium Development Goal
NCCAP	National Climate Change Action Plan

NCEA Netherlands Commission for Environmental Assessment

NDMA National Drought Management Authority

NEMA National Environment Management Authority

NGO National Research Council

OECD Organization for Economic Co-operation and Development

ODI Overseas Development Institute

RELMA Regional Land Management Unit

RoK Republic of Kenya

RWH Rainwater Harvesting

RWHT Rainwater Harvesting Technology

SEI Stockholm Environment Institute

SID Society for International Development

SPSS Statistical Package for Social Science

UNDP United Nations Development Programme

UNEP United Nations Environment Programme

UNESCO United Nations Education, Social and Cultural Organization

UNICEF United Nations International Children Education Funds

UNSW University of New South Wales

USAID United States Agency for International Development

USEPA United States Environmental Protection Agency

USGCRP United States Global Change Research Program.

USGS United States Geological Survey

WASREB Water Services Regulatory Board

WELL Water and Environmental Health at London and Loughborough

WHO World Health Organization

WRMA Water Resources Management Authority

WSP-AF Water and Sanitation Program-Africa Region

WSSCC Water Supply and Sanitation Collaborative Council

WWAP World Water Assessment Programme

OPERATIONAL DEFINITION OF TERMS

Access to domestic water source is the proportion of people using improved drinking water sources, spend 30 minutes or less to fetch water, the source is less than 1 kilometre away from its place of use and that it is possible for them to reliably obtain at least 20 litres per member of a household per day.

Adaptation refers to efforts by society or ecosystems to prepare for or adjust to future climate change. These adjustments can be protective that is preventing any negative impacts of climate change or opportunistic that is taking advantage of any beneficial effects of climate change (NRC, 2010)

Adaptation strategies: This is adjustment to ecological, social or economic system in response to observed or expected changes in climatic stimuli and their effects and impact.

Adopter: in the context of this study, a person was said to be an adopter if he/she was formally harvesting rain water for domestic uses by investing in rooftop and surface runoff rainwater harvesting technologies and has made use of the technology for five years.

Agro-Ecological Zones: Are geographical areas exhibiting similar climatic conditions

Climate change: Any change in parameters used to describe climate (means and/or variability) over time, whether due to natural variability or as a result of human activities. It may be due to rainfall variability or as a result of human activity.

Improved water sources: these include piped water into dwelling, plot or yard, public tap/ standpipe, tube well/ borehole, protected dug well, protected spring and rainwater collection. Improved drinking water sources are more likely to provide safe drinking water than unimproved sources.

Rainfall Variability: refers to change in rainfall amount, variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes among others) of rainfall on all spatial and temporal scales beyond that of individual precipitation events.

Rainwater Harvesting Technology (RWHT): is a technique used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams.

Rainy Day: The specific day during the long rains or short rains season that receives not less than 0.85 mm of rain.

Rainy season: In this study rainy season was defined as the period from March to July representing long rains and October to December representing short rains.

Unimproved drinking water sources: The proxy indicators are unprotected dug well, unprotected spring, cart with small tank/ drum, tanker, surface water (river, dam, lake, pond, stream, canal, irrigation and channel) and bottled water. Bottled water is considered to be improved only when the household uses water from an improved source for cooking and personal hygiene.

Rooftop rain water harvesting is a system of collecting rainfall water from the roof of a building and storing it in some storage facilities for future use when there is shortage of water.

Surface run-off harvesting - is a system of collecting run-off from a catchment using channels or diversion systems and storing it in a surface reservoir.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study Problem

Water is life and is an essential requirement for the proper functioning of human settlements. Though essential for human life, this basic necessity is not accessible more than three-quarters of of the world's popopulation, most of who are poor (UNICEF, 2014). This implies that water scarcity a major problem for the world's populace. It is projected that by 2025, the number of people affected by water scarcity will increase from about 1.7 billion people today to around 5 billion people (IPCC, 2001b). Access to domestic water represents a day-to-day struggle for many citizens living in developing countries (Herischen, Ruwaida & Blackburn, 2002; Chapitaux, Houssier, Gross, Bouvier & Brissaud, 2002; UN-Water/WWAP, 2006). About 200 million of Africa's population corresponding to about 25 % currently experience high water stress (Boko, Niang, Nyong, Vogel, Githeko, Medany, Osman-Elasha, Tabo & Yanda, 2007). Studies have shown that the population at risk of increased water shortage in Africa is projected to be between75-250 million and 350-600 million people by the 2020's and 2050's respectively. Despite considerable improvements in access to freshwater in the 1990s, only about 62% of the African population had access to improved water supplies in 2000 (WHO/UNICEF, 2000; Vörösmarty, 2005). People living in rural areas are the worst affected, with only 41% of the rural population of Sub-Saharan Africa having access to clean water (UN-Water, 2014). A study carried out by the Food and Agriculture Organization projected that 48 countries in Africa, including Kenya, would face water shortage by 2025 with the USAID reporting that about seventeen million (about 43%) Kenyans currently lack access to improved water supply (USAID, 2011).

According to Dungumaro (2007), increased settlements, human population growth, ignorance, and pricing are the major causes of water shortage. Schollars have argued that socioeconomic status is a significant determinant of household access to water in households (Lawrence, Meigh & Sullivan, 2002). Other variables closely connected with the availability of and accessibility to water include, among others, household size and gender of the household head (Dungumaro, 2007). Overdependence on secondary sources of water coupled with the increasing climate change has increased water scarcity in the world. Climate change and to an extent climate variability, is an additional threat that puts increased pressure on already stressed hydrological systems and water resources (Mwenge Kahinda, Taigbenu & Boroto, 2013). Hydrological resources such as streams, rivers and ponds that are mainly rain-fed are adversely affected by climate change (Onyenechere, Azuwike & Enwereuzor, 2011). Boko *et al.*, (2007) noted that climate change and variability are likely to impose additional pressures on water availability, water accessibility and water demand in Africa. Eastern and southern African countries are characterized by water stress brought about by climate variability and wider governance issues (Ashton, 2002; UNESCO-WWAP, 2006). Several studies have found that climate change has altered not only the overall magnitude of rainfall but also its seasonal distribution and inter-annual variability worldwide (Easterling, 2000; Trenberth, Jones, Ambenje, Bojariu, Easterling, Klein Tank & Zhai, 2007; Zeng, Neelin, Lau & Tucker, 1999).

Developing countries, Arid and Semi-Arid Lands (ASALs) and the poor in society are the most vulnerable and likely to be hit hardest by climate change due to their low adaptive capacity (IPCC, 2007b). Climate change will compound existing poverty (IPCC 2001a). Its adverse impacts will be most striking in the developing nations due to their: geographical and climatic conditions, high dependence on natural resources, and limited capacity to adapt to a changing climate. Within these countries, the poorest, who have the least resources and the least capacity to adapt, are the most vulnerable (IPCC 2001a). Africa, according to studies, is one of the most vulnerable continents to climate change and climate variability due to weak adaptive capacity (Boko *et al.*, 2007). The existing developmental challenges such as endemic poverty, complex governance and institutional dimensions; limited access to capital, including markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts have contributed to Africa's weak adaptive capacity (Boko *et al.*, 2007). Poverty determines vulnerability through several mechanisms, principally in access to resources to allow coping with extreme weather events and through marginalization from decision making and social security (Kelly and Adger, 2000). A number of countries in Africa already face semi-arid conditions (Boko *et al.*, 2007). Although arid and semi-arid regions are already climatically stressed with high temperatures, low rainfall and long dry seasons, they are often thought of as being particularly vulnerable to climate change (ACDI, 2016).

The extent and scope of regional climate change impacts depend on the degree of mitigation (Adger, Khan & Brooks, 2003). Adaptation to climate is not a new phenomenon. Throughout human history, societies have adapted to climate variability (Burton, Diringer & Smith, 2006). Many countries and regions in the world are already taking actions that will help them manage the challenges of climate variability. Africa region is one of them. The approach that each has followed is specific to the context of the region or the country. A number of adaptation measures that can be used to reduce vulnerability to rainfall variability have been suggested by several studies. These include: access and use of seasonal rainfall forecasts, use of water conservation techniques, rainwater harvesting (RWH), multiple and efficient use of water resources, migration to new areas and protecting and restoring stream and river banks to ensure good water quality and safe guarding water quantity by building flood defenses and raising the levels of dykes (NRC, 2010; USEPA, 2009; EU, 2014; Yesuf, Di Falco, Deressa, Ringler & Kohlin, 2008; Burton *et al*., 2006; Smith, 2012). UNEP (2006) observed that many communities and countries facing water shortages because of climate change could significantly boost supplies by collecting and storing rain falling freely from the clouds. Throughout the ages, this has been a traditional way of enhancing domestic water supply (UNICEF, 2004).

Rainwater harvesting is a very old practice and has been in parts of the world for more than 4000 years (Worm and Hattum, 2006). The technology is popular in rural Australia, parts of India, Africa and parts of the United States. (Global Development Research Center, 2002). The importance of traditional, small scale systems of rainwater harvesting in sub-Sahara Africa has recently been recognized (Critchley and Growing, 2013). Rainwater harvesting (RWH) has been proposed as one of the options to improve water supply especially in rural and peri-urban areas of low-income countries (Opare, 2012; Cruddas, Carter, Parker, Rowe & Webster, 2013) as well as in all agro-climatic zones (Amha, 2006). However, the technology is more suitable in arid and semiarid areas (ASALs) (Branco, Suassuna, Vainsencher, 2005; Abdulla & Al-Shareef, 2009) to ensure water availability and access especially during prolonged dry season and drought (Enfors, 2009, Mugerwa 2007 and RELMA, 2007). Improving domestic water supply by rainwater harvesting saves ASALs women and children who spend 3-5 hours per day collecting water and more in periods of drought (NCEA, 2015).

Rainwater harvesting technology (RWHT) can be implemented to alleviate temporal water supply problems and supplement conventional water supply systems, as demand is increasingly growing (Mwenge Kahinda, Taigbenu & Boroto, 2007). However, the full potential of this type of water supply has not been fully exploited many countries. Factors limiting its adoption include lack of finance (Mburu, Kung'u & Muriuki, 2015), space requirements (Traboulsi H. & Traboulsi M., 2015), lack of access to credit facilities (Gbetibouo, 2009), legislation and co-ordination (Mwenge, Kahinda & Taigbenu, 2011), use of poor roofing materials and high cost of storage tank (Opare, 2012; Cruddas *et al*., 2013), installation and maintenance of DRWH systems (Roebuck, Oltean-Dumbrava & Tait, 2011), lack of knowledge on climate change adaptation (Nzeadibe, Egbule, Chukwuone & Agu, 2011), limited knowledge of the potentials of RWH (Kohlitz & Smith, 2015) and poor quality of domestic rainwater (Oke & Oyebola, 2014). Wealth, technology, education, skills, infrastructure, access to resources, various psychological factors and management capabilities can also modify adaptive capacity (Block and Webb, 2001; Ellis & Mdoe, 2003; Adger & Vincent, 2005; Brooks, Adger & Kelly, 2005; Grothmann & Patt, 2005).

Climate, with particular reference to rainfall, is known to be changing worldwide (Chaponniere & Smokhtin, 2006). Rainfall exhibits notable spatial and temporal variability in Africa (Hulme, Doherty, Ngara & New, 2005). Inter-annual rainfall variability is large for the most part of the continent and, for some regions; multi-decadal variability is also significant. The water supply is highly variable: dry or wet spells can range from months to decades. During recent decades, Eastern Africa has been experiencing an increasing dipole rainfall pattern on the decadal time-scale. The dipole is characterized by increasing rainfall over the Northern sector and declining amounts over the southern sector (Schreck & Semazzi, 2004). The annual rainfall cycle in East Africa is influenced by the movement of the Inter-Tropical Convergence Zone (ITCZ), which migrates between 15◦S and 15◦N between January and July respectively, and by the monsoon circulation (Ogallo, 1992). These rainy seasons occur during the transitions between the winter and summer monsoons, when air in both hemispheres converge near the equator (Hastenrath, Polzin & Camberlin, 2004). Eastern Africa's diverse topography contributes to the high spatial variance in seasonal distribution of rainfall. The "short rains" have shown more inter annual variability than the "long rains" despite the larger amounts of rainfall received in March, April and May (Hastenrath, Nicklis & Greischar, 1993; Black, Slingo & Sperber, 2002; Clark, Webster & Cole, 2003). Projections in East Africa suggest that increasing temperatures due to climate change will increase rainfall by 5 - 20% from December to February, and Decrease rainfall by 5-10% from June to August by 2050 (Hulme, Doherty, Ngara, New, & Lister, 2001; IPCC, 2007).

Climate change and climate variability are already taking place in Kenya and their effects are being felt (Okoth-Ogendo, Ogallo, Hulme, Conway, Kelly, Subak & Downing, 1995). The climatic factors of greatest economic and social significance are temperature and rainfall with the latter, eliciting more concern than the former. Rainfall in Kenya is variable, especially in ASALs (NCEA, 2015). Climatic variations in Kenya have been associated with global climatic systems such as the El-Niño/South Oscillation (ENSO) phenomenon and Quasi-Biennial Oscillation

(QBO) (Ogallo, 1992; NCEA, 2015). They have also been associated with shifts in dry land or desert margins and the rise or fall of water levels in lakes and rivers. For instance, lakes Turkana, Baringo, Bogoria, Elementaita, Nakuru, Naivasha and Magadi are estimated to have occupied much larger area in the Holocene period (Okoth-Ogendo *et al*., 1995). As in the rest of the tropical regions, droughts and floods are common phenomena in Kenya. The two are triggered by the same factors and can be either mild or disastrous. They are more common in the arid and semi-arid regions. The main causes/sources of floods are storm surges, El niño/La niña events, and other extremes of climate variability, land terrain, poor drainage systems and regulation of dams (WHO, 2002). The intensity of drought also seems to be increasing over the years as a result of the changing climate (Orindi, Nyong & Herrero, 2007). Notable ones are the 2000/2001 and 2006 droughts which were the worst in at least 60 years (since 1940's) (Orindi *et al*., 2007).

Approximately 80% of Kenya’s land mass is arid and semi-Arid (ASAL) characterized by average annual rainfall of between, 200mm to 500mm per year, and is prone to harsh weather conditions according to Serigne, (2006). Some areas in the northwest and east receive only 200 mm per year (NCEA, 2015). Kenya has a population estimated at 38.6 million (RoK, 2010). Over two thirds of the country is classed as ASALs (Orindi *et al*., 2007), and these areas are home to approximately 30% (~12 million) of Kenya’s people, a third of Kenya’s population (UNDP, 2016). The principal climatic hazard in the ASALs is drought. Most of the droughts exhibit such characteristics as false and late onset of the rains, pronounced breaks during the rainy season, and early cessation of the rains, leading to drastic alterations in the pattern of seasonal rainfall distribution (Jones & Thornton, 2003; Lobell & Burke, 2010; Nyoro, Ayieko, & Muyanga, 2007). Baringo County in mid-west Kenya is predominantly ASALs. While Kenya, like countries in other parts of the world, have considerable experience in dealing with climate variability, climate change is likely to present them with new and tougher challenges. Consequently, the country needs to adopt new strategies to cope with new situations. The current technologies and approach especially in water are unlikely to be adequate to meet projected demands, and increased climate variability will be an additional stress (IPCC, 2001).

Kenya is already counted as one of the most disaster-prone countries in the world, ranking 6thamong all countries in terms of population affected by natural disasters (annual average, 2000-2009) and first among East African countries (Guha-Sapir, Hoyois & Below, 2013). Droughts are the most common disasters affecting Kenya (UNDP, 2016). Major droughts currently occur every ten years, and moderate droughts or floods every three to four years, with devastating results (NCEA, 2015). The recurrence and intensity of droughts has increased in Kenya, particularly affecting the Arid and Semi-Arid Lands (ASALs), which now experience droughts almost on an annual basis (UNDP, 2016). According to the Intergovernmental Panel on Climate Change, Kenya will suffer more intense and frequent droughts in the 21st Century. Flash floods are periodically experienced in Arid and Semi-Arid Lands (ASALs). Kenya is highly vulnerable to climate change because it is a predominantly dry country. Kenya's most vulnerable areas to climate change are the ASALs in the north and east. In these areas, the population is poor and access to infrastructure and markets is low (NCEA, 2015). Increase in frequency of droughts will present major challenges for food security and water availability in these areas in spite of the country acting early to adapt to climate change by implementing the Kenya Arid Lands and Resource Management Project (ALRMP). In addition, the government has realized the need to incorporate climate change issues. A new project is being undertaken – Kenya Adaptation to

Climate Change in Arid Lands (KACCAL) (World Bank, 2007b). However, the country still faces considerable challenges in reaching the water and sanitation Millennium Development Goals (USAID, 2006).

The Kenyan government has introduced reforms in the water sectors through the Water Act of 2002 with a view of conserving and improving water access in Kenya. The water sector reforms appear to have done well in establishment of institutional framework with little impact on improving water accessibility. There is also the National Climate Change Response Strategy (2010) and National Climate Change Action Plan (2012) – policy documents that provide guidelines on how to address the challenge of climate variability in Kenya. There are also efforts by development agencies to improve water accessibility, especially in ASAL areas of Kenya. Notable ones are CARE International, World Vision, Kenya Rainwater Association (KRA) and UNDP. The contribution of development agencies appear scattered in across the country. Despite the efforts, households in Baringo County continue to suffer from water inaccessibility; a situation usually exacerbated by climate variability. Little has been done at local level to safeguard against the uncertainties induced by rainfall variability and even where there is contribution, there is no assessment on its effect on households. In order to ensure safe and adequate water for all Kenyans, the country needs innovative technologies and proactive strategies that will empower its citizens in meeting their water demands.

Baringo County, like the rest of the ASAL areas in Kenya, is characterized by low and erratic rainfall, low fertility, fragile soils with low nutrient content, low organic matter content and poor physical properties for water infiltration and storage (Muchena & van der Pouw, 1981). In 1970, there were seven perennial rivers in Lake Baringo catchment (Jenny and Svensson, 2002). Today only two of them remain with significantly reduced water discharges during dry seasons. The rest of the rivers have become ephemeral like the other watercourses in the area (Odada, Onyando & Obudho, 2006). Water currently in use in Baringo is few rivers, traditional river wells, boreholes, lake and springs (RoK, 2006). This study therefore sought to establish the effects of rainfall variability on household access to water in order to provide them with relevant and appropriate information that can inform their adaptation appropriately and reduce vulnerability to rainfall variability. Domestic Rainwater Harvesting, which provides water directly to households, would enable a number of households in rural areas to access water that conventional technologies cannot supply.

1.2 Statement of the problem

Climate variability is acknowledged in Kenya. However, Baringo County suffers from intensive floods, severe droughts combined with short rainy seasons and drought related losses like any other County situated in the northern regions of Kenya. Given that many households in Baringo County are poor, they are vulnerable to rainfall variability. Household water needs in the County are met from nearby surface water sources or withdrawn from traditional wells (RoK, 2006). However, in the dry season, wells, streams and rivers dry up forcing women and children who do the considerable labour involved in water collection to travel longer distances in search of water for domestic use from unprotected sources. High rainfall variability negatively impact on household access to improved water sources. Many households find it difficult to store quantities of rain falling in very short periods so that it can be used over the entire year. Little has been done at local level to safeguard against the uncertainties induced by rainfall variability and even where there is contribution, there is no assessment on effect on households. It is against this background that this study assessed the effect of rainfall variability on household access to water and the adoption of rainwater harvesting as an adaptation strategy to climate variability in Baringo County.

1.3 Objectives of the Study

1.3.1 Broad Objective

The broad objective of this study was to assess the effect of rainfall variability on household water access and use of rainwater harvesting as an adaptation strategy to climate change in Baringo County.

1.3.2 Specific Objectives

The study was guided by the following objectives:

i To analyze rainfall variability trends in agro-ecological zones LM 5, IL 6 and LH 2 for the period 1981 -2010 in Baringo County

ii To establish the effects of rainfall variability on access to domestic water in Baringo County

iii To determine adoption of rainwater harvesting technologies (RWHT) as an adaptation strategy to climate variability in Baringo County

iv To determine variations in adoption of rainwater harvesting technologies (RWHT) among households by agro-ecological zones in Baringo County v To assess constraints to use of rainwater harvesting technologies (RWHT) at household level in Baringo County

1.4 Hypotheses

To achieve the objectives of the study, the following hypotheses were posited and tested

$H_0$1: There is no variation in rainfall patterns in agro-ecological zones LM 6, IL 6 and LH 2 for the period 1981 -2010 in Baringo County

$H_0$2: There is no relationship between rainfall variability and access to domestic water in Baringo County

$H_0$3: Households have not adopted Rainwater Harvesting Technologies (RWHT) as an adaptation strategy to climate variability in Baringo County

$H_0$4: There is no significant variation in levels of adoption of rainwater harvesting technologies (RWHT) among households by agro-ecological zones in Baringo County

$H_0$5: There are no constraints in using rainwater harvesting technologies among households in Baringo County

1.5 Justification

Kenya is projected to become a water scarce nation in the next 25 years (USAID, 2006) hence; innovations that may help to increase the availability of water are of major importance. Baringo has two rainy seasons and effective RWH systems can decrease the risk of flooding during extreme rainfall events while providing access to clean water during the expected prolonged dry seasons expected because of climate change. It also has an important role to play in poverty reduction, sustainable development and adaptation to climate change (McCartney and Smakhtin, 2010). Countries with low rainfall variability typically have high GDPs (gross domestic products) while countries struggling with large seasonal variability in water availability typically have low GDPs (Brown and Lall, 2009). Increasing the capacity to store water and reduce seasonal differences in availability by use of RWHT to bridge the dry season with wet season may help to redress this balance.

The burden of caring for family members who suffer from waterborne diseases and going for water often falls disproportionately on female members of the household in Africa (KNBS, 2010) hence limiting their time on other activities such as education, income generating and food-related activities, such as preparing food and feeding young children (Bergeron & Esrey, 1993). Again, sickness forces children to miss school and can damage their ability to learn (Carter, Tyrrel & Howsam, 1997). Improving domestic water supply by rainwater harvesting saves women and children from the tedious work of fetching water (UNEP & SEI, 2009). This service will also contribute both directly and indirectly to income generation, health, and education anticipated by Kenya vision 2030 and MDG number seven that calls for reducing by half the proportion of people without sustainable access to safe drinking water by 2015. The findings of the study are expected to inform water authorities and communities in Baringo on adaptation strategies to climate variability that would lead to improved access to water.

1.6 Scope and Limitation

The study was conducted in Baringo County, Kenya. Though climate variability is a function of rainfall, temperature, evaporation, wind and humidity, this study focused on rainfall because it is the most significant climatic factor in tropical Africa, Kenya included. Analysis of rainfall data was limited to annual variations in rainfall amounts and its perceived impact on household access to domestic water in Baringo County.

In this study, efforts were made to include as much data as possible, which was quality, controlled before usage. The rainfall data however had missing values, although this was less than 10% of the total number of observations. For the three rainfall stations used in the study, Perkerra had a different period of data (1981-2008). Chemususu and Nginyang had data for the period 1981-2010. The variation arose as a result of failure of documentation by the Kenya Meteorological Service (KMD). Nonetheless, the data was within the above 25-year threshold required for a climatological analysis (Atheru, 1999).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews previous works and trends that have been recorded related to the research problem of this study. It presents documented literature on rainfall variability, effects of rainfall variability, use and levels of adoption of rainwater harvesting. The chapter also identifies the current gaps in the literature and also presents the theoretical and conceptual framework that will guide this study.

2.2 Climate Change and Variability

Climate Change and Climate Variability are two important characteristics of climate. Climate change has emerged as one of the defining scientific, political and socioeconomic issues of the twenty-first century. IPCC (2007) describes climate change as a change in the state of the climate that can be identified by changes that persists for an extended period, usually decades or longer. Although an area's climate is always changing, the changes do not usually occur on a time scale that is immediately obvious to people. Weather changes can be observed from day to day but slight climate changes are not as readily detectable. Climate takes the several elements into account, most important of which are: air temperature and humidity, type and amount of cloudiness and precipitation (e.g rainfall), air pressure, and wind speed and direction. According to FAO (undated), a change in one weather element can produce changes in regional climate. For example, if the average regional temperature increases significantly, it can affect the amount of cloudiness as well as the type and amount of precipitation that occur. If these changes occur over long periods, the average climate values for these elements will also be affected.

FAO (undated) describes climate variability as variations in the mean state and other climate statistics such as standard deviations, and the occurrence of extremes among others on all temporal and spatial scales beyond those of individual weather events. Variability may result from natural internal processes within the climate system (internal variability) or from variations in natural or anthropogenic external forces (external variability). Every year in a specific time period, the climate of a location is different. Some years have below average rainfall, while some have average or above average rainfall. Climate variability is influenced by warming in the Indian Ocean (Funk, Senay & Asfaw, 2005; 2008; Verdin, Funk, Senay & Choularton, 2005; Funk & Brown, 2009). While the warming has had a large impact on Eastern long rains (Funk, Dettinger, Michaelsen, Verdin, Brown, Barlow & Hoell, 2008; Funk & Verdin, 2009), short-rains (October-December) are strongly influenced by El Niño Southern Oscillation (ENSO) phenomenon (Nicholson & Selato, 2000) and the Indian Ocean Dipole (IOD) (Abram, Gagan, Cole, Hantoro & Mudelsee, 2008). Other determinants of climate variability include: Inter-Tropical Convergence Zone (ITCZ), topography, urbanization and global warming.

It is widely projected that as the planet warms, climate and weather variability will increase. Climate change is inevitably resulting in changes in climate variability and in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events (IPCC, 2012). Climate change can be detected through changes in the average patterns of climate parameters like rainfall, temperature, wind and pressure, among others (Rok, 2013). The Intergovernmental Panel on Climate Change (IPCC) has also recommended indicators that can be used to detect climate change. Some of these indicators include the “number of nights with temperature below/above certain threshold values", cold and warm spells indicators, the daily temperature range, extremely wet days, and the number of heavy precipitation days; among others (Zhang and Yang, 2004; King'uyu, Kilavi, Omeny, Muigai and Njogu, 2011). Several approaches can be used for the analysis of climate change, including statistical and graphical techniques. Modelling is one technique used to simulate climatic variables to generate projections of climatic conditions in the future.

Although the exact magnitude of the changes in temperature, precipitation, and extreme events has not been worked out, on the basis of several General Circulation Model (GCM) scenarios, the future long-range climatic outlook for Kenya signifies an increase in mean annual temperature of 2.5°–5°C magnitude, with up to 25% increase in precipitation (Mendelsohn, Morrison, Schlesinger & Andronova, 2000). In Kenya, present temperature and rainfall trends as well as the increasing frequency of extreme events are expected to continue (NCEA, 2015). Rainfall forecasts vary, depending on which model is used. Even though Intergovernmental Panel on Climate Change (IPCC) models for East Africa predict general rainfall increases, some models applied to the national level predict decreases of 50-150 mm between 2000 and 2025 for most of Kenya (Parry, Echeverria, Dekens & Maitima, 2012). Regardless of which model is used, projections suggest that changes will be different according to location and season. One, the highest increases (or the lowest decreases) are expected for the north of the country with increases up to 40% projected until 2100, in the form of more intense rains. Second, for the long wet season, a 100 mm decrease in precipitation is expected, although a slight increase may occur in highlands and coast and lastly for the short wet season, an increase in rainfall is predicted, especially for the Rift valley (Odera, Thomas, Waithaka & Kyotalimye, 2013).

According to NCEA (2015), temperature projections are more consistent across climate change models. An average increase of 0-2.5ºC is expected for the country between 2000 and 2050, with 1-2ºC as the most likely range (Odera *et al*., 2013). Some models suggest an increase of 4ºC by 2100. Highest increases are expected for the far northeast and smallest increases for the southeast. In general, the plateaus, mountain ranges and coastal area will remain cooler than inland lowlands. Temperature increases will be seasonal, with the smallest increase expected for the start of the long wet season (March – May) (NCEA, 2015). All predictions have indicated increases in frequency of days and nights that are considered hot in the current climate. In this case an additional 15.6% of days per year (57 days) have been shown to be the average number of days in Kenya between 1960 and 2003 (McSweeney, New & Lizcano, 2008). Future projections indicate 17-45% as the number of hot days by 2060s and 23-75% of days per year by 2090s. Hot nights have increased by an average of 113 days (31%) between 1960 and 2003. Hot nights are projected to increase more quickly attaining 32-75% of nights by 2060s and 40-95% by 2090s (McSweeney *et al.,* 2008).

There is emerging evidence that climate change is increasing rainfall variability and the frequency of extreme events such as drought, floods, and hurricanes (IPCC, 2007). Boko *et al*. (2007) project that Africa is likely to warm across all seasons during this century with annual mean surface air temperatures expected to increase between 3°C and 4°C by 2099, roughly 1.5 times average global temperatures. Projections in East Africa suggest that increasing temperatures due to climate change will increase rainfall by 5 - 20% from December to February, and decrease rainfall by 5-10% from June to August by 2050 (Hulme *et al*., 2001; IPCC, 2007).

Analyses from General Circulation Models (GCM's) indicate an upward trend in rainfall under global warming over much of Burundi, Kenya, Rwanda, southern Somali and Uganda (Schreck & Semazzi, 2004). There has been an increase in mean annual temperature by 1.0^{o}C since 1960 in Kenya. This has been projected to increase by 1.0^{o}C to 2.8^{o}C by 2060s and 1.3^{o}C to 4.5^{o}C by 2090s (McSweeney *et al*., 2008). Analysis of long-term climatic data for eastern Africa indicates that climate is absolutely changing with an overall tendency towards enhanced temperatures and rainfall.

Increasing rainfall intensities in Kenya will result in more frequent and heavier floods (accompanied by landslides) and simultaneously prolonged periods of drought. Nation-wide droughts will occur more regularly, but they will mainly affect farmers and pastoralists in the east and north of the country. Glacial melt is expected to continue, eventually leading to complete disappearance of Mount Kenya's glaciers. Finally, rising sea levels will increase the risk of floods in coastal areas. Coastal erosion, a loss of coastal wetlands, and salt intrusion are expected, resulting in total economic costs of sea level rise equal to 7-58 million USD per year by 2030 and 31-313 USD million per year by 2050 (Parry *et al*., 2012).

2.3 Rainfall variability

Rainfall variability refers to variations in the average state and other statistics such as standard deviations, the occurrence of extremes among others of rainfall on all spatial and temporal scales beyond that of individual precipitation events (Odjugo, 2010). Examples of variability include prolonged periods of high lake levels and flows of rivers draining large parts of East and Central Africa (Conway, D., Persechino, A., Ardoin-Bardin, S., Hamandawana, H., Dieulin, C., & Mahe, 2009). While mean temperature varies with elevation, the more remarkable climatic variation is with respect to precipitation (Orindi *et al*., 2007). Rainfall variability is an important feature of semi-arid climates, and climate change is likely to increase that variability in many of these regions. According to Feng, Porporato & Rodriguez-Iturbe (2013), Climate change has altered rainfall variability. Such changes in the rainfall regimes will be most keenly felt in arid and semiarid regions where water availability and timing are key factors controlling biogeochemical cycles (Zeng *et al*., 1999). An understanding of rainfall variability and trends in that variability is needed to help vulnerable dry land dwellers and policymakers address current climate variation and future climate change.

Several studies have been carried out on rainfall at different temporal scales - from daily to annual and in different areas. According to Onyenechere *et al.* (2011), variability like climate change maybe due to internal or external variables. Long term fluctuations in rainfall distribution pattern around the world have been linked to the effects of climate change (Scott, McBoyle & Schwartzentruber, 2004). According to Taylor, Scanlon, Döll, Rodell, Beek, Wada & Holman (2012), climate change will affect rainfall distribution and weather patterns. Inter-annual variability in Africa is influenced by several factors: El Nino Southern Oscillation (ENSO), Inter-Tropical Convergence Zone (ITCZ), topography, urbanization and global warming (Matondo, 2010).

Kenya’s climate varies from tropical on the Indian Ocean coast to arid further inside the country, influenced primarily by the inter-tropical convergence zone, by relief (Great Rift Valley and high mountains) and by large water bodies (FAO, 2016). Long-term average annual precipitation is

630 mm, ranging from less than 200 mm in Northern Kenya to over 1 800 mm on the slopes of Mount Kenya. In many areas of Kenya, rainfall has become irregular and unpredictable; extreme and harsh weather is now the norm; and some regions experience frequent droughts during the long rainy season while others experience severe floods during the short rains (RoK, 2013). Currently, Kenya has a tropical climate, hot and humid at the coast, temperate inland and very dry in the north and northeast parts of the country (NCEA, 2015). Most of the country is arid or semi-arid: 80% of the country receives less than 700 mm of rainfall per year, while some areas in the northwest and east receive only 200 mm per year and maximum 24-hour precipitation can equal around 76 mm3. Areas near Lake Victoria and the central highlands east of the Rift Valley however can receive 1,200-2,000 mm rain per year (Parry *et al*., 2012).

Rainfall in Kenya is variable, especially in arid and semi-arid lands. Micheni *et al*. (2004) noted that drier parts of Kenya's central highlands, eastern Kenya, continue to experience high unpredictable rainfall patterns, persistent dry-spells/droughts coupled with high evapotranspiration (2000–2300 mm year−1). Annual variations follow El Niño and La Niña episodes (higher and lower than average rainfall (Parry *et al*., 2012). The current trends indicate that the first rains of the long wet season have become unreliable and on average significantly reduced (NCEA, 2015). The first rains are sometimes insufficient to support a harvest or even livestock rearing, especially in the east of the country. While the average number of rainy days during the short wet season has reduced from 60 to 30, rainfall has become more intense and the season is being prolonged into January and February, leading to higher total rainfall for this season (NCEA, 2015). Rainfall intensity has increased all over the country, but especially in the coastal area (Parry *et al*., 2012; Hayes, 2007). The area of west-central Kenya receiving 500 mm of rain or more has shrunk since 1960 and is likely to keep shrinking over the next 30 years (UNEP -Global Environmental Alert Service, 2011). Mean annual temperatures have increased by 1ºC since 1960, equal to an average increase of 0.2ºC per decade (Parry *et al*., 2012).

In Kenya, droughts have affected more people and have had the greatest economic impact (8% of GDP every five years) (NCEA, 2015). As many as 28 droughts have been recorded in the past 100 years, at an increasing frequency (Huho and Mugalavai, 2010). Droughts are often nation-wide, but normally have the most severe effects in ASALs. While droughts affect most people, floods have caused the greatest losses of human lives (NCEA, 2015). They are more localized than droughts, seasonally affecting parts of Nyanza and western provinces, especially around the Lake Victoria basin, the Tana River drainage basin, and coastal settlements. ASALs periodically experience flash floods. Since 1950 six serious floods occurred in the country, on average resulting in a loss of 5.5% of GDP every seven years. Of particular concern is the glacial melt at Mount Kenya. The mountain had 18 glaciers in 1900, but in 2008 only seven of them still existed. Since these glaciers supply water to the Tana and Nzoia rivers, there has been a serious decrease in water availability (Parry *et al*., 2012).

In Kenya, researchers such as McSweeney *et al*., 2008, Davies, Vincent & Beresford (1995), Ojany & Ogendo (1988), Sutherland, Bryan & Wijendes (1991) and Camberlin (1996) have observed changing rainfall patterns. Inter-annual and intra-annual rainfall variability is high in Kenya, and in the last half-century, rainfall means have been decreasing inland and increasing on the coast (Orindi *et al*., 2007). Over two thirds of the country, particularly areas around the northern parts of Kenya receive less than 500mm of rainfall per year and are classified as Arid and Semi-Arid Lands (ASALs) (Orindi *et al*., 2007). FAO (2016) observed that the general annual rainfall variations in Kenya and in the Baringo area, follows the passage of the Inter-Tropical Convergence Zone (ITCZ) and the changes in wind directions, which are accompanied by dramatic shifts in precipitation regimes between very dry and very rainy. The rainfall regime of Kenya is dominated by two mainly dry seasons, and two rainy seasons. The rainy seasons are known as the "long rains" and the "short rains". The rainfall distribution pattern is bimodal with long rains falling from March to May and short rains from October to December for most parts of the country (WRMA, 2013). This is a simplified picture of the Kenyan rainfall regime. In the reality the local patterns are more complex because of the influence of the north-south trending mountain ranges and the Rift Valley (Davies *et al.*, 1995).

Seasonal rainfall in Kenya is determined mainly by the migration of the Inter-Tropical Convergence Zone (ITCZ), relatively narrow belt of very low pressure and heavy precipitation that forms near the earth's equator (McSweeney *et al*., 2008). The exact position of the ITCZ changes over the course of the year, migrating southwards through Kenya in October to December, and returning northwards in March, April and May. This causes the Kenya to experience two distinct wet periods – the 'short' rains in October to December and the 'long' rains in March to May. The amount of rainfall received in these seasons is generally 50-200mm per month but varies greatly, exceeding 300mm per month in some localities. The onset, duration and intensity of these rainfalls also vary considerably from year to year (Davies *et al*., 1995). The movements of the ITCZ are sensitive to variations in Indian Ocean sea-surface temperatures and vary from year to year. One of the most well documented ocean influences on rainfall in this region is the El Niño Southern Oscillation (ENSO). El Niño episodes usually cause greater than average rainfalls in the short rainfall season (OND), whilst cold phases (La Niña) bring a drier than average season (McSweeney *et al*., 2008).

According to Ojany and Ogendo (1988), the monthly rainfall distribution in Baringo mainly follows a characteristic bimodal pattern. The short rains occur in October- November and the long ones in April to August. But the long rains consist of two major peaks, one in April-May and one in July-August. That second peak in July-August is the major contributor to the Baringo region's noticeable divergence from the typical two-rainy season pattern. The most southerly position of the ITZC occurs in January when the establishment of the northeast trades occurs. During December to February the western parts of the country, including the Baringo region, are dominated by very dry winds from the Sahara (Ojany & Ogendo, 1988), but stable conditions and low rainfall characterize this period in the whole country. From March to June the northeast flow weakens and a low-pressure system over Lake Victoria give rise to convergent easterly flow bringing moist air from the southern Indian Ocean (Sutherland *et al*., 1991) and thus produce the first rains of the year (the long rains) as the ITCZ is moving northward.

The ITCZ usually hits the Baringo region in the end March or beginning of April, which indicate the start of the wet season there. The most northerly position of the ITCZ occurs in July, over the Sudan. From June to September the southeast trade winds bring maritime air from the Indian Ocean, but despite the maritime origin of the air this is a dry season for large parts of the country. But in the Baringo region the rainfall continues and intensifies in July-August once again. It has been suggested (Davies *et al*., 1995, Sutherland *et al*., 1991) that this second peak is caused by high, naturally unstable, winds known as the Congo Airstream penetrating from the southwest through Equatorial Africa. Another explanation includes interactions between convective thunderstorms, associated with breezes initiated by the pressure of Lake Victoria, and westerlies amplified by the Congo Airstream (Camberlin, 1996). From September to November the ITCZ retreats, and as the south trade almost has disappeared it's replaced by strengthened easterlies carrying moisture from the ocean (Ojany & Ogendo, 1988). The convergence creates the second rainy season in October and November; the "short rains", in Baringo as well as in the whole country.

These studies have described determinants of East African climatology. This has been useful in the monitoring and prediction of climate in East Africa. The studies however did address rainfall variability. The present study sought to analyze rainfall variability with specific focus on annual trends, rainfall amount and distribution of rainfall. The analysis aims at quantifying the magnitude of variation in Baringo County. This information shall be used to relate the implication of rainfall variability on water access at household level. Characterizing rainfall variability is of great importance to rural households not only in Baringo County but also in other parts of Kenya that have the same climatic conditions.

2.4 Effects of Rainfall Variability on Household Access to Water

Land cover, high potential evaporation rates along with precipitation patterns in Africa determine seasonal variations in soil moisture and groundwater recharge as well as surface water availability (Carter & Parker, 2009; Kundzewicz & Döll, 2009). Climate is, with particular reference to rainfall, known to be changing worldwide (Chaponniere & Smokhtin, 2006). This variability throughout Africa brings considerable implications for society and causes pervasive acute human suffering and economic damage (Conway & Hulme, 1996). There has been growing concern worldwide as to the pattern and effects of climate changes particularly rainfall on settlement and infrastructures (Chaponniere & Smokhtin, 2006). The high levels of variability in rainfall and river flows in Africa across a range of spatial and temporal scales have important consequences for the management of water resource systems (Peel, McMahon & Finlayson 2004; Conway *et al*., 2009). They negatively affect water resources such as streams, rivers and ponds that are mainly rain-fed (Chaponniere & Smokhtin, 2006). The effects of climate change are most pronounced among poor and marginal populations whose livelihoods are primarily natural resource based, and where climate change has a potential to cause long-term transformations in local social-ecological systems (Taylor *et al.,* 2012).

The water sector in Africa is strongly influenced by, and sensitive to, changes in climate including periods of prolonged climate variability (Boko *et al*., 2007). Evidence of inter annual lake-level fluctuations and lake-level volatility, for example, has been observed since the 1960s, probably owing to periods of intense droughts followed by increases in rainfall and extreme rainfall events in late 1997. Riebeek (2006) gave examples of Lakes Tanganyika, Victoria and Turkana. After the 1997 flood, Lake Victoria rose by about 1.7 m by 1998, Lake Tanganyika by about 2.1 m, and Lake Malawi by about 1.8 m, and very high river-flows were recorded in the Congo River at Kinshasha (Conway, Allison, Felstead & Goulden, 2005). The heavy rains and floods have been probably attributed to large-scale atmosphere-ocean interactions in the Indian Ocean (Mercier, Cazenave & Maheu, 2002). Climate change and variability are likely to impose additional pressures on water availability, water accessibility and water demand in Africa (Boko *et al*., 2007). The population at risk of increased water stress in Africa is projected to be between

75-250 million and 350-600 million people by 2020's and 2050's respectively. Climate change will have serious and adverse consequences for many development sectors in Africa, and threatens the economies and livelihoods of many African countries (World Bank, 2013).

Access to water in Kenya is likely to become more difficult due to population growth, economic expansion, unsustainable management of water and forest resources, and changes in rainfall pattern (RoK, 2010). Floods, droughts and rising sea levels are just some of the environmental impacts of climate change on Sub Saharan Africa (World Bank, 2013). Kenya is already extremely susceptible to climate-related events and such events pose a serious threat to the socio-economic development of the country (RoK, 2013). Droughts and floods in particular have devastating consequences on the environment, society and the wider economy. Kenya's geographic location makes it prone to cyclical droughts and floods. Global climate change is expected to make such types of cyclical climate-driven events increase in intensity and frequency (WHO, 2016). The adverse impacts are compounded by local environmental degradation, primarily caused by habitat loss and conversions, pollution, deforestation and overgrazing. Forest cover, for example, has reduced from 12 per cent in the 1960s to 6 per cent today (RoK, 2010). According to the science of climate change, these impacts are likely to continue to affect the country in the future. Since Kenya's contribution to global emissions of greenhouse gases is negligible, it is not responsible for causing this problem (RoK, 2013).

According to NCCAP, Kenya has in recent years had its share of climate-related impacts including; prolonged droughts; frost in some of the productive agricultural areas; hailstorms; extreme flooding; receding lake levels; drying of rivers and other wetlands; among others leading to large economic losses and adversely impacting food security (RoK, 2013). More frequent and severe droughts were perceived to be responsible for the reduced water level in Lake Baringo and intermittency of most rivers which were previously permanent. Lake Baringo was reported to have receded for approximately 2 kilometers. According to Kipkorir (2002), while annual rainfall has been decreasing in Baringo, annual and monthly rainfall has been homogenous between 1965 and 2000 implying that the rainfall amount per rainy day is increasing. The shrinking of Lake Baringo was attributed to frequent droughts and siltation due to soil erosion in the lake Basin. Onyando, Kisoyan & Chemelil (2005) reported a decrease in the depth of lake from 8 meters in 1969 to 1.7 meters in early 2003. A study conducted by Jenny and Svensson (2002) in Baringo found that a number of streams have dried out and become seasonal in the past few decades. The study also reported fluctuating water discharge amounts in rivers such as Perkerra. The 2010 National Climate Change Response Strategy (NCCRS) recognized the importance of climate change impacts for Kenya's development. This National Climate Change Action Plan developed in 2012 is the logical next step to enable Kenya to reduce vulnerability to climate change and to improve the country's ability to take advantage of the opportunities that climate change offers (RoK, 2013).

Climate change has caused a shift in the seasonal variability of weather and climate and thus a change in the normal timing and length of wet and dry seasons and increase in the seasonal variation of the water bodies (Odjugo, 2010). The IPCC report of 2001 argued that changes in the total amount of rainfall and in its frequency and intensity directly affect the magnitude and timing of runoff and the intensity of floods and droughts (Cubasch, Meehl, Boer, Stouffer, Dix, Noda & Yap, 2001). The report continued to state that it can have major impacts on water resources, affecting both ground and surface water supply for domestic and other uses. This suggested the implications of decrease or increase for rainfall received in an area and its importance to every facet of human's life. As rainfall received varies over time and space so do water availability varied over time and space that determines the variation in sanitation and development of people all over the world (Ifabiyi & Ashaoulu, 2013). Kundzewicz and Döll, (2009) observed that changes in precipitation patterns and river flow regimes will cause changes in the frequency and magnitude of floods and droughts across Africa. Flooding and drought will have wide-ranging secondary impacts on, for example, food security, hydroelectric power generation and domestic water supply. According to Ishaku, Majid & Joha, (2011), water accessibility is dependent on rainfall variability and this affects household's access to water supply.

Current and future climate change effects impact water availability and food security in Kenya (NCEA, 2015). The projected increase in evaporation, altered rainfall patterns, sea level rise, and accelerated loss of glaciers will further decrease available water for agriculture and other purposes. Although these problems occur all over the country, they are least severe in Nyanza and the Western province (USGS and USAID, 2010). Kenya is a water scarce country with per capita supply of water at approximately 647m3/year and future projections showing a drop to 359 M^3/year by the year 2020 against global benchmark of 1000 M^3 per person per year due to population growth year (Onjalo, 2002). Water and sanitation in Kenya is characterized by low levels of access, in particular in urban slums and in rural areas, as well as poor service quality in the form of intermittent water supply (WASREB, 2009). Only 9 out of 55 water service providers in Kenya provide continuous water supply. According to USAID (2006), water availability helps inform the way in which Kenya approaches water resources management and water supply and sanitation (WSS) service.

While 35.5 million people in Kenya gained access to both improved drinking water sources and improved sanitation in 2006, another 11.9 million need to gain access from 2007 to 2015 to reach the MDG sanitation target and 11.9 million needs to gain access to meet the drinking water target. From the baseline in 1990 to the target date in 2015, the number of rural dwellers without access to basic sanitation will decrease, whereas the number of urban residents without access will increase because of population growth (WHO/UNICEF, 2006). According to JMP (2008), some regions of the world will reach the drinking water and sanitation target but others will not if the current trend is confirmed. For example, in sub-Saharan Africa, with an 85% increase in urban population from 1990 to 2004, the number of urban dwellers unserved with either safe drinking water or basic sanitation doubled from 1990 to 2004. Kenya is off-track to meeting its 90 % target for water and sanitation access (USAID, 2006).

Kenya's most vulnerable areas to climate change are the ASALs in the north and east because the population here is poor (RoK, 2013) and access to infrastructure and markets is low which is limiting adaptive capacity to climate change (Jenny and Svensson, 2002). A large portion of Kenya's population lives in poverty. There are major regional differences: poverty is highest in the Rift Valley, Eastern, and Nyanza provinces (40-70% live on less than 2 USD per day) and lowest in some better-off areas in the Central, Rift Valley, Coast, and Nairobi provinces (10-20%) (Odera *et al*., 2013). Poverty levels have increased in recent years, especially in the densely populated central highlands, where also the most intensive agriculture is found. Over ten million Kenya (Patel, Mbagaya & Imo, 2012). Economic gains mainly benefit the wealthiest quintile of Kenyans, thus contributing to increasing social and economic inequality (Parry *et al.*, 2012). Poverty contributes to people's vulnerability to climate change as it limits their social and financial options for adaptation. Another factor contributing to Kenya's vulnerability to climate change is weak administration and management of land due to a lack of comprehensive national policies. This has caused land fragmentation and disparities in ownership (Odera *et al.*, 2013), potentially resulting in a lack of conservation measures that could help farmers to adapt to (effects of) climate change

Women are among the people most vulnerable to climate change (NCEA, 2015). They manage over 40% of Kenya's smallholder farms and provide 80% of the labour for crop production. The hard work required of women for the purposes of ensuring that there is water in the household also involves girl children (Dungumaro, 2007). A majority of women (80%) spends 1-5 hours per day looking for firewood, and in ASALs women spend 3-5 hours per day collecting water – and more in periods of drought (NCEA, 2015). Because these are women's responsibilities, decreased availability of natural resources due to climate change will seriously affect them. Indirect effects on women and girls include climate change-induced conflicts and disease outbreaks particularly malaria and diarrhea (KNBS, 2010), which cause an extra household care burden. Women's adaptive capacity to climate change is limited by their restricted access and ownership over resources (women own only 1-5% of land titles in Kenya) and capital (Parry *et al.*, 2013).

Some of the on-going responses to climate change in the water sector in Kenya by the government and other stakeholders include: enforcement and/or enactment of laws for efficient water resource management, increasing capture and retention of rainwater, water quality monitoring, de-silting rivers and dams, protecting and conserving water catchment areas, investing in decentralized municipal water recycling facilities, campaigns on water harvesting, developing hydrometric network to monitor river flows and flood warning (NCEA, 2015). National Drought Management Authority (NDMA) was established in the Ministry of Development of Northern Kenya and other arid areas. Its role was to improve water management to prepare for abundance and scarcity. WRMA in the Ministry of Water and Irrigation manage water resources and provide water services. There are also efforts by NGOs such as UNDP. UNDP adapt to Climate Change in Arid and Semi-Arid Lands (KACCAL) in Kenya (2013-2017) to facilitate adaptation of key national and local level stakeholders to long-term climate change through capacity development, policies and programmes adjustment, and pilots for coping mechanisms for smallholder farmers and pastoralists (UNDP Adaptation Learning Mechanism, 2013). Kenya Rainwater Association (KRA) has been working to implement rainwater harvesting and management systems (RHM) and complementary technologies across Kenya since 1994. A founder member of the Greater Horn of Africa Rainwater Partnership (GHARP), KRA works in arid and semi-arid lands (ASALs) with poor farmers and local community groups, to help provide access to a sustainable water supply; improve food security; and help farmers develop their livelihoods (Ngigi, Kariuke & Allan 2013). CARE increase the capacity of vulnerable households to adapt to climate variability and change and to incorporate Community Based adaptation (CBA) approaches for vulnerable communities in development policies and program (NCEA, 2015).

Climate variability and change is making water security harder to achieve and sustain especially in the poorest countries. According to Grey and Sadoff (2007), global climate change is likely to increase the difficulty and costs of ensuring water security. Generally, climate change is expected to lead to reduced water availability in the countries that are already water scarce and an increase in the variability with which the water is delivered (Hirji & Ibrekk, 2001). The water security challenge will therefore be compounded by climate change and it will require considerable adaptation by all countries (Sperling, 2003). This will particularly be the case in poor countries which lack the institutions and infrastructure to manage, store and deliver their water resources and where climate change will be superimposed on existing and in some cases extreme, vulnerabilities. In many of the poorest countries, particularly in sub-Saharan Africa, the currently unmanaged levels of climate variability are several times greater than predicted climate change (Grey & Sadoff, 2007). Falkenmark (2000) found that although many developed countries are focusing on mitigating climate change, developing countries are more focused on adaptation to current climate variability. Success in adaptation to variability is a prerequisite for adaptation to climate change. In all cases, however, adaptive capacity both social and physical will need to be improved to protect the poorest and most vulnerable populations (Grey & Sadoff, 2007).

These studies have described effects of rainfall variability on water resources but do not provide sufficient understanding of inter- and intra-annual and seasonal rainfall variability, which directly impacts on household access to water. This study analyzed rainfall variability with specific focus on annual trends and rainfall amount and their effects on household water availability. These studies further confirmed that rainfall variability and its effects are spatio-temporal and therefore the need to carry out location-specific studies that address the status of various climatic zones.

2.5 Adaptation to Rainfall Variability

There is an increasing emphasis on preparing for climate variations by encouraging adaptation-a process whereby societies improve their ability to manage climate risks and climate fluctuations (Heltberg, Siegel, & Jorgensen, 2010). IPCC (2014) describes adaptation to climate change as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Responses to climate changes can be either reactive or proactive (Smit, Blain & Keddie, 1997). Reactive strategies are adapted after the climate change has been experienced while proactive are those adapted to prevent or reduce the impacts of adverse climate change. Adaptive response can also be classified according to duration covered by the adaptation strategy, that is, short or long-term. Short term strategies are those that are done in one season while long terms are across seasons. In many cases local adaptation measures are coping strategies that is they are reactive and short-term (Bohle, 2001) which can limit the scope for adaptation in the longer term. In this study both short- and long-term responses are regarded as adaptation. Climate change adaptation strategies are characterized by adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change or take advantage of new opportunities (IPCC, 2001). Adaptation can therefore involve building adaptive capacity, thereby increasing the ability of individuals, groups, or organizations to adapt to changes and implementing adaptations decisions, that is, transforming that capacity into actions. Hence adaptations strategies are continuous stream of activities, actions, decisions and attitudes that informs decisions about all aspects of life, and that reflect existing social norms and processes.

Due to the extent of likely repercussions of a changing climate on human and natural systems, it has become a matter that man need to understand and respond to. According to Islam, Sallu, Hubacek & Paavola (2014), adaptation is inevitable to address the impacts of climate variability and change. The major aim in any climate change contest is to identify options for reducing the extent and effects of future climate change (Anita, Dominic & Neil, 2010). Adaptation to changes in climate is not anything new. Throughout history, human societies have frequently demonstrated a strong capacity for adapting to different climates and environmental changes (Adger, Agrawala, Mirza, Conde, O'Brien, Pulhin, Pulwarty, Smit & Takahashi, 2007). However, the current rate of global climate change is unusually high compared to past changes that society has experienced (USGCRP, 2009). In an increasingly interdependent world, negative effects of climate change on one population or economic sector can have repercussions around the world (USGCRP, 2009). Kenya was among the first non- Least developed countries in Africa to develop government plans for responses to climate change across key economic sectors (Okoti, Maina & Newsham, 2013). Kenya's recent National Climate Change Response Strategy (NCCRS), (RoK 2010) and the national climate change implementation framework (2012) illustrate that climate change has acquired the status of a key national policy challenge.

Households especially in the more arid and semi-arid environments where rainfall variability impacts most strongly on water resources, have developed coping strategies to safeguard against the uncertainties induced by seasonal and annual rainfall variability. These strategies include: Access and use of seasonal rainfall forecasts, use of water conservation techniques, rainwater harvesting (RWH), using scarce water resources more efficiently, migration to new areas and protecting and restoring stream and river banks by building flood defenses and raising the levels of dykes (NRC, 2010; USEPA, 2009; EU, 2014; Yesuf *et al.*, 2008; Smith, 2012; UNEP, 2006). The strategies can be applied at either local, regional, national or the international level. Ogalleh, Vogl, Eitzinger & Hauser (2012), in analyzing perceptions and responses in Kenya, found that smallholders' perceptions are that climatic variability is increasing. In dealing with the negative impacts of this variability, the smallholders in this community use diversification of crop varieties, migration and sale of livestock. Okoti *et al*. (2013) found that to deal with immediate climate change impacts in Kenya, Kenyans perceived the need to focus on increasing vegetation cover, expand carbon sinks and bridge the gap between the dry spells.

Rainwater harvesting has been used in Kenya for many years with most focus on the arid and semi-arid areas (ASALs) and rural areas (Otieno, 1994). Rainwater harvesting has been used to enhance household water, food and nutritional security in Kitui West, Lower Yatta and Matinyani Sub-Counties of Kenya (Luvai, Makau, Gitau, Mugachia, Ocharo, Kamau & Wambua, 2014). It has also been used in Makueni County to address the problem of food insecurity (Kimani, Gitau & Ndunge, 2015). Rainwater harvesting will continue to be an adaptation strategy for people living with high rainfall variability for domestic supply (Barron, 2009). RWH systems are viable options both for storing water for domestic use and for recharging groundwater aquifers. Unlike big dams, which collect and store water over large areas, small-scale rainwater harvesting projects loose less water to evaporation because the rain or run-off is collected locally and can be stored in a variety of ways (UNEP, 2006). In spite of greater rainfall variability than many other places, per capita water storage is lower in Africa than elsewhere in the world (McCartney & Smakhtin, 2010) despite rainwater's high potential for alleviating the impacts of climate change on water security in many areas of Africa including Kenya (Mwenge Kahinda, *et al.*, 2013).

According to Taylor *et al*. (2012), while there is an increasing recognition that many adaptation actions are local and build off experience of managing past climatic risks (Christoplos, Anderson, Arnold, Galaz, Hedger & Klein, 2009), there can be barriers and limitations to adaptation. Komba and Muchapondwa (2015) noted that for those communities who undertake any adaptation at all, the choice of specific method depends on a number of elements, including socioeconomic, environmental and institutional factors, as well as the economic structure of the country. Thus, the choice of adaptation methods depends on a range of variables which are considered essential for the availability, accessibility and affordability of particular adaptation measures (Komba and Muchapondwa, 2015). Limits and barriers to adaptation restrict people's ability to identify, evaluate and manage risks in a way that maximizes their wellbeing (IPCC, 2007; IPCC, 2012; Adger, Lorenzoni & O'Brien, 2009; Moser & Ekstrom, 2010). Barriers to adaptation can prevent the development and implementation of adaptations from taking place (Adger *et al*., 2007). High adaptive capacity does not necessarily translate into successful adaptation due to presence of barriers (O'Brien, Eriksen, Sygna & Naess, 2006). Limits and barriers to adaptation can be natural, technological, economic, social or formal institutional (Islam *et al*., 2014). These can come from several fronts including inadequate climate information (Mbah & Nwunuji, 2016; Deressa, Hassan, Ringler, Alemu, &Yesuf, 2009), inadequate financial resources (Mbah & Nwunuji, 2016), partial understanding of climate impacts and uncertainty about benefits of adaptation (Hammill & Tanner, 2011), institutional inertia and lock-in (path dependency) (Chhetri, Easterling, Terando & Mearns, 2010), poverty (Mbah & Nwunuji, 2016), disconnect between climate science and policy leading to a lack of use-inspired research (Moser, 2010), insufficient credit access (Bryan, Deressa, Gbetibouo & Ringler, 2009), and weak market systems (Kabubo-Mariara, 2009). The capacity of local communities to adapt to climate change and mitigate its impacts will also depend on their socio-economic and environmental conditions (IFAD, 2009).

Least Developed Countries (LDCs) have limited capacity to deal with climate change impact hence they have identified adaptation as their top climate-change priority (USEPA, 2013). Within developing countries, the poorest, who have the least resources and the least capacity to adapt, are the most vulnerable (IPCC, 2001). Developing countries, Arid and Semi-Arid Lands (ASALs) and the poor in society are the most vulnerable and likely to be hit hardest by climate change due to their low adaptive capacity (IPCC, 2001a). The most adverse effects of climate change are felt mainly by developing countries, especially those in Africa due to their low level of coping capabilities (Jagtap, 2007; Nwafor 2007; Adebayo, 2011). The risks threaten approximately 70% of rural people living in extreme poverty around the world (OECD, 2007). As climate changes, it's the world's poor and disadvantaged people who are being hit hardest (UNSW Climate Change Research Centre, 2013).

Economic barriers limit adaptation of low-income households and communities (Adger *et al*, 2007). Lack of financial capital is one barrier to adaptation such as adoption of rainwater harvesting (Mburu *et al*, 2015*:* Bryan, Ringler, Okoba, Koo, Herrero, & Silvestri, 2011; Gbetibouo, 2009). The fact that adaptation strategies are costly (Mendelson and Williams, 2004) makes farmers vulnerable to the negative effects of climate change. Lack of funds hinders small-scale farmers and other people from getting the necessary resources and technologies (Mbah, & Nwunuji, 2016). In recent years, microfinance has emerged in many developing countries but it does not often reach the poorest and most vulnerable groups (Amin, Rai & Topa, 2001; Helms, 2006). Budget constraints can also pose a barrier when adaptation measures involve high upfront cost. Those with limited financial capital will focus on short-term gain rather than on the potential long-term benefits of reduced vulnerability (Thaler, 1999). Supporting pro-poor climate adaptation begins by giving primacy to enabling activities that grant the poor the rights, resources and access they need to sustain and benefit from their ecosystem assets (Bapna, Mcgray, Withey & Mock, 2009). Fighting climate change is a global responsibility. But poor countries will need financial and technical assistance from rich countries to shift to a low-carbon economy, while promoting development and reducing poverty.

Technological barriers to adaptation include lack of hard engineering structures, lack of smaller equipment, tools and techniques (Reeder, Jon, Luke & Owen, 2009; Islam *et al*., 2014). Adger *et al.,* 2007 noted that while some adaptations may be technologically possible, they may be constrained by economic and cultural barriers. Technological barriers may also lead to inaccurate information due to, for example, limitations in modelling the climate system or lack of accurate weather forecasts. Insufficient information and knowledge on the impacts of climate change may hinder adaptation (Cruz, Harasawa, Lal, Anokhin &Punsalmaa, 2007). Lack of information to adaptation options could be attributed to the fact that researches on climate change and adaptation options have not been strengthened in the country hence, information is lacking in this area (Mbah & Nwunuji, 2016). Various studies in developing countries, including Kenya, report a strong positive relationship between access to information and adaptation behaviour of households (Yirga, 2007). Access to information through extension services increases the probability of adapting to climate change (Nhemachena & Hassan, 2007). Informal institutions and private social networks like group membership play two different roles in adaptation to climate change strategies. First, they act as channel for information about new strategies. Second, they can facilitate cooperation to overcome collective action dilemmas, where the adoption of technology involves externalities (Oloo, 2013).

According to Adger *et al.* (2007), ethics (how and what people value), knowledge (how and what people know), risk (how and what people perceive) and culture (how and what people live) are key aspects of social barriers. People perceive, interpret, and think about risks and adaptation to them depending on their world views, values and beliefs (Moser & Ekstrom, 2010; Adger *et al.*, 2009). Smith and McCarty (2006) noted that people frequently underrate the possibility of the occurrence of climate events even if they are aware of the risks. Formal institutional barriers may also limit adaptation because they define the processes and rules that govern and regulate access and entitlement to livelihood assets (Islam *et al.*, 2014). Institutional barriers have limited the ability of the rural communities to cope with extreme climate events by limiting access to markets and in terms of unfavorable development policies (Eakin, 2005; O'Brien, Sygna, & Haugen, 2004). Institutions can limit the choice of livelihood strategies for some people; on the other hand, they can open up opportunities for others (Scoones, 1998) and favour some groups over others (Sallu, Twyman & Stringer, 2010).

Innovative technologies and integrated solutions are needed at the appropriate scales for adaptation to climate change (UN water, 2006). According to European Union (2014), adaptation strategies are needed at all levels of administration: at the local, regional, national and also the international level. Many countries, Kenya included are taking a national-scale approach to adaptation and have developed national adaptation policies and programs to address climate change vulnerabilities (RoK, 2010). Local actors are the key to achieving real impact on the ground (European Union, 2014). While international donors and agencies and national governments play important roles in establishing effective enabling environments and channeling resources and technical support, ultimately effective adaptation takes place through the dynamics of local governance, civil society engagement, and economic development building from the actions of local authorities, civil society organizations, and private sector businesses.

These studies describe an international and national-scale approach to adaptation. These are also appropriate scales for adaptation to climate change. This study however focused on local adaptation at community level through affordable, simple and safe rainwater harvesting (RWH) systems. Very little has been done at local level to safeguard against the uncertainties induced by seasonal and annual rainfall variability.

2.6 Rainwater

There are limited sources of water available to provide clean drinking water to the entire population of Africa according to World Health Organization (WHO, 2006). Most drinking water supplies in Africa use point sources such as wells or boreholes (WSP-AF, 2002). However, people live near hills containing perennial springs and streams in many places. Here piped water supplies, usually flowing by gravity or in some cases pumped, may be more appropriate (WSP-AF, 2002). Shallow or deep groundwater provides the daily water supply for about half of Africa's population of almost one billion (Carter & Parker, 2009). The only natural input to other sources of water (surface and ground water) is rainfall. The total amount of water available at any given time is an important consideration. Rainfall is relied on for both surface and groundwater (Taylor *et al*., 2012). Rainwater harvesting provides additional water supply and reduces pressures of demand on surrounding surface and groundwater resources, saves consumer spending on water, helps create green oases and reduce vulnerability in the event of disrupted supplies, reduce storm flow, decrease incidence of flooding and short peak flows (Barron, 2009).

In Kenya, 52.6 % of the population's main supply of water is through an improved source (KNBS and SID, 2013). This is often piped water with 5.9 % having piped water into their dwelling and 19.2 % having access to piped water. During the rainy periods, rain is the main source of drinking water for about 52% of the total drinking water supply. In dry periods the rural population relies on springs, rivers and streams for their drinking water. Boreholes are also relatively common among 12% of the population. However, the single most common source of water across Kenya is the river (unimproved) at 23.2 %. This reflects disproportionate access to clean water resources and supply of related infrastructure. Individuals in rural areas have one and half times less access to improved water sources than their urban counterparts. Baringo County is one of the counties with the least access to improved water sources at 23.4% (KNBS and SID, 2013).

A large percentage of the Kenya's population relies on alternative ways of providing for their daily water needs, mostly by collecting it from running watercourses or domestic groundwater wells, the majority of which are of poor quality and run dry during the drier months of the year (Ogendi & Ong'oa, 2009). Water currently in use is a few rivers, a few river wells, boreholes, lake, springs, and the average distance to and from water sources for domestic is 6.5 km (RoK, 2006). In the last three decades, to increase accessibility to water, the government sank boreholes, constructed catchment dams and provided conveyance infrastructure (Ngigi & Macharia 2006). However, water scarcity still remains the number one ranking issue among most people in Kenya today (Ogendi & Ong'oa, 2009). This is partly because most of the dams and boreholes in arid and semi-arid lands (ASALs) were built without input from local communities. Little consideration was given to the cultural setting of the surrounding communities, which are mostly pastoralist communities that move (Ogendi & Ong'oa, 2009).

Surface water sources are often highly polluted, and infrastructure to pipe water from fresh, clean sources to arid areas is too costly of an endeavor (Awuah, Nyarko, Owusu & Osei-Bonsu, 2009). Groundwater is the best resource to tap to provide clean water to the majority of areas in Africa, especially rural Africa, and groundwater has the benefit of being naturally protected from bacterial contamination and is a reliable source during droughts. However, the high costs associated with drilling for water, and the technical challenges in finding sources that are large enough to serve the population in need, present challenges that limit tapping the resource (WHO, 2006). Rainwater harvesting is one of the alternative technologies for delivering drinking water and can be done anywhere. Through the ages, this has been a traditional way of enhancing domestic water supply (UNEP & SEI, 2009). Rainwater harvesting systems are viable options both for storing water for domestic use and for recharging groundwater aquifers. Rainwater harvesting enables individual households and communities to collect and store rainwater for future use (UNICEF, 2004).

Technically appropriate solutions are necessary to increase the coverage of water supply in rural areas (WSSCC, 2010). Whether the water derives from different sources such as from surface water, spring, ground water or even rainwater catchments, local, or is developed from different methods, such as gravity schemes, wells, boreholes, the decentralized systems are usually the most cost-effective approach. Rainwater harvesting enables people at household and community levels to manage their own water, thereby reducing their reliance on, and burden of, central supply systems. Besides access to safe water, rainwater harvesting yields numerous benefits: environmental (no negative impact), social (empowers people), economic (relatively low cost), as well as contributing to sustainable development (poverty reduction) WSSCC (2010).

The importance of traditional, small scale systems of rainwater harvesting in sub-Sahara Africa has recently been recognized (Critchley and Growing, 2013) and is gradually being adopted with high degree of success in the four Great Horn of African countries (Ethiopia, Kenya, Tanzania and Uganda) (Kiggundu, 2002). The technology has been exploited in Kenya for many years with most focus on the arid and semi-arid areas (ASALs) and rural areas (Otieno, 1994). McCartney and Smakhtin (2010) noted that even relatively small volumes of water storage could, by safeguarding domestic supplies during dry periods, significantly increase economic productivity and enhance people’s well-being. Lack of water storage infrastructure is cited as a major constraint to economic development in many developing countries (Grey & Sadoff, 2006;

Brown & Lall, 2009). Domestic Rainwater Harvesting, which provides water directly to households, would enable a number of households in rural areas to access water that conventional technologies cannot supply.

These studies have described rainwater harvesting as alternative technologies for delivering drinking water. The studies however did not address rainwater harvesting as an adaptation to climate change. This study analyzed the use of rainwater harvesting as coping strategies to safeguard against the uncertainties induced by seasonal and annual rainfall variability in ASAL's. A review of existing literature (e.g. Grey & Sadoff, 2006; Brown & Lall, 2009; WSSCC, 2010) also does not provide adequate reasons as to why households have not widely adopted these cheap and beneficial practices considering all the advantages of using RHT. This study also aimed at determining variation in adoption of RWHT in Baringo County.

2.6.1 Components of Rainwater Harvesting

2.6.1.1 Catchment area

The catchment of a water harvesting system is the surface that receives rainfall directly and drains the water to the system (Worm & Hattum, 2006). It's the part of the land that contributes some or its entire share of rainwater to the target area outside its boundary (Desta, 2004). Catchment surfaces can be either natural or treated (runoff inducement). It is a runoff producing area which may include agricultural, rocky or marginal land, rooftop, paved road among others (Desta, 2004). Worm and Hattum (2006) identify two types of catchment areas: rooftop catchment and surface run- catchment. Any roofing material is acceptable for collecting water.

However, water to be used for drinking should not be collected from thatched roofs or roofs covered with asphalt. Also lead should not be used in these systems. Galvanized, corrugated iron sheets, corrugated plastic and tiles make good roof catchment surfaces. Flat cement or felt-covered roof can also be used provided they are clean.

2.6.1.2 The delivery system/ Diversion channels

This leads water from the catchment area to the silt trap and then to the tank (Nega, 2005). The delivery system from the rooftop catchment usually consists of gutters hanging from the sides of the roof sloping towards a downpipe and tank. This delivery system or guttering is used to transport the rainwater from the roof to the storage reservoir. For the effective operation of a rainwater harvesting system, a well-designed and carefully constructed gutter system is crucial because the guttering is often the weakest link in a rainwater harvesting system. With high intensity rains in the tropics, rainwater may shoot over the (conventional) gutter, resulting in rainwater loss and low harvesting production; splash guards can prevent this spillage. The delivery system from the surface catchment should be made of compacted earth, or lined with cement. It should have a very gentle gradient to prevent it from being damaged (Worm and Hattum, 2006).

2.6.1.3 Storage reservoirs

This is the place where runoff water is held from the time that it is collected until it is used. According to Worm and Hattum (2006), there are two categories of storage reservoirs: surface tanks and subsurface tanks. Surface tanks are most common for roof collection. Materials for surface tanks include metal, wood, plastic, fiber glass, brick, inter-locking blocks, compressed soil or rubble-stone blocks, Ferro cement and reinforced concrete. The choice of material depends on local availability and affordability. In most countries, plastic tanks in various volumes are commonly available on the market. Surface tanks are generally more expensive than underground tanks, but also more durable. A tap is required to extract the water from the surface tank. Common vessels used for very small-scale water storage in developing countries include plastic bowls and buckets, jerry cans, clay or ceramic jars, old oil drums or empty food containers. For storing larger quantities of water the system will usually require a tank above or below the ground. Tanks can vary in size from a cubic meter (1,000 liters) up to hundreds of cubic meters for large reservoirs. In general, the size varies from 10 up to a maximum of 30 cubic meters for a domestic system at household level and 50 to 100 cubic meters for a system at community or school level, of course very much dependent on the local rain pattern throughout the year.

2.6.1.4 Silt trap/sediment pond

According to Nega (2004), it is a small pit used to catch sediment carried by the water. It prevents the tank from becoming clogged. The size of the trap depends on the amount of runoff (heavier runoff means a bigger trap) and the amount of sediment it carries. If there is a lot of sediment, it is preferred to make two-chamber trap- one chamber to catch sand and the second one to trap finer silt. Filter mesh can be added to trap leaves and other debris. Mostly silt trap is dug at least 3 meters away from the storage tank. This is to prevent water from overtopping during heavy rains and damaging the tank (Nega, 2005).

2.6.1.5 Target area

This is where the harvested water is used. In agricultural production, the target is the plant or the animal, while in domestic use, it is human being or the enterprise and its needs (Nega, 2004).

2.6.2 Rainwater Harvesting Technologies

According to Kenya Rainwater Association (2010), different types of rainwater harvesting management systems have been implemented throughout Kenya as a strategy to secure water resources in rural areas. In Sub Saharan Africa where rainfall is low, unpredictable and also expected to decline due to climate change, rainwater storage in farm ponds, water pans, subsurface dams, and earth dams is gaining importance as a supplement to irrigation, livestock watering (Ngigi, 2009) and conventional water supply systems (Mwenge Kahinda *et al*., 2007). Much actual or potential water shortages can be relieved if rainwater harvesting is practiced more widely. It is also an effective strategy to manage floods in- situ and ex-situ, particularly in high rainfall areas (Ngigi, 2009). Collected rainwater can supplement other water sources when they become scarce or are of low quality like brackish groundwater or polluted surface water in the rainy season (Worm and Hattum, 2006). It also provides a good alternative and replacement in times of drought or when the water table drops and wells go dry. Therefore, rainwater harvesting (RWH) could be used to satisfy water demands during dry spells and to create opportunities for multiple uses.

Rainwater harvesting is a simple low-cost technique that requires minimum specific expertise or knowledge and offers many benefits. Researchers such as Gould (1995), Mugerwa (2007), Enfors (2009), Relma (2009) and Ngigi *et al*., (2013) have observed the benefits of rainwater harvesting. However, there are few studies describing the detailed effects of the schemes on water availability, demands, and vulnerability in the case of climatic variations – especially in the light of future climate change. Rainwater harvesting has been used for ages and examples can be found in all the great civilizations throughout history (Worm and Hattum, 2006). The technology can be very simple or complex depending on the specific local circumstances. Customarily, in Uganda and in Sri Lanka, rainwater is collected from trees using banana leaves or stems as gutters; up to200 liters may be collected from a large tree in a single rain storm. With the increase in accessibility of corrugated iron roofing in many developing countries, people often place a small container under their roof space to collect rainwater (Worm and Hattum, 2006). One 20-litre container of clean water captured from the roof can save a walk of many kilometers to the nearest clean water source. In addition to small containers, larger sub-surface and surface tanks are used for collecting larger amounts of rainwater.

In rainwater harvesting, people collect and store rainwater in buckets, tanks, ponds and wells (Worm and Hattum, 2006). Rainwater harvesting systems can be classified according to the runoff generating process, the size of a catchment and the type of storage. Runoff generating processes are rivers, lakes and rainfall. The storage type could be storage within a soil profile, a tank or a reservoir and the size or scale of the system determines whether it is regarded a micro or macro scheme (Greater Horn of Africa Rainwater Partnership, 2010). Rainwater harvesting techniques can be applicable in all agro-climatic zones (Amha, 2006). However, it is more suitable in arid and semi-arid areas (Branco, Suassuna, Vainsencher, 2005; Abdulla & Al-Shareef, 2009). These are areas of average annual rainfall of 200-800mm (rarely exceeding 800mm) according to Serigne, (2006). The average temperature is above 18^0c. The rainfall may come in one or two seasons. In such an environment, rain fed crop production is usually difficult without some form of rainwater harvesting and water sources such as streams, rivers and ponds that are mainly rain-fed are unreliable (Onyenechere *et al.*, 2011). The collected rainwater is a valuable supplement in ASALs that would otherwise be lost by surface run-off or evaporation. Generally, the technique can be applicable in the following circumstances: Where water supply, for domestic and animals is not sufficient, in arid and semi-arid areas (ASALs), where the potential for crop production is diminishing, due to environmental degradation, in the area where other permanent water sources like rivers, springs etc. are not available or uneconomical to develop and use them, in dry environment where low and poorly distributed rainfall normally makes agricultural production impossible and in rain fed areas where crops can be produced but with low yield and with high risk of failure.

According to Greater Horn of Africa Rainwater Partnership (2010), Rainwater harvesting systems can be classified by the runoff generating process, the size of a catchment and the type of storage. Runoff generating processes are rivers, lakes and rainfall. The storage type could be storage within a soil profile, a tank or a reservoir and the size or scale of the system determines whether it is regarded as micro or macro scheme. Finkle and Sergerros (1995) classified rain water harvesting into roof water harvesting, in-situ water harvesting, run-off harvesting, flood water harvesting and subsurface water harvesting. According to Awulachew, Merrey, Kamara, Van Koppen, Penning de Vries, Boelee & Makombe (2005), rainwater harvesting systems are generally categorized into two; in-situ water conservation practices, small basins, pits, bunds/ridges; and runoff-based systems (catchment and/or storage). However, the storage system is usually used in supplemental irrigation (Binyam & Desale, 2015). There are two main techniques of rain water harvesting namely storage of runoff on surface for future use and recharge to groundwater and shallow aquifer according to MacDonald and Davies (2000).

2.6.2.1 Rooftop rainwater harvesting

Roof water harvesting is a system of collecting rainfall water from the roof of a building and storing it in some storage facilities for future use when there is shortage of water (Haile & Merga, 2002). Water can be stored in artificial constructions (e.g. water tanks, drums, jars, jerry cans, cisterns), in surface reservoirs (ponds, dug-outs, artificial reservoirs) and in the sub-surface as soil moisture or groundwater. Roof water harvesting is generally practiced as a way to obtain relatively clean drinking water as well as water for domestic purposes. This method involves a relatively small catchment area, the size of the individual's roof of their house, with gutters and pipes to guide the water into a tank on the ground. Often a tap is attached to the tank for individuals to access this water (Haile & Merga, 2002).

Roof water harvesting at household level is important in the rural highland areas where the terrain is rugged and the villages and hamlets are scattered (Binyam & Desale, 2015). In such areas, it is difficult to think that communities can be served by centralized water supply schemes, at least it is expensive. Other sources require long walk and time for women and children to fetch water (Alem, 1999). The technology has the advantage of being low cost, relatively simple in design (household technology), less laborious and time saving (Alem, 1999). They are more appropriate in areas where there are no rivers, ground water sources and where rainwater is the only feasible means of water supply. The emergence of this technique these days is due to the increasing shortage of water from the conventional sources: shallow wells, perennial springs and rivers/streams (Binyam & Desale, 2015).

Storage Tanks

Tanks are built from a wide range of materials including metal, plastic, fiber glass, bricks, interlocking blocks, compressed-soil or rubble-stone blocks, Ferro cement, and concrete. Regardless of the material used to make them, good tanks share common key features: They should be should be watertight, durable and affordable – cost is a key influence on tank choice – and should not contaminate the water. Surface tanks vary in size from 1 m3 to more than 40 m3 for households and 100 m3 or bigger for schools, hospitals and other institutions. Tank size is also dependent on the rainfall pattern and demand for water. Areas with seasonal rainfall will require larger 3 tanks of 25 m3 – 35 m2 and a roof exceeding 100 m2 to satisfy the demand in an average household in the dry season. There is another benefit of surface tanks over sub-surface ones, in that water can be easily extracted through a tap just above the tank's base. This has made surface tanks popular in rural households for drinking water (Mati, 2001).

Cisterns

These are man-made caves or underground constructions to store water. The walls of these cisterns are often plastered to prevent water loss, deep percolation and evaporation (Prinz &

Singh, 2000). Runoff collected from bare lands, cultivated hill slopes or road catchments is guided and stored in underground storage tanks (Wondimkun & Tefera, 2006). The cisterns have plastered walls and covered surfaces. In most cases, settling basins are attached in front of the inlet to reduce sedimentation and otherwise, regular cleaning is required. It's widely practiced in East Africa (Kenya, Ethiopia, Tanzania, and Uganda) and South Africa (Zimbabwe, Botswana). Unlike the traditional open ponds, the recently developed cisterns in different parts of Sub-Saharan Africa are covered to reduce evaporation losses, and their walls are plastered to avoid seepage losses. The most important materials for construction and covering of these types of rainwater storage tank include cement, clay, clay–cement, lime–clay or lime–cement and polythene sheets. The cost of these materials makes macro-catchment rainwater harvesting systems expensive and poor farmers are discouraged from investing in them. However, in Ethiopia, locally available materials, such as termite-mound earth (either in blocks or as mud) are used to construct cisterns (Mills, 2004). Inspired by successful chinese experiences, the Ethiopian government has given much attention to developing and promoting different designs of underground rainwater storage tanks-cisterns in moisture- stressed, rain-fed agro-ecosystems (Bekele, Kebede, Taddese & Peden, 2006).

Wells

These are the most common of the surface runoff techniques. They tap into the water table from a hole excavated on the surface. Wells have been employed as a source of water for thousands of years, with one of the oldest wells found dating back to 8100 – 7500 BC. Like other forms of water harvesting, wells have been adapted to meet the needs of individuals living in specific regions. There are three types of wells namely: tube well, bore well (borehole) and dug well. A tube well is a type of water well in which a long 100–200 millimeters (3.9–7.9 in) wide stainless steel tube or pipe is bored into an underground aquifer. The lower end is fitted with a strainer, and a pump lifts water. In areas where the shallow aquifers have dried up and existing tubewells are tapping deeper aquifer, roof to rain water harvesting through existing tubewell can be adopted to recharge the deeper aquifers. When aquifers are located very deep underground it is necessary to use a deep-bore well for water extraction. Boreholes with 50 mm or 2" diameter will be sunk into the ground as monitoring wells for the measurement of groundwater level and hydrometry.

The traditional and still most common method of obtaining groundwater in rural areas of the developing world is by means of hand-dug wells (WaterAID, 2008). With the prior knowledge that groundwater is present and rather close to the surface, a hole is dug until the groundwater level is reached. Inflowing groundwater is collected and extracted with the help of pumps or buckets. Dug wells are usually 3 to 10 feet in diameter, 10 to 40 feet deep and lined with brick, stone, tile, wood cribbing or steel rings to prevent the walls from caving in. They depend entirely on the natural seepage from the penetrated portions of water table aquifer. Given suitable geological conditions, dug wells provide a low-tech solution to the challenges of rural water supply and can be implemented with a high level of community participation and locally available material and tools. They can provide a viable alternative to unhygienic, unprotected water sources while avoiding the investment and maintenance costs associated with more sophisticated water supply systems. However, supervision and careful operation and maintenance are important. Protection of the surrounding areas must be ensured to prevent contamination. Hence, capacity building on how to manage and use the system must be implemented. Dug-wells are major sources of water for both agricultural and domestic water uses (Alem, 2003). Dug wells have disadvantages to driven or drilled wells. They are more difficult to protect from contamination, and their yields are also very low because they do not penetrate into the reliable, productive water table.

2.6.2.2 Surface runoff harvesting

Surface run-off harvesting - is a system of collecting run-off from a catchment using channels or diversion systems and storing it in a surface reservoir (Rockstrom, 2000). Run-off harvesting from a catchment using channels or diversion systems is stored in surface reservoir- water pans/ponds and dams (Rockstrom, 2000). In this system, surface runoff from small catchments or adjacent road runoff is collected and stored in manually and/or mechanically dug farm ponds or dams. This technology helps in reducing floods in some low lying areas (Binyam & Desale, 2015). It also helps in reducing soil erosion and contamination of surface water with pesticides and fertilizers from rainwater run-off which results in cleaner lakes and ponds (Rockström, 2002). However, this technology requires relatively high investment costs compared to rooftop rainwater harvesting (Binyam & Desale, 2015).

Dams

Earthen dams (micro-dams)

Earth dams are perhaps the most widespread method of water harvesting, especially from river valleys. Earth dams are constructed to collect water from river valleys (Kimani *et al*., 2015). A dam can be constructed to collect water from less than 20 km^2 for a steep catchment and 70 km^2 for a flat one. Despite its poor quality, water collected from earth dams is used to cater for livestock and domestic purposes (Kimani *et al*., 2015). Water from earth dams is also used for irrigation and other purposes such as construction. In Tanzania, low earth dams called 'malambo' have been built, especially in Dodoma, Shinyanga and Pwani regions (Hatibu & Mahoo, 2000). Larger sized rainwater storage systems such as ndivas in Tanzania and micro-dams in Ethiopia are communally constructed around foots of hill slopes to store the runoff from ephemeral or perennial rivers. The reservoirs are neither plastered at their walls nor covered on their surfaces. The water is mostly used for supplemental irrigation communally and for cattle in Southern Africa in Botswana, West Africa in Burkina Faso and in East Africa in Tanzania and Ethiopia (Haregeweyn, Poesen, Nyssen, de Wit, Haile, Govers & Deckers, 2006; Makurira, Mul, Vyagusa, Uhlenbrook & Savenije, 2007).

Earthen dams are usually built with support from donor-funded projects due to the high costs of construction. For instance, in Laikipia District in Kenya, the excavation of an earth dam 15,000 m^3 cost about US$5,000 (Mati, 2002). Earth dams have short life span due to high rates of evaporation and sedimentation. Kimani *et al*. (2015) noted that dams' failure is common in the arid and semi-arid lands (ASALs) due to land degradation, heavy pressure from livestock and denuded groundcover. Evaporation from open water storage in ASALs can have a water loss that amounts to 0.9 - 1.4m within a period of 6 months (Falkenmark, Fox, Persson & Rockstrom, 2001). Within the Makueni County of Kenya, 159 surface dams have been developed (RoK Makueni County, 2013). However, the technology faces a problem of evaporation as in other arid and semi-arid lands. Unpredictable rainfall and shortages leading to frequent drought spell, high evapo-transpiration rates have resulted to unreliability and unsuitability of earth dams (Kimani *et al*., 2015).

Sand dams/Sub-Surface Dams

Sand/sub-surface dams are barriers constructed across sandy riverbeds to retain water within the trapped sand upstream; they store water in the sand, preventing run-off. The dams are constructed to store part of the natural flow in seasonal rivers. The sand carried by the river will settle upstream of the dam and gradually fill the streambed. Hence, the sand will reduce evaporation and contamination of the water in the sand body behind the dam. The sand filters and cleans the water, and also tops up the ground water aquifer. Water from the sand/sub-surface dams is extracted through traditional scooped holes, or through a pipe that leads to a tank or an infiltration gallery leading to a sealed shallow well and is used for domestic, livestock and small-scale irrigation purposes. The water stored in sand/sub-surface dams is also protected from high evaporation rates and thus the water can last for long periods without drying up as compared to open water storage facilities (Kimani *et al*., 2015). This is widely practiced in East Africa: Kenya and Ethiopia.

Within the Kitui Subcounty of Kenya, about 500 sand dams have been developed over 10 years to store water for the dry season (Aerts, Lasage, Beets, De Moel, Mutiso G., Mutiso S., & De Vries, 2007). These sand dams are used for domestic water supply and irrigation, also enhancing groundwater recharge (Hut *et al*., 2008). The percentage of storage by sand dams relative to total seasonal runoff amounts to 3.8% for the April–October season and 1.8% for the November–

March season (Aerts *et al*., 2007). In Tanzania, dugout ponds, which are found on roadsides where contractors have excavated soil for road construction, collect water, and villagers exploit this for domestic, livestock and vegetable production (Hatibu & Mahoo, 1999). In South Africa, jojo tanks of 0.75–20 m have been popularized for collecting rainwater from rooftops, when it is used mainly for domestic purposes (Mokgope & Butterworth, 2001). Similar tanks of various designs have been promoted by non-governmental organizations in many African countries.

Water pans/ ponds

Water pans/ponds are small earth dams whose storage capacities do not exceed 20,000 m^3 and have a shallow depth of less than 5m. According to Kimani *et al*. (2015), water from pans is mainly used for livestock and domestic purposes. However, the water is suitable for livestock and irrigation (Waswa & Mpinduzi, 2007). Runoff collected from cultivated hill slopes, natural water courses, footpaths or cattle tracks is stored in un-plastered and open ponds (Reij *et al*., 1996; Habtamu, 1999; Ngigi, 2003). The stored water usually suffers from losses due to seepage and evaporation. The technology is widely applicable in mainly in East Africa: Kenya, Ethiopia, Tanzania and Somalia. However, the commonly used traditional open rainwater ponds do have a short lifespan after the rainy seasons, as the water is lost via seepage (except for rock catchment dams) and evaporation. Seepage is a major problem in water storage in earthen reservoirs, accounting for losses up to 69% of the harvested water (Fox & Rockstrom, 2003). Within the Makueni county of Kenya, about 289 water pans have been developed (Kimani *et al*., 2015). However, most of these pans do not survive an entire drought season due to high rates of evaporation, leaching and sedimentation. Methods of extracting water from these pans have also been an issue. Most of the community use water cans and calabashes to extract water from the pond and carry the water cans by back/or hand. Water from these pans is at high risks of pollution since most of them are not fenced and animals drink water from them directly (Kimani *et al*., 2015).

2.7 Factors affecting adoption of Rainwater Harvesting Technologies (RWHT)

The suitability of any technology depends on a wide range of factors (ADB, 2009). Household characteristics, institutional factors, and local climatic and agro-ecological conditions are the key determinants of the speed of adoption (Maddison, 2006; Gbetibouo, 2009). Institutional factors that influence adoption of new technologies includes access to credit, information provision, and land tenure. The household characteristics that influence adoption decisions include age, education level, gender of the head of the household, family size, and source of income. A technology must be accessible, affordable and appropriate for the target community (Coupe, 2001; Coventry, 2003) if it is to be successfully adopted and sustainably used. Existing research largely ignores the complex environment within which RWH systems must fit (Cullis & Pacey, 1992; Scoones, Leach, Smith, Stagl & Stirling, 2007; Vohland & Barry, 2009) and implementation frameworks focus primarily on technical aspects (Hatibu & Mahoo, 1999; ADB, 2009). Steps need to be taken to incorporate non- technical factors into these frameworks to ensure that the technology is only implemented where suitable.

A study in Tanzania on adoption of RWHT by Shikur and Beshah (2013) found that physical factors, household socioeconomic and institutional factors such as sex of the household head, family size, years of experience of household head , availability of labour, suitability of farm slope for runoff harvesting, type of soil , external support on rainwater harvesting practice, training on areas of rainwater harvesting technology, credit facilities, extension service on RWH practice, land security and income have significant relationship with adoption of rain water harvesting technology. It is well documented that physical factors, household socioeconomic and institutional factors influence adoption of RWHT (Chilot, Shampiro & Mulat, 1996; Kansana, 1996; Asfaw, Gungal, Mwangi & Seboka, 1997; Mwanga, Mussie, Mwangi & Verkuijl, 1998; Tesfaye, 2006). Inequalities in access to improved sources of water such as rainwater are indicative of severe deprivation (UNDP, 2006). These inequalities have historically been attributed to low incomes, cultural, economic, regulatory and institutional set up (UNDP, 2006). Lawrence *et al*., (2002) noted that socioeconomic status is a significant determinant of household access to water in households. The adoption rate of RWH schemes appears to be higher in areas where the government provides incentives for farmers, (Tumbo, Mutabazi, Byakugila & Mahoo, 2010), although some forms of political intervention, such as social support, have been found to be unfavourable to the success of RWH projects (Jodha, 1990).

Institutions can play the most important role in learning and knowledge exchange, development of best practices, farmer support, and the management of RWH systems (Nijhof, Jantowski, Meerman, & Schoemaker, 2010) and may help provide the poorest households with resources needed for the adoption of the technology (Bunclark & Lankford, 2011). The source of income and assets' endowments has a significant influence on the ability of households to adopt certain technological practices (Reardon & Vosti, 1997; Nkonya, Pender, Kaizzi, Kato, Mugarura, Ssali & Muwonge, 2008; Gbetibouo, 2009). Households with higher income and greater assets are less risk averse than lower income households, and therefore in better position to adopt new technologies (Shiferaw & Holden, 1998). According to Kimenyi and Mbaku (1995), economic status of a household is closely linked with the affordability of services such as water. Thus, households with no reliable source of income are likely to use water from unimproved source. Shikur and Beshah (2013) found that adopters of RWH technology have better income than their counterparts. Rainwater harvesting technologies were not widely adopted by farmers in arid and semiarid areas of West Africa because they did not have the resources to move large quantities of earth and stones necessary for larger water harvesting systems (Rosegrant, Cai, Cline & Nakagawa, 2001). Access to credit for agricultural purposes for example can relax farmers' financial constraints & expected to make farm households willing to participate in water harvesting activities (Molla, 2005).

Other variables closely connected with the availability of water in the household include, among others, education of the household head (Dungumaro, 2007; Koskei *et al*., 2013). Education is often assumed to increase the likelihood of embracing new technologies. This is because it enhances the ability of household to perceive climate change (Nkonya *et al.*, 2008). Similarly, education enables households to access and conceptualize information relevant to making innovative decisions (Adesina & Forson 1995; Gbegeh & Akubuilo, 2012; Daberkow & McBride, 2003; Shiferaw, Okello & Reddy, 2009; Ochieng', Owuor & Bebe, 2012,). According to Shikur and Beshah (2013), adopters of rainwater harvesting technology have better education status than their counterparts.

Household size as a proxy to labour availability may influence the adoption of a new technology positively as its availability reduces the labour constraints (Marenya &Barrett, 2007). Given that the bulk of labour for most household operations in sub-Saharan Africa is provided by the family rather than hired, lack of adequate family labour accompanied by inability to hire labour can seriously constrain adoption practices (Nkonya *et al*., 2008). Shikur and Beshah (2013) found the average family size for adopters of RWH technology to be higher than their counterparts. Nonetheless, households with many family members may be forced to divert part of their resources to provision of basic needs rather than implementation of new technology. Economic resources are often more limited in larger households than smaller households (KNBS, 2010) because of high dependency ratio that is brought about by large family sizes.

A study in East Africa noted that household size is one of the most accurate predictors of per capita water use within villages (Rosen and Vincent, 1999). They found that households with 4-5 members averaged a little over 10 liters/person/day, while those with more than 12 members averaged just 7 liters/person/day. It is well documented that residential demand for water is influenced by heterogeneity associated with differences in the size of the household (Arbués, Villanua & Barberan, 2010; Demeke, 2009; Lawrence *et al.,* 2002). According to Koskei E.C., Koskei R.C., Koskei M. C. & Koech (2013), household size determines variation in levels of access to improved water by households. Average daily water consumption varies depending on household size. Households with fewer members tend to use more water per member than multiple-person households.

The relative importance of high labor required for the construction of water harvesting systems, runoff harvesting, rooftop harvesting and fetching water signifies its central importance in RWH technology. Bunclark and Lankford (2011) in Botswana found that an important factor affecting the adoption of rainwater harvesting systems was the reluctance of farmers to dedicate their labour to implementing the systems. According to the participants, problems regarding labour availability were primarily attributed to a lack of willingness to work on farmland among the rural population. According to Shikur and Beshah (2013), household with high labor availability could adopt RWH technology than households with low labor availability. The total cost of labor and time required to rupture sandy soil is relatively lower than clay and loam soil (Molla, 2005). This is an indication that household with sandy soil have more ease to adopt rainwater harvesting technologies in ground catchment system. Cost of rainwater harvesting is also difficult to be covered by individual household level. Households need governmental and non-governmental support for the construction of RWH technology. Shikur and Beshah (2013) gave an example of Tanzania where farmers were ready to adopt RWH technology if half the cost was covered by external support.

The effect of gender of the household head on adoption decisions is location-specific (Gbetibouo, 2009). In many parts of Africa, women are often deprived of property rights due to social barriers (Gbegeh & Akubuilo, 2012). An extensive literature that focuses on the close link between poverty and household headship by gender suggests that female-headed households have limited access to resources (KNBS, 2010; Mbugua, 1997; Oppong, 1997; World Bank, 1991). While women have needs for improved and alternative water sources, they may not have the money, resources, power, or confidence to ensure that their needs are met (UNDP, 2005) because they have fewer capabilities and resources than men (De Groote & Coulibaly, 1998; Marenya & Barrett, 2007; OECD, 2009; Gbegeh & Akubuilo, 2012). In Kenya, a higher proportion and number of individuals in male-headed households have access to improved water sources than female-headed households (KNBS and SID, 2013). According to Shikur and Beshah (2013), female-headed households hardly have the privilege to own RWH structures such as ponds. This often undermines their capacity to embrace labour-intensive innovations. However, female-headed households are more likely to take up climate change adaptation measures (Nhemachena & Hassan, 2007; Gbetibouo, 2009). The possible reason for this observation is that in Africa, its women's responsibility to ensure that there is water in the household (Dungumaro, 2007).

Land security and training in rainwater harvesting area determine adoption of RWH technology (Shikur & Beshah, 2013). According to Lloyd and Baiyegunhi (2015), security of land rights has a statistically-significant positive effect on adoption of RWHT. Farmers who feel their land rights are secured are more likely to adopt RWHT. Security of tenure is a requirement for households to be able to carry out long or medium term investment (Shikur & Beshah, 2013). Various information sources can influence the probability of adoption differently (Daberkow & McBride, 2003). Similarly, different sources of information become influential during different stages of adoption process. The mass media for instance, are important in the early awareness stage, while interpersonal information sources such as extension officers and fellow villagers are critical in transferring more technical and adoption-promoting information (Daberkow & McBride, 2003). A study in South Africa by Lloyd and Baiyegunhi (2015) found that women were less likely to adopt new technology because they did not have secure land rights.

A review of existing literature (e.g. Chilot *et al*., 1996; Kansana, 1996; Asfaw *et al*., 1997; Mwanga *et al.,* 1998; Tesfaye, 2006; Ngigi, 2003, Shikur & Beshah, 2013) do not describe the constraints to use of RWH technology in improving access to domestic water that this study sought to address. These studies however address the factors affecting adoption of Rainwater Harvesting Technologies (RWHT) in improving agricultural productivity.

2.8 Policies and legislations in Kenya

2.8.1 Climate Change Relevant National Policies and Legislation in Kenya

Some of the current Government of Kenya policies, plans, strategies and initiatives that provide a supportive framework for implementing climate change responses include the following according to RoK (2010).

- **The Constitution of Kenya (2010)** which provides ground for the formulation of adaptation and mitigation legislation, policies and strategies by guaranteeing the right to a clean and healthy environment under the Bill of Rights.
- **Vision 2030**, the national development blue print encapsulates flagship programmes and projects with aspects of adaptation and mitigation.
- **The National Policy for the Sustainable Development of Northern Kenya and other Arid Lands** focuses on climate resilience requiring government to find solutions to address climate challenges and to come up with measures to manage drought and strengthen livelihoods. The policy also focuses on an enabling environment for accelerated investments in “foundations” to reduce poverty and build resilience and growth. The establishment of the National Drought Management Authority (NDMA), the

National Disaster Contingency Fund and the Council for Pastoralists education are provided for in the policy.

- **The National Disaster Management Policy, 2012** institutionalizes disaster management and mainstreams disaster risk reduction in the country's development initiatives. The policy aims to increase and sustain resilience of vulnerable communities to hazards.
- **Environmental Management and Coordination Act (EMCA, 1999):** The Act is the principle instrument of government for the management of the environment. and provides for the relevant institutional framework for the coordination of environment management including the establishment of the National Environment Management Authority (NEMA) which is the Designated National Authority (DNA) for Clean Development Mechanism (CDM) and the National Implementing Entity(NIE) for the Adaptation Fund
- **Water Act, 2002**: The EMCA 1999 and the Water Act of 2002 provide the overall governance of the Water Sector. The regulations and strategies following on from this Act, recognize the climate change implications on health, sanitation and water
- **The Kenya Forestry Master Plan 1995-2020** provides for an overarching framework for forestry development in the country for the 25-year period up to 2020 and was the blue print for reforms in the sector, including the Forest Act of 2005 and Forest Policy of 2007. It recognizes the environmental role of forests including water values, biodiversity values, climate change values through carbon sequestration and other environmental services.
- **The Second National Environment Action Plan (NEAP, 2009-2013)** provides for a broad framework for the coordination of environmental activities by the private sector

and government to guide the course of development activities, with a view to integrating environment and development for better management of resources.

- **Kenya National Climate Change Action Plan (2013-2017).** The Action Plan aims at implementing climate change adaptation and mitigation measures. It equips the country with important actions in responding to the challenges faced because of climate change. It encourages people-centred development, ensuring that climate change actions support Kenya's achievement of development goals. It also supports efforts towards the continued attainment of Vision 2030. This Action Plan guides the transition of the country towards a low carbon climate resilient development pathway.

2.8.2 Policy Frameworks and legislations for Water in Kenya

Effective governance is regarded as essential for national water management frameworks (Kakumu, 2007). Many countries are therefore striving to institute effective governance in their water sector. The first water law to be enacted in Kenya was the Water Ordinance of 1927, the second law was the Water Act Cap 372 of 1974 while the third and most current law is the Water Act of 2002 (KWAHO, 2009). In order to effectively manage and protect the water resources in a sustainable manner, management and development have been separated through enactment of the Water Act 2002. The Kenyan water sector underwent far-reaching reforms through the Water Act No. 8 of 2002. The 1974 Kenya Water Act underwent major revisions in 1999 and 2002, which mainly focused on the decentralization of water services and separating water policy formulation from regulation and services provision (RoK, 2007). In addition, the 2002 National Water Policy defined the government's role as regulatory and delegated water service provision to the private sector, municipalities and communities. Previously, service provision had been the responsibility of a single National Water Conservation and Pipeline Corporation as well as of a few local utilities established since 1996 (Mwango, 2009). In spite of the decentralization of water services and separation of policy formulation from service provision, the roles of the different actors (e.g., communities, non-governmental organizations, and private sector) involved in the water sector (users, managers, suppliers, conservationists) remain a challenge to the realization of the goal of Kenya's water policy because they are ambiguous and often conflicting (Ogendi & Ong'oa, 2009). Ogendi and Ong’oa (2009) noted that whereas participation of all stakeholders in decision-making processes is encouraged and emphasized, few attempts have been made to incorporate ethics into water use and management. The rights of people to access water and control their environment have not been incorporated into the country's water policy.

Improving the management and protection of water resources to ensure that water is available for equitable allocation for all the demands in the country including water for domestic use and other water uses is a high priority (World Water Assessment Programme, 2006). The act introduced new water management institutions to govern water and sanitation issues in Kenya (KWAHO, 2009). An autonomous institutional framework comprising the Water Resources Management Authority (WRMA) and its Regional Catchment Offices is in place as well as the appointment of Catchment Area Advisory Committees (CAACs) and the establishment of Water Resource Users Associations (WRUAs). The establishment of these institutions was to allow for decentralization, participation and sustainability in the management of water resources. The WRMA, CAACs and the Water Services Regulatory Board (WSRB) became operational by December 2004. Water allocation is performed by WRMA, who deliver water permits only after ecological and basic human needs, international treaties and inter-basin water transfers, reserve and domestic water demands have been met (WRMA, 2013). Eight Water Services Boards (WSBs) have been established. After the passage of the act service provision was gradually decentralized to local Water Service Providers (WSPs). These are linked to eight regional Water Services Boards (WSBs) in charge of asset management through Service Provision Agreements (SPAs). The Act also created a national regulatory board (WASREB) that carries out performance benchmarking and is in charge of approving SPAs and tariff adjustments. Rift Valley Water Services Board (RVWSB) is one of the eight water services boards in Kenya, formed under the provision of the Water Act 2002. Baringo County is one of the areas covered by the Rift Valley Water Services Board (RVWSB) (RoK, 2002).

Kenya as a country is facing a number of serious challenges related to water resources management (Sammy, 2004). A number of these challenges are because of factors both within and outside the water sector (Ministry of Water and Irrigation, 2009). The problems and challenges facing the country include water scarcity, catchments degradation, growing population, climate variability and water resources degradation. Rift Valley Catchment Area has an estimated population of 4million people thus faces enormous challenges in management of its limited water resources (WRMA, 2013). The major sources of water are both surface and ground water. Rainfall patterns within the Catchment are extremely variable not only spatially and temporary, but also in terms of rainfall intensities. This makes the natural flows of water in the water courses highly variable in space and time (WRMA, 2013). Catchment degradation has caused reduced infiltration, increased flash floods, soil erosion and siltation in the reservoirs which undermines the limited available water resources in the catchment. The main causes of catchment degradation have been deforestation, encroachment of water sources and population pressure (WRMA, 2013). Climate variability and increasing demand for water as a result of development and population pressure are factors that the sector may not be able to control but can initiate mitigation measures to ensure sustainable water resource development (World Water Assessment Programme, 2006).

Public (pipe borne) water supply in Kenya is mainly provided by the Water Services Boards in good quality and sufficient quantity for industrial and domestic use of the entire citizens (KWAHO, 2009). The major source of public water supply available to the Water boards is surface water. Since surface water is the source of water available to the boards, any increase or decrease in rainfall would affect the quantity of water available for the boards to supply to the community. Also, excessive rainfall which might leads to flood can increase the turbidity level of the water thereby affecting its quality (KWAHO, 2009). The quality and quantity of water in some parts of Rift Valley Catchment Area have been negatively affected due to over-abstraction of surface water, inappropriate land use practices, soil erosion and encroachment of riparian lands (WRMA, 2013). Other major pollutants of water bodies in the region are effluent released from urban centers, sewage outfalls, excessive nutrient and agro-chemicals from rural sources. An example of the negative impact is the reduction in depth of Lake Baringo, from over 15 metres in 1921 to an average of 1.8 metres today, which is due to reduced inflows and increased sediment load from surrounding unprotected and degraded catchments (WRMA, 2013). The water sector reforms appear to have done well in establishment of institutional framework with little impact on improving accessibility.

2.9 Theoretical Framework

This study was based on the diffusion of innovation theory (Rodgers, 2003, Vijayabhjinandana, 2007). The theory states that people adopt new technological innovations at different times and at different rates. Technology adoption, similar to diffusion, is a process that begins with awareness of the technology and progresses through a series of steps that end in appropriate and effective usage. Rogers proposes that four main elements influence the spread of a new idea and technology: the innovation itself, communication channels, time, and a social system (Rodgers, 2003). Vijayabhjinandana (2007) and Rodgers (2003) agreed that adoption of innovations followed hierarchical or pyramidal stages namely: awareness, interest, evaluation, trial and usage.

The study adopted diffusion of innovation theory to develop the framework for measurement of adoption of rainwater harvesting technologies. The study used five stage adoption processes namely: awareness, interest, evaluation, trial and usage to measure adoption of rainwater harvesting technologies. The theory identifies several fundamental questions that should be addressed to assess the value of rainwater harvesting technologies in addressing households' vulnerability to rainfall variability. These include:

i) Is the household aware of rainwater harvesting technologies?

   The theory enables the researcher to understand that the household is exposed to the technology but lacks complete information. It is therefore important to guide households on the use of technology and its benefits in order for them decide whether they want to investigate further

ii) Does a household have an interest in rainwater harvesting technologies?

The theory informs the study in that technology has no value if the household does not become interested in it and seeks additional information

iii) Has the household evaluated rainwater harvesting technologies?

This helps understand if an individual mentally applies the technology to his present and anticipated future situation, and then decides whether or not to try it

iv) Has the household tried rainwater harvesting technologies?

This question provides guidance that if people have not developed the skills and knowledge required in using the technology effectively, they may not make full use of the technology.

v) Has the household demonstrated appropriate and effective use of rainwater harvesting technologies?

This helps understand if a household has decided to continue the full use of innovation

vi) What factors influence adoption of rainwater harvesting technologies?

This depends mainly on financial and material resources that constraint households adaptive capacity and hence implementation of rainwater harvesting technologies.

Generally, diffusion of innovation theory provides a basis for this study. It provides a guide line through which implementation of innovations such as rain water harvesting can be undertaken. The study assumed that rain water harvesting is an innovation which needs to be embraced in order to adapt to varying climate with a view of improving water accessibility.

2.10 Conceptual framework

The conceptual framework (Figure 2.1) defines the dependent, intervening and independent variables that provided guidelines on how to undertake the study and indicates that rainfall variability and non-climatic factors determines implementation of rainwater harvesting technologies. The purpose of using rainwater harvesting as climate change adaptation strategy is to reduce harm to the households likely to be affected by variations in rainfall amounts. To implement Rainwater Harvesting Technology (RWHT), the households need resources which can be financial or other material resources, social networks, knowledge and availability of information. Action is further shaped by constraints and resources that the household has little control over, including physical factors, biophysical factors, government policies, culture, needs and preferences of households. With the means and minimal constraints, the individuals and communities are able to respond in a way that ensures reduced vulnerability and therefore increased access to domestic water. The level of implementation of RWH influences vulnerability to rainfall variability.

Adaptations are the result of interactions between climatic factors such as variation in rainfall amounts and non-climatic factors such as technological advances, institutional arrangements, availability of resources and information exchange. For instance, annual variation in rainfall amount may have similar impacts on household access to water in two regions but differences in economic and institutional arrangements in the two regions may result in quite different impacts on households and hence in quite different responses (adaptations). Policies that increase the welfare of the poorest members of a society can also enhance adaptive capacity and reduce vulnerability to climate variability.

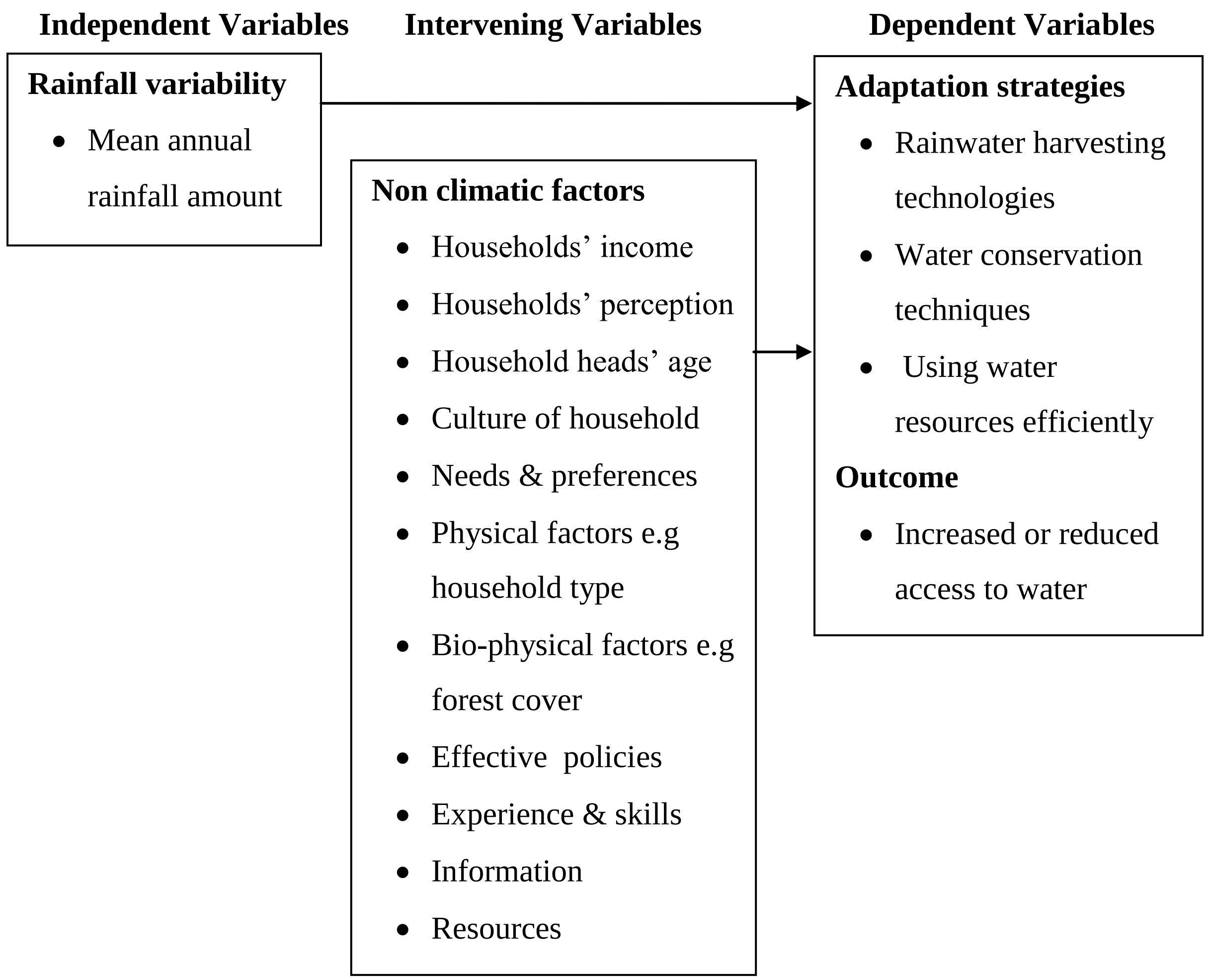


Figure 2.1: Conceptual Framework relating rainfall variability to water accessibility and adaptation.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the method that was used to carry out the study. It gives details on the research desig, study area, population of the study, sample size and sampling procedures, instrumentations and data analysis procedures.

3.2 Research Design

The research design is the plan for the study, providing the overall framework for collecting the data, outlining the detailed steps in the study and providing guidelines for systematic data gathering (Straus and Corbin, 1998). Polit (2001) define a research design as the researcher's overall for answering the research question or testing the research hypothesis. This study was both qualitative and quantitative in nature and as a result, quantitative and qualitative methods were included in the research design. Different types of research design have been widely documented. For the purpose of this study, a descriptive survey design was used to collect information according to objectives. Descriptive research is designed to provide a picture of a situation as it naturally happens (Burns and Groove, 2003). In this research, the study phenomena had already taken place and were therefore studied in retrospect. Researcher did not directly control or manipulate the variables because they were deemed to have already naturally occurred. Survey design is appropriate in studies where data would be collected from a large sample as was the case in this study because it would be the most efficient method of collecting survey data (Kasomo, 2007). No other method of observation can provide this general capability. Therefore, a descriptive survey was carried out on the sample of Baringo households to explore and describe rainfall variability and use of rainwater harvesting technologies as at the time of study.

3.3 Study Area

The study was conducted in Baringo County. Baringo County is located in the former Rift Valley Province of Kenya (Figure 3.1). It lies between Latitudes 00 degrees 13" South and 1 degree 40" north and Longitudes 35 degrees 36" and 36" degrees 30" East. The County is cut across by the Equator at the southern part. It borders Turkana and Samburu Counties to the North, Laikipia County to the East, Nakuru County to the South and Kericho, Nandi, Uasin Gishu, Elgeyo Marakwet and West Pokot Counties to the West. The County covers an area of 11,015.3 sq.km of which 165 sq.km is covered by surface water and it has a population density of 50 people per sq Km and 110,649 households (KNBS, 2013).

According to the Census that was carried out in 2009, the population of Baringo County is approximated to be 555,561 people and this figure is projected to increase by about 5% in the next census.

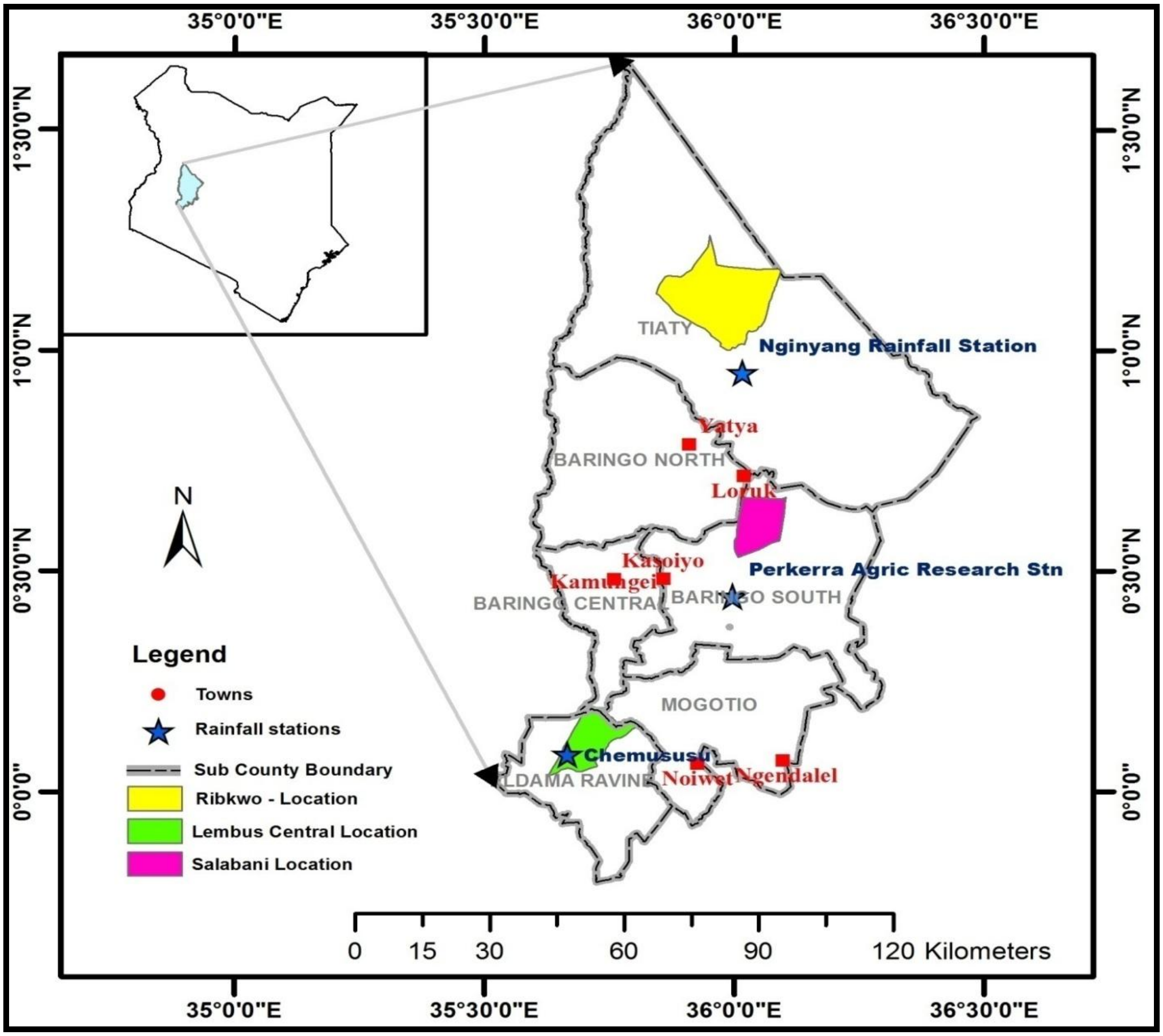


Figure 3.1: Location of the study area (Baringo County)

Source: Survey of Kenya (2014)

Baringo County is divided into three major agro-ecological zones namely the highlands, midlands and lowlands and the following sub- zones: UH 1, UH 2, LH 2, LH 3, UM 3, UM 4, UM 5, LM 4, LM 5, LM 6 and IL 6 (Appendix iii) (RoK, 2013). The County covers a range of climatic zones, from semi-arid (zone iv), arid (zone v), and very arid (zone vi) through semi-humid (zone iii) and sub-humid (zone ii), to a small portion in the humid zone (zone 1) (see figure 3.1). The mean annual rainfalls in these zones are 450 mm to 900 mm (semi-arid), 800 mm to 1,400 mm (semi-humid), 1,000 mm to 1,600 mm (sub-humid) and 1,100 to 2,700 mm (humid). The mean annual potential evaporation amounts for these areas are 1,650 mm to 2,300 mm (semi-arid), 1,450 mm to 2,200 mm (semi-humid), 1,300 mm to 2,100 mm (sub-humid), and 1,200 mm to 2,000 mm (humid). These differences are due to large variations in altitude, ranging from over 2200 m.a.s.l. at the Tugen Hills in highland to under 900 m.a.s.l. in the central and northern parts, the lowlands (Jenny and Svensson, 2002). The annual average temperature is about 25°C in highlands while in lowlands; temperatures are above 32°C (RoK, 2013).

3.4 Target population

Target population is a population from which the sample is to be selected (Mugenda & Mugenda 2003). The study targeted all the households in three Agro-Ecological zones in Baringo County. These are LM 5 (lower Midland), LH 2 (Lower Highland) and IL 6 (Inner Lowland) with a total of 4,759 households (RoK, 2010). Rainfall data from Perkerra, Chemususu and Nginyang Meteorological stations was used to represent Agro-Ecological zones LM 5, LH2 and IL 6 respectively. A total of 376 households in the three Agro-Ecological zones comprised the sample size.

3.5 Sample and Sampling Procedure

The study used purposeful sampling and stratified proportionate random sampling procedures to obtain the sample for household survey. Within Baringo County, the locations were stratified according to the agro-ecological zones. The rationale for dividing the County according to climatic zones was so that it would be possible to determine the effects of climate variability on household water availability in the different climatic zones.

Lembus Central, Salabani and Ribkwo locations were purposefully selected for the study. They were selected because of having Agro-ecological zones LH2, LM5 and IL6 respectively to ensure that the researcher picks extreme climates only and ensure proper representation of the respondents within the whole Baringo County area coverage. Selection of administrative locations (for household survey) was also guided by the geographic location of rainfall stations. Lastly, random selection of the respondents within locations was made proportionate to the population of each location as per the household census report of 2009 (RoK, 2010). The study targeted 376 households which constituted 7.9 % of the total number of households in the three agro ecological zones. The selection of respondents was informed by household population by location level. This information was acquired from the County Development Officer at Kabarnet, the County headquarters. Lembus Central location has a population of 2,668 households while Salabani has a population of 963 households and Ribkwo 1128 households. These were the three strata where proportional representation was obtained.

The sample size was obtained using the following formula (Krejcie & Morgan, 1970):

$$s = [x^2NP\ (1-P)] \div [d^2\ (N-1) + x^2P\ (1-P)]$$

Where:

s = required sample size

N = the population size

x^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level

P = the population proportion

d = the degree of accuracy expressed as a proportion

Therefore,

s = [3.841 x 19734 x 0.5(1-0.5)] ÷ [0.052(19734-1) + 3.841 x 0.5(1-0.5)]

s = 376 households

Sampling fraction (Sf) was obtained thus:

Sf = Sample size ÷Population =376÷4,759 =0.079

Each category of population was multiplied by this fraction to obtain the corresponding category of the sample. When the sub-populations were multiplied by the sampling fraction, the samples indicated in table 3.1 below were obtained.

Table 3.1: Locations and Sample Sizes

Location	**AEZs**	**Population**	**Sample Size**
Lembus Central	LH2	2,668	211
Salabani	LM5	963	76
Ribkwo	IL6	1, 128	89
Total		4, 759	376

From the table above, 211 households in Lembus Central, 76 in Salabani and 89 in Ribkwo location was selected. A total of 376 respondents were selected for the study. Their participation during the interviews was however based on systematic random sampling technique. A systematic sample of 376 members was chosen from a population list drawn through the assistance of chiefs of the three locations. To obtain K, which was 13 for this case, the total population (4,759 households) was divided by the desired sample (376 households). The researcher randomly selected a number from 1 to 13. The researcher started at the household numbered 3 and then choose every 13th member of the list.

As for the key informants, purposeful sampling was used to select those to be interviewed. These were selected from among meteorologists, NGO officers, chiefs, NDMA officers and water officers based on their positions of authority. These key informants were selected for the interview in consideration that they have insights on the subject of climate and water and use of RWHT by the households in the County.

The choice of rainfall stations for this study was informed by agro-ecological zones (Jaetzold *et al.*, 2007) and percentage of missing data (less than 10% for any given year as required by the World Meteorological Organization). Thus, the selected rainfall stations were Nginyang (IL6), Perkerra (LM5) and Chemususu l (LH2) (Fig. 3.1) and each had a data set of over 20 years and it is fairly a representation of the entire Baringo homogenous climatological zone identified by RoK (2013).

3.6 Data Collection Instruments

The study utilized three instruments to collect data. These are: questionnaire (Appendix i), key Informant interview schedule (Appendix 2) and observations which were sometimes combined with informal discussions with the respondents. The questionnaire was used to collect data on socio-economic characteristics, water access and use of RWHT by the sampled population while the interview schedule was used to collect in-depth information from key informants to provide information on rainfall data and water data of Baringo County. Observation was used to supplement and enrich data collected via the interview. Additionally, photographs of the various water sources and rainwater harvesting technologies in the study households were taken by researcher.

3.7 Validity of the Instruments

Validity refers to the extent to which a research instrument measures the variables it purports to measure (Kathuri & Pals, 1993). It is the degree to which one can draw accurate and meaningful inferences based on the instrument (Mugenda & Mugenda, 2003). Content and construct validity were used to evaluate the inferences based on the results from the instruments. Content validity is the degree to which an instrument actually measures the variable it claims to measure (Kathuri & Pals, 1993). That is to ensure the items in the data instruments represent the content area. Construct validity is a measure of the degree to which data obtained from an instrument meaningfully and accurately reflects a theoretical concept (Mugenda & Mugenda, 2003). To establish content and construct validity, the research instruments were extensively reviewed by the researcher's supervisors and other research experts from the university.

3.8 Reliability of the Instruments

To test the reliability of the instruments, a pilot study using a random sample of 30 households was carried out in Rongai Sub County. This was chosen because it has similar characteristics to those of the study area. Twenty (20) respondents is the recommended smallest number that yields meaningful results in a survey research (Kathuri & Pals, 1993). The researcher chose 30 households to ensure proper representation of the residents in the area. The piloted questionnaires were later subjected to the Cronbach's formula analysis technique to gain desired reliability coefficient. Cronbach's alpha reliability ranges between 0 and 1, and reliability coefficient of the least $\alpha = 0.7$ will be accepted (Frankell & Wallen, 2009). If the coefficient falls below 0.7 ($\alpha = 0.7$), adjustments is done on the instruments items to ensure that the required reliability coefficient is obtained.

3.9 Piloting of Data Collection Tools

All the three tools were pre-tested before administration to the respective target respondents. The instruments were pretested in Rongai Sub County that depicts almost the same agro-ecological characteristics as the study area. Piloting helps pretest the research instruments. Piloting of instruments also helps eliminate ambiguities, misunderstandings and inadequate items (Wiersma, 1985). Mulusa (1990) explained that piloting is important in reviewing blank spaces, inaccurate responses and inconsistencies. According to Mugenda and Mugenda (2003), data collection tools should be piloted for the purposes of ensuring reliability.

3.10 Sources of data

This study relied on both primary and secondary data sources. Primary data was obtained from households and key informants while secondary data was obtained from Kenya Meteorological Department. The first category was households drawn from across the three main agro-ecological zones in Baringo County: LH2, LM5 and IL6. These represented Lembus Central, Salabani and Ribkwo respectively. The second set of data comprised government and non-governmental institutions in the County. The third set of data was obtained from officials in Kenya Meteorological Department. Other secondary data sources included: books, journals, abstracts, dissertations, theses and policy research working papers.

3.11 Data Collection Methods

The researcher collected data from the selected respondents after receiving research clearance letter from the Institute of Postgraduate Studies at Kabarak University and research permit from the National Commission for Science. Primary data was obtained from households through personal interviews by use of structured and semi structured questionnaire and making observations. The questionnaire was used to collect data from households on socioeconomic characteristics, access to water, rainfall variability, use of RWHT, levels of adoption of RWHT and constraints to use of RWHT in Baringo County. The questionnaire was administered to all the 376 households in the study area.

Besides the questionnaire, Key Informant Interview Schedule was used to collect in-depth data on rainfall variability, RWHT and access to water. Key informants' interviews were used to collect valuable data that was used to check the validity of responses obtained through use of questionnaires. According to O'Connor (2011) and Mugenda and Mugenda (2003), key informants' interviews may provide flexibility to explore new ideas and issues that had not been anticipated in planning the study but that are relevant to its purpose.

Observations were made of the various water sources, water harvesting structures and the nature of their construction. Information obtained through observation enabled comparing of the reported information with the actual occurrences in the study area. Additionally, photographs in the study area were taken by researcher. The photographs have helped to illustrate the various water sources and adaptation strategies that were used by the households. The use of photographs augmented findings from other data collection procedures

Daily rainfall data was collected for three stations: Perkerra, Chemususu and Nginyang to represent agro-ecological zones LM5, LH2 and IL6 respectively. The rainfall data for Baringo stations is managed by Kenya Meteorological Department. The data sets obtained included both daily and monthly rainfall. Rainfall data was used to analyze trends in annual rainfall. The data collected from LH2 and IL6 was for the period 1981 – 2010 while the data collected from LM5 was for the period 1981 – 2008. Climatological analysis recommends 30 years but this study utilized this data because there was no sufficient data.

3.12 Data Analysis Methods

Data analysis was guided by the objectives and hypotheses of the study as described below.

Table 3.2: The objectives, corresponding variables and methods of analysis

Objective	Measurable Variables	Analysis methods
1. Analyze rainfall variability trends in agro-ecological zones LM 5, IL 6 and LH 2 for the period 1981 -2010	Annual rainfall amount	Trend analysis of annual rainfall, coefficient of variation & percentages
2. To establish the effects of rainfall variability on household access to domestic water in Baringo County	Perceived effects of rainfall variability, Distance to water source, collection time, type of water source, quantity of water p/c/d, location of source	Pearson Moment Correlation analysis,
3. Determine adoption of RWHT as an adaptation strategy to climate variability in Baringo County	Interest, awareness, evaluation, trial and use of rainwater	Percentage of households practicing rainwater harvesting,
4 Determine variations in levels of adoption of RWHT among households by agro ecological zones in Baringo County	-Adopters of RWHT	chi-square test to test significant difference in levels of adoption by agro ecological zones
5. Assess constraints to use of rainwater harvesting technologies (RWHT)	Constraints to use of RWHT	Percentages

3.12.1 Rainfall Data

Annual rainfall variability was analyzed using rainfall data. This analysis yields an understanding of the character of rainfall variability in each of the AEZs. Daily rainfall data was obtained from Kenya Meteorological Department in digital form hence there was no need for entering daily rainfall data. The data was aggregated into monthly and annual totals and these were analyzed for the trend. To show rainfall variability, this study carried out a trend analysis. The year-to-year variation of annual rainfall (Y) over the studied agro-ecological zones was expressed in terms of normalized rainfall anomaly. This was done by use of rainfall data which was normalized using the following formula:

$$Y = (r - R)/S$$

Where:

r = actual rainfall (amount) of a given year

R= mean rainfall of the total length of period

S= standard deviation of the total length of period

Normalized values were used to show deviation of rainfall from mean. The mean is represented by zero. Results of the values were cumulatively added to each other for the period of record and plotted to achieve long-term trends of annual rainfall. The mean annual rainfall for the three agro ecological zones LM 5, IL 6 and LH 2 was calculated. A coefficient of variation (CV), defined as the ratio of standard deviation to the mean, was also calculated for rainfall amount for each station. Coefficient of variation for annual rainfall and seasonal rainfall was used by Recha, Makokha, Traore, Shisanya, Lodoun & Sako (2012), Sivakumar (1991), Shisanya (1990), Slegers (2008) and Tilahun (2006).

3.12.2 Household Survey and Interview Schedules Data

Household survey data sought information on household socioeconomic characteristics, access to domestic water, rainfall variability, adoption of RWHT and constraints to use of rainwater harvesting technologies in Baringo County. Households access to water was assessed based on WHO/UNICEF Joint Monitoring Programme (JMP) guidelines and this included distance covered collecting water, time spent fetching water, quantity of water collected, location of water source and use of water sources classified as improved (WHO/UNICEF, 2008).

In order to determine communities' perceptions of rainfall trends and variability, respondents were asked two sets of questions. The first was asking household heads if they have observed any change in rainfall pattern, and if so, how many years back they had noticed this change. Respondents were also asked how the weather had changed over the years, i.e. what the weather was like a long time ago and what changes they had observed over the past five years. To establish whether there was a relationship between rainfall variability and household access to domestic water, households' perceptions on rainfall variability was correlated with water access variables (distance, time, location, type of source and quantity of water).

Adoption was measured using one of the procedures mentioned by Agbamu (2006); calculating percentage of adopters. The use of percentage involved asking respondents to respond yes (1) or No (0) to the technologies they have adopted. Five stage processes of adoption were used to develop a framework for measurement of adoption. The five stages are: awareness, trial, evaluation, interest and usage. The respondents were asked to tick yes or no against stages of adoption of rainwater harvesting technologies. The percentages yes or no were calculated. The adoption level was the summation of the numerical values of the Yes responses. This appears to be the commonest approach to the measurement of adoption (Hill & Linehan, 2011; Seizgn, Kaya, Kuleka & Kumbasaroglu, 2011; Imbur, Agwu & Akinnagbe, 2008; Ifejika P.I., Akinbile, Ifejika I.I. and Oladeji, 2008). Constraints to adoption of rainwater harvesting technologies at household level were calculated by running a percentage frequency table to determine the total number of respondents who mentioned a particular constraint.

To determine whether there was a significant variation in levels of adoption among the three agro-ecological zones, chi-square statistic was used. Percentage and frequencies of adopters were first calculated. The results were then computed and their significance tested using chi-square. Calculated chi-square, X^2, was attained by the formula:

$$X^2 = \Sigma (O-E)^2 / E$$

Where X^2 is chi-square,

Σ is summation,

O is observed frequency,

E is expected frequency.

The calculated X^2 is then compared with the critical table X^2 at the required degree of freedom (d.f) and probability. If the calculated X^2 is less than the critical value in the table at a given level of significance (in this case 5%) for a given degree of freedom, it is concluded that the null hypothesis, H_0, is true and therefore no differences between the variables. But if the calculated table chi-square value is greater than the tabular X^2 value, then it is concluded that the H_0 does not hold, giving way to acceptance of the alternative hypothesis, H1, and a confirmation that there exists a difference between the variables under investigation.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the response rate and research findings of household socioeconomic characteristics, rainfall variability, and effect of rainfall variability on access to domestic water and adoption of Rainwater Harvesting Technologies (RWHT) in Baringo County.

4.2 Response Rate and Socio-economic Characteristics of Respondent

This sub-section presents results of the response rates of household survey and key informants. The subsection further presents results on socio economic characteristics of respondents.

4.2.1 Response rates

The percentage of respondents who responded to a survey was 100 %. The study targeted 13 key informants and 376 households and all were interviewed. According to Punch (2003), high survey response rates helps to ensure that survey results are representative of the target population. A survey must have a good response rate in order to produce accurate useful results (Hamilton, 2003).

4.2.2 Gender of the household head

Understanding the gender of the household head is important in making decisions regarding household water availability and adaptation to rainfall variability. From the findings (Table 4.1), 64 % of the households sampled were male- headed while 36 % were female-headed. Most households were male-headed hence more households are likely to adopt rainwater harvesting technologies as an adaptation strategy to rainfall variability in Baringo County. Previous adoption studies have found that women are less likely to adopt new technology (Lloyd & Baiyegunhi, 2015; Adesina & Chianu, 2002) because female-headed households have limited access to resources (KNBS, 2010; Mbugua, 1997; Oppong, 1997; World Bank, 1991). Although most households were male-headed, it was noted that women were more concerned with quality and quantity of water based on gender division of work in the family. This finding therefore calls for involvement of women in adoption of the technology to respond to rainfall variability.

4.2.3 Age of the household head

Age was clustered into 8 categories each with an interval of 6 years ranging from 18 years and the final category covered 60 years and above. In this study, 31 % of the respondents were aged between 18 and 30 years, 51 % were aged between 31 and 50 years, 11 % were aged between 51 and 60 years and only 6 % of the respondents were aged 60 years and above (Table 4.1). The results indicate that majority of the respondents were within the active and productive age range. They are in their prime age and in position to make crucial decisions regarding implementation of adaptation strategies to rainfall variability. They have better potential to be trained in adaptation mechanisms to rainfall variability. Older household heads are less likely to adopt the technology (Lloyd & Baiyegunhi, 2015). According to the theory of human capital, young members of a household have a greater chance of absorbing and applying new knowledge (Sidibe, 2005).

Table 4.1: Distribution of households' demographic characteristics

Demographic characteristics	Frequency	Percentage
Gender		
male	241	64
Female	135	36
Total	376	100
Source of income		
Wage employment	107	29
Self-employment	94	25
Business	98	26
Crop sales	77	20
Total	376	100
Education level		
No formal education	90	24
Primary	92	25
Secondary	132	35
Post-secondary	62	16
Total	376	100
Age bracket of household head		
18 and below	2	1
18-30	118	31
31-40	106	28
41-50	87	23
51-60	43	11
61 and above	20	6
Total	376	100
Household size		
3 members and below	34	9
4 to 7 members	241	64
8 to 10 members	85	23
11 members and above	16	4
Total	376	100

Source: Survey Data, 2015

4.2.4 Source of income

The main occupations of the household heads in Baringo County are shown in Table 4.1. About 29 % of respondents interviewed earned their livelihood from wage employment. About 25% of the respondents were self-employed while 56 % engaged in other forms of income generating activities such as crop sales (20 %) and business (26 %). The study also established that main source of income for households in highland (LH2) was wage employment (34 %), midland (LM5) was crop sales (41 %) and lowland (IL6) was livestock business (61 %). People in LM5 inhabit close to Lake Baringo. They combine rain-fed cultivation with supplementary irrigation while those in IL6 inhabit the northern part of the area and are heavily dependent on livestock and in particular goats. The ones in highland (LH2) settle up on the humid hills with good conditions for rain fed farming. Occupation influences the household's income and hence the amount of funds available to spend on water and rainwater harvesting structures.

4.2.5 Household size

Household size was recorded by the number of children and full time dependants in the household. Table 4.1 shows distribution of respondents according to the number of dependants within their households by categories. The greater proportion of households (64 %) had 4-7 members. Over half of this percentage had over 8 members. It would appear that majority of households have large families. Households with less than three family members constitute only 9 %. The study found that the smallest household size in the study area had one member and the largest household was composed of fifteen members. The average family size of the sample households, in this case, was found to be 7 persons, which is higher than the national average of

6 persons (Ministry of planning and National Development, 2008). Given that family labour is the main source of labour, large family households dominate the households and they may be motivated to adopt rainwater harvesting technologies in order to meet the high demand for water requirements.

However, it was noted that high numbers of members per family are mainly young people and this definitely is an indication of a high demand of resources to sustain big families in the area. The household size is important in adaptation to rainfall variability as it influences the adaptive capacity of the household. Households with more members are more likely to experience poverty (Kimenyi & Mbaku, 1995) than smaller households. A large household compounded with high level of poverty require a lot of financial resources for provision of basic needs. This eats the financial and natural capital that would have been spared for implementation of appropriate adaptation strategies to rainfall variability.

4.2.6 Education Level of the household head

The education level of the household head enables the household to acquire useful information on alternative water sources during dry periods due to ability to read and comprehend materials related to rainfall variability and adaptation strategies. Education improves the capability for resourcefulness and invention. Formal education can also provide a way of gaining employment, which is a source of income that can be used in implementation of adaptation strategies to rainfall variability.

Table 4.1 shows that 35 % of the sample respondents attained secondary education, 25 % attained primary education, and 24 % had no formal education while only 16 % had post-secondary education. The study established that the levels of education of household heads varied among the three agro-ecological zones of Baringo County. From Table 4.2, majority of the respondents (50 %) interviewed in highland (LH2) had attained secondary education, in midland (LM5) 45% attained primary education while in lowland (IL6), 66 % had no formal education. It was noted that most respondents dropped out of school after primary education in LM5 because of lack of school fees and search for employment to support the family because rain fed agriculture was no longer reliable while in LH2, most respondents did not attend school to tend cattle and goats and others felt that education is not important. Low educational attainment leads to low incomes hence less resources will be available for the implementation of adaptation mechanisms. The study findings indicate that education status is generally low in Baringo County and this negatively impacts on their adaptive capacity and vulnerability to effects of rainfall variability.

Table 4.2: Distribution of respondents’ source of income and education level by Agro-ecological zones

Variables	Agro-Ecological zones		
	LH2 (%)	LM5 (%)	IL6 (%)
Source of income			
Wage employment	34	7	32
Self-employment	29	36	7
Business	15	16	61
Crop sales	22	41	0
Total	100	100	100
Education level			
No formal education	5	26	66
Primary	20	45	19
Secondary	50	25	8
Post-secondary	25	4	7
Total	100	100	100

Source: Survey Data, 2015

4.3 Trend Analysis of Rainfall Variability

The study sought to determine rainfall trend in agro-ecological zones LM 5 (Perkerra station), IL 6 (Nginyang station) and LH 2 (Chemususu station) of Baringo County from the year 1981 to 2010. The mean annual rainfall for agro ecological zones LM 5, IL 6 and LH 2 was 616.9, 792.81 and 2209.13 respectively. According to the performed analysis (Table 4.3), maximum annual rainfall (1517.7 mm) was observed in the year 2010 in Nginyang station while in Chemususu station, maximum annual rainfall (6471.4 mm) was observed in the year 2005. For Perkerra station, maximum annual rainfall (926.8 mm) was observed in the year 2007. The minimum annual rainfall (99.6 mm) was observed in the year 2000 in Nginyang station while in Chemususu station, minimum annual rainfall (353.8mm) was observed in the year 1984. The lowest annual rainfall (237.6 mm) recorded in Perkerra station also was in 2002. The findings concur with those of Opiyo *et al*., (2014) who observed the lowest annual rainfall (54.2 mm) in 1984 in Lodwar, Turkana County. The lowest rainfalls recorded in the same year (1984) in the two agro ecological zones may be linked to the 1983-85 droughts which afflicted Africa's dry lands. There was a failure of Kenya's 'long rains' in April-May of 1984 (ODI, 1987).

The coefficients of variation for annual rainfall amount for IL 6 (Nginyang station) is 0.45 while LM 5 (Perkerra station) stands at 0.33. LH 2 (Chemususu station) exhibits a very high coefficient of variation for annual rainfall amount (0.70) (Table 4.3). According to Araya and Stroosnijder (2011), a coefficient of variation greater than 0.30 is an indicator of large rainfall variability. On the basis of Araya and Stroosnijder results, there is significant variation in annual rainfall among the three agro-ecological zones in Baringo County. The results are in line with those of Kansiime, Wambugu & Shisanya (2013) who noted highest coefficients of variation for highland for both annual and seasonal rainfall. The large rainfall variability in Baringo County may be linked to the 1982, 1994 and 2007 El Nino rains that characterized the average annual rainfall in Kenya (RoK, 2000). Arthur, Jagtap & Rosenzwei (2002) also found that annual rainfall increased during El Nino events compared with neutral years and that highland sites had the highest rainfall variability between El Nino events than lowland sites. Shisanya, Recha & Anyamba (2011) also reported above normal rainfall during short rains season than preceding long rains season rainfall in ASALs of Kenya during El Nino years. Links between El Nino and climate variability have also been suggested by other studies (e.g. Anyah & Semazzi, 2007: Ngongondo, 2006).

Table 4.3: Summary of Rainfall Variables for the Study Sites

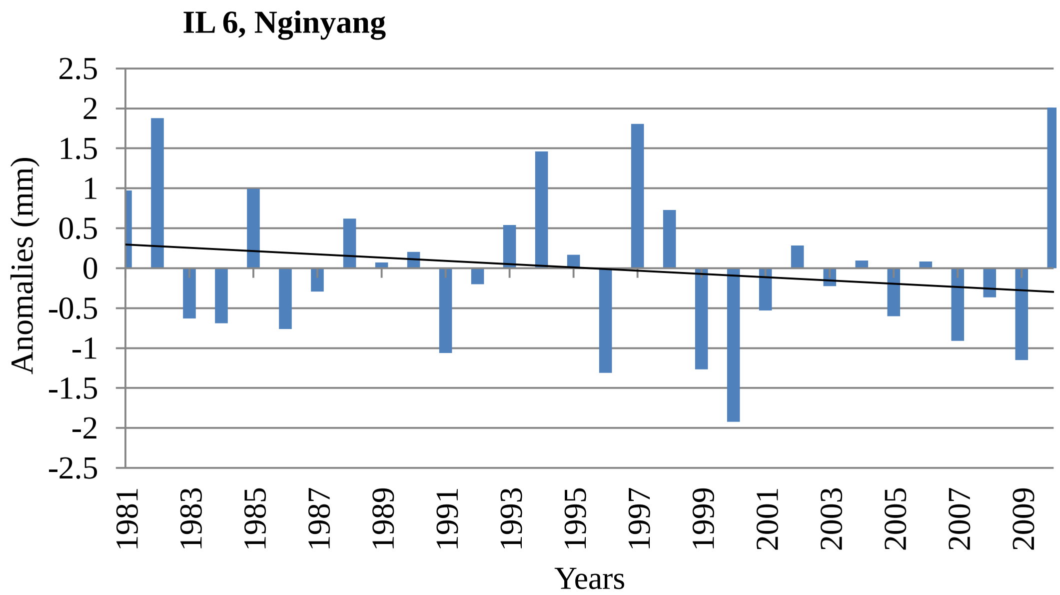
Agro-Ecological zone	**Rainfall**	**Annual**
IL6	Minimum (mm)	99.6
	Maximum (mm)	1517.7
	Mean (mm)	792.81
	Coef. of Variation	0.45
LH2	Minimum (mm)	353.8
	Maximum (mm)	6471.4
	Mean (mm)	2209.13
	Coef. of Variation	0.70
LM5	Minimum (mm)	237.6
	Maximum (mm)	926.8
	Mean (mm)	576.1
	Coef. of Variation	0.33

Source: Author, 2016

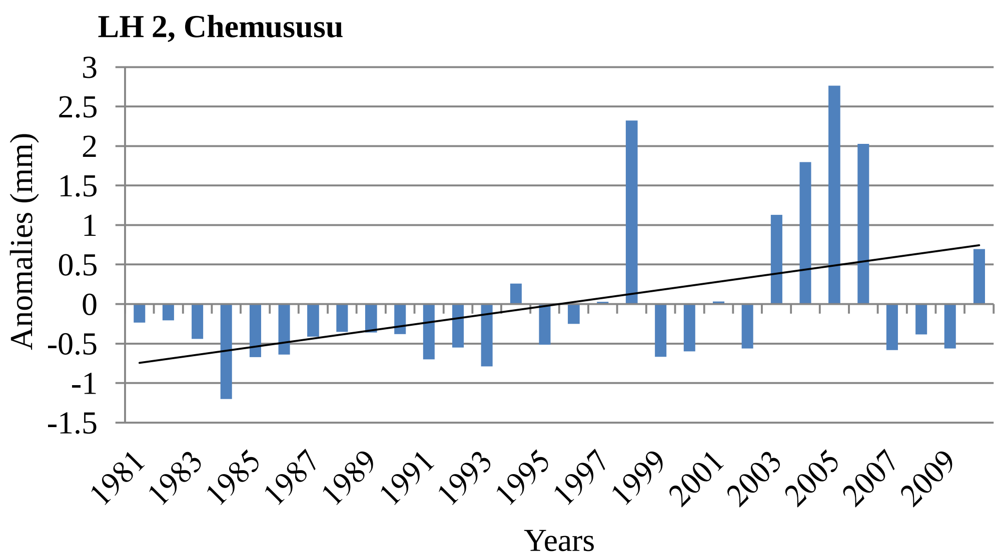
According to the results of the trend analysis (figure 4.1a), rainfall in AEZ IL6 (Nginyang rainfall station) of Baringo County has been on the decrease over the period of study. The years 1982, 1994 and 1997 recorded highest amount of rainfall while the years 1996, 1999, 2000 and 2009 recorded the lowest amount. Rainfall in the years 1996, 1999, 2000, and 2009 decreased at the rates of -1.4 mm, -1.2 mm, -1.9 mm and -1.1 per annum respectively. The findings concur with those of Jenny and Svensson (2002) who observed a similar pattern in Baringo lowlands. Kansiime *et al*., (2013) also observed a decreasing trend of total annual rainfall for low lying areas in Uganda. However, according to Arthur *et al*., (2002), sites in the highland wet eco-region of Kenya had the greatest decrease in annual rainfall than lowland and midland.

The results of the trend analysis (figure 4.1b) show that rainfall in AEZ LH 2 (Chemususu station) of Baringo County depicted increasing trends over the period of study. The years 1983, 1984, 1991 and 1993 depicted highest negative decreasing trends while the years 1998, 2003, 2004, 2005 and 2006 depicted highest positive increasing trends. The results are in line with those of Kansiime *et al*., (2013) in Uganda who observed an increasing trend of total annual rainfall for highland areas. Basalirwa (1995) also predicted an increase of approximately 10-20% in rainfall for high ground areas, and more drying conditions for low lying areas of Uganda.

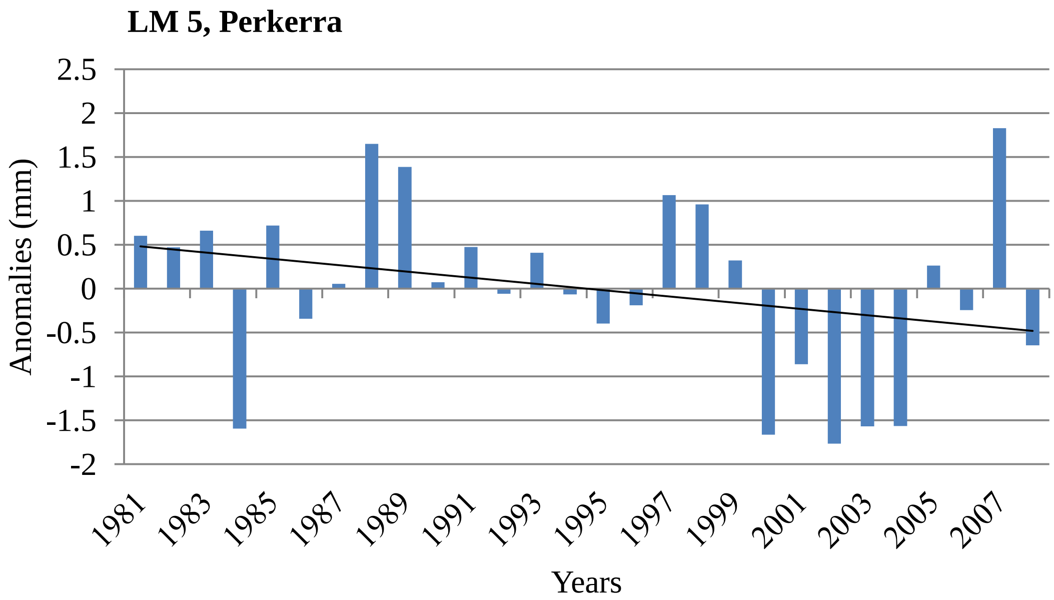
At AEZ LM5 (Perkerra rainfall station), the results of the trend analysis (figure 4.1c) show that there was a decrease in rainfall over the period of study. The year 2007 depicted highest increasing trend. A noticeable decrease of rainfall was observed in the years 1984, 2002 and 2004 while the other years showed a fluctuating decreasing and increasing scenarios which were not noticeable. The findings concur with those of Jenny and Svensson (2002) who observed a similar pattern in the same station in Baringo. Arthur *et al* (2002) also observed a decrease in annual rainfall in midland sites of Kenya. The results are in contrast with those of Kansiime *et al*., (2013) in Uganda who observed an increasing trend of total annual rainfall for mid lying areas.



(a) Annual rainfall anomalies and trend (black line) for Nginyang rainfall station



(b) Annual rainfall anomalies and trend (black line) for Chemususu rainfall station



(c) Annual rainfall anomalies and trend (black line) for Perkerra rainfall station

Figure 4.1: Rainfall anomalies and Trends

Source: Author, 2016

Trend analysis performed on annual scale to examine if there are patterns in the data at this scale showed varied results. Rainfall shows year to year variability. The data also revealed wide variation in rainfall trends by agro-ecological zones. Graphical visualization of annual rainfall data in the studied agro-ecological zones presented in Figures 4.1a illustrates annual rainfall trend patterns for the period 1981 to 2010 in Baringo lowland (Ribkwo) while Figure 4.1b illustrates annual rainfall trend patterns for the period 1981 to 2010 in Baringo highland (Lembus Central). There is an observed increasing trend of total annual rainfall for Baringo highland and a decreasing trend for Baringo lowland. Further analysis of annual trends (Figure 4.1c) depicted decrease in rainfall over the period 1981 to 2008 in Baringo midland (Salabani). This variation in rainfall amounts among the three agro-ecological zones may be attributed to variations in altitude and land use intensity in the specific locations. Households and key informants' perceptions of climate variability are in line with actual climatic data, noting variability in the amount and distribution of rainfall within and between the years (Figure 4.2).

Almost all the households (98 %) interviewed agreed that the amount and distribution rainfall has changed over the last five years (Figure 4.2). They noticed a decrease in the amount of rainfall or shorter rainy seasons. All the key informants interviewed including chiefs, water officers, NGO's (ACTED) and NDMA officers agreed that rainfall is changing and is no longer as it was years back. All the respondents that were interviewed believe that the climate is changing and is no longer as it was some years back. They indicated that these changes were mainly associated with rainfall amount and distribution. People's perception is that rainfall is lesser today than was in previous years. This is a common finding from other studies on perceived and actual rainfall trends and variability such as in Lower Eastern Kenya (Omoyo *et al*., 2015), Eastern Uganda (Shisanya *et al*., 2011), semi-arid central Tanzania (Slegers, 2008), Ethiopia (Tilahun, 2006) and Sudano-Sahelian regions (Sivakumar, 1991).

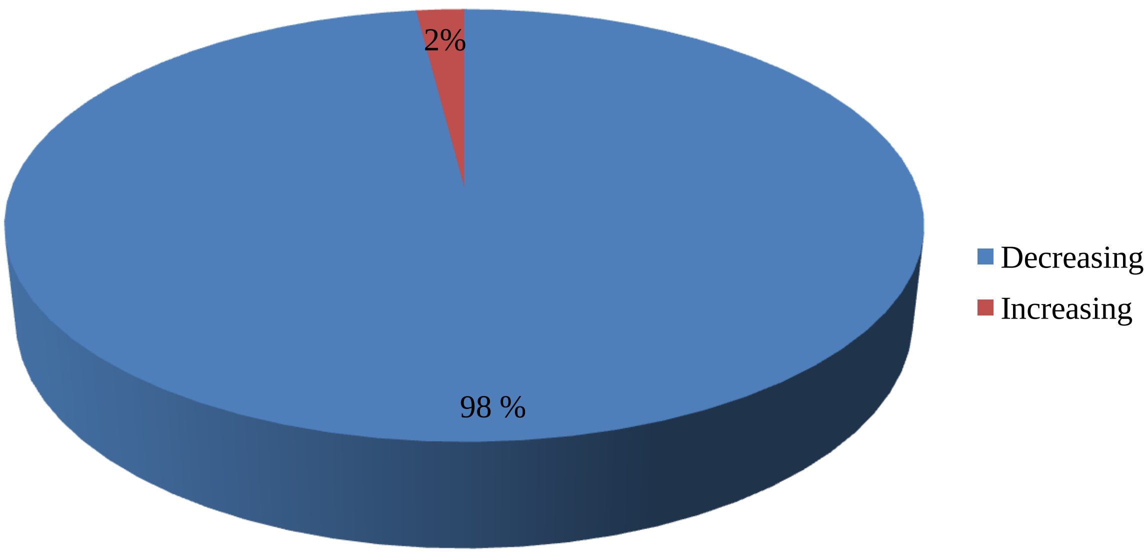


Figure 4.2: Perceived Amount and distribution of Rainfall over the last 5 years

Source: Field survey, August 2015

4.4 Effects of Rainfall Variability on Access to Domestic Water

In this study, an assessment of access to water was based on WHO/UNICEF Joint Monitoring Programme (JMP) guidelines; distance covered collecting water, time spent fetching water, quantity of water collected, location of water source and use of water sources classified as improved (WHO/UNICEF, 2008). All these variables are essential for a declaration of access to water. Access to water in this case meant that the household spent 30 minutes or less to fetch water, used water sources classified as improved, had their water source located within one kilometer of their home and were able to reliably obtain at least 20 liters per member of a household per day as recommended by WHO/UNICEF.

The results (Figure 4.3) indicated that only 29 % of the households sampled in Baringo County had access to domestic water while 71% had no access.

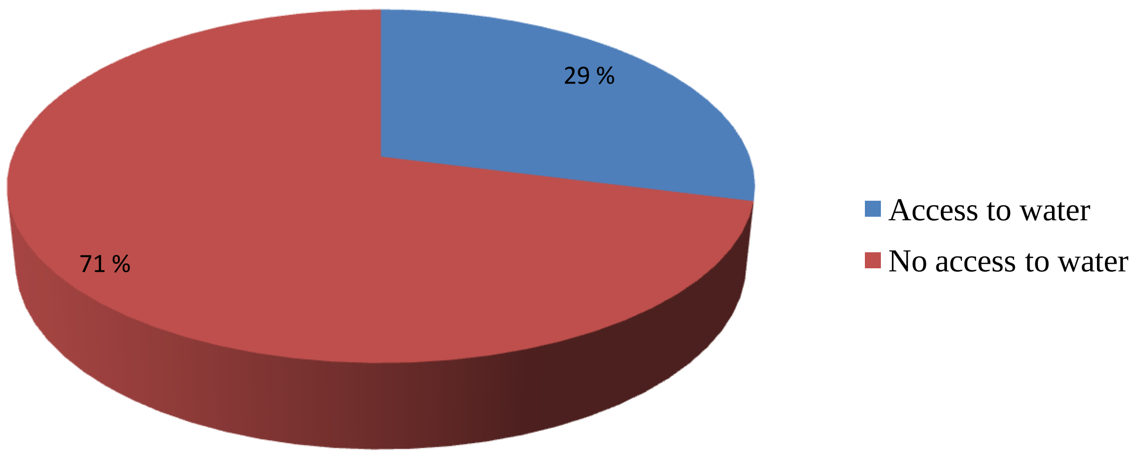


Figure 4.3: Household access to domestic water in Baringo County

Source**:** Field survey, August 2015

Figure 4.4 and plate 4.1 present the types of water sources used among the sample households. As in other developing countries, households in the sample utilized more than one type of water source for drinking and other purposes. Only 37 % of the households used unimproved domestic water sources; surface water. Majority of the households (57 %) used improved water sources; borehole (32 %), tap water (26 %), protected spring (2 %), rainwater (2 %) and bottled water (1 %). Improved water sources include sources that, by nature of their construction or through active intervention, are protected from outside contamination, particularly faecal matter and are more likely to provide water suitable for domestic use than unimproved technologies. It was established that out of the 37% households that used surface water, majority used the worst drinking water source -a dam and this may limit the quantity of suitable drinking water. Streams and protected springs were almost exclusively mentioned in Lembus Central (LH2) while dams, boreholes and dug wells in Ribkwo (IL6). Most of the households in Salabani (LM5) mentioned lake, dam and streams as their main sources of water.

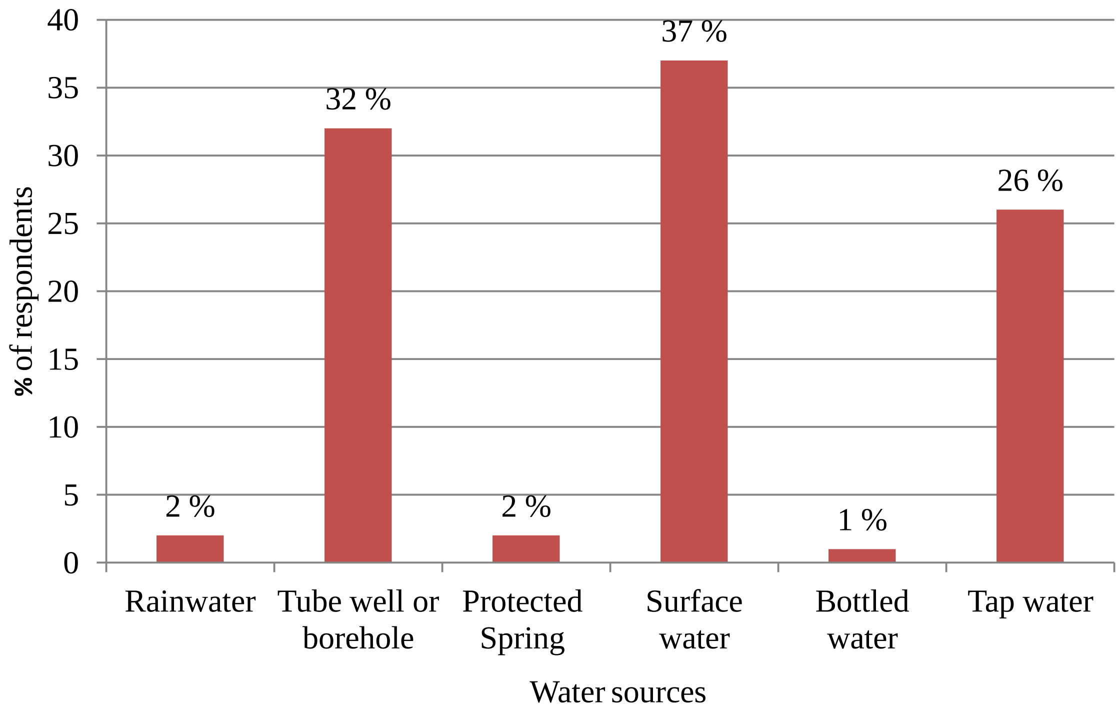


Figure 4.4: Water sources used in Baringo County

Source: Field data, August 2015.

(a) Unprotected dug well in Ribkwo

(b) Dam (Molok) in Ribkwo

(b) Storage tank collecting rainwater in Lembus Central

(d) Tap water (public standpipe in Salabani)

(e) Arama Spring in Lembus Central

(f) River Labos in Salabani

Plate 4.1: Water sources used by households in Baringo County in August 2015

Source: Field survey, August 2015.

Results indicated that 49 % of the respondents had their water source located in their own yard or plot while 48 % elsewhere. It was established that only 3 % of the households sampled had their water source located in own dwelling as shown in figure 4.5. WELL (1998) noted that when water is outside the dwelling, average use drops to roughly one third the average use at a compound tap and one tenth that of household with water piped into the dwelling. The households that fetched water from a source that was not immediately accessible to the household transported using a donkey in Lembus Central and human-powered transport in Ribkwo and Salabani. The considerable labour involved in water collection in Baringo is almost exclusively done by women and children. Girls carried large containers full of water on their backs (see plate 4.2). Water sources that are considered clean can become contaminated between point - of - collection, storage and household use (KNBS, 2010). The extent and impact of this kind of water contamination is unknown in the area and calls for further investigation to be better understood.

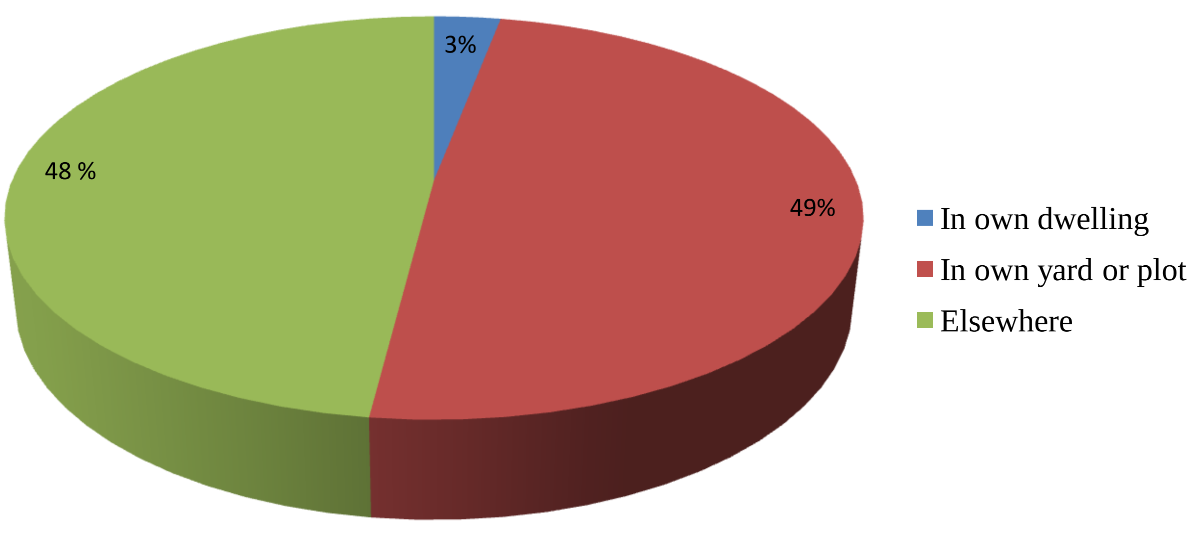


Figure 4.5: Location of water source in Baringo County

Source: Field data, August 2015

(a) Transportation of water using donkey in Lembus Central (b) Human-powered transport in Salabani

Plate 4.2: Transportation of water

Source: Field survey, August 2015

The percentage of respondents who covered long distance to watering points was highest (85 %) in Ribkwo (IL6). In Salabani (LM5), 80 % of the sampled population covered more than 2km to reach water points while in Lembus Central (LH2) only 44% in of the sampled population had their water source located more than a kilometer away from their dwelling (Figure 4.6). It was noted that a section of the households in Salabani depend on dam and rivers which dry up during the dry season forcing women and children to travel longer distances in search of water from other sources. The increase was less in Lembus Central and this can be attributed to rainwater harvesting, the sinking of boreholes and construction of a large community dam (Chemususu) which provide an additional source of water. It would be helpful if similar efforts were directed to other parts of the County to improve access to clean water.

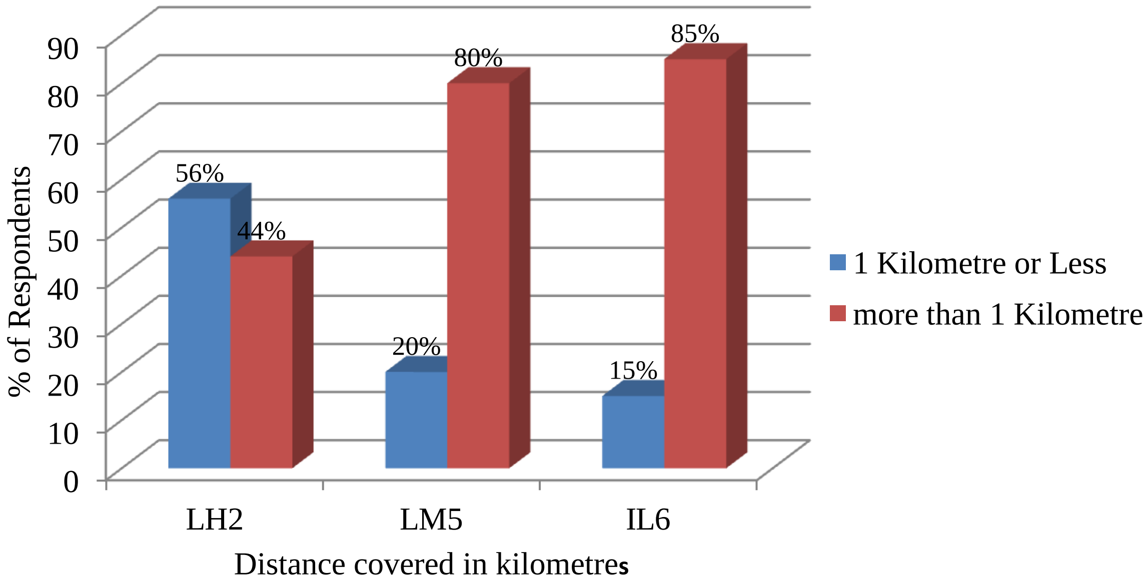


Figure 4.6: Distance covered collecting water

Source: Field data, August 2015

The quantity of water used per capita per day by each member of a household in the sample was obtained by dividing the total volume of water collected for domestic use (in litres) per day in a household by total number of members in a household. The respondents were asked how much water had been collected since the same time the day before. The responses were given in numbers of containers rather than liters and therefore the researcher needed to have a series of pictures of the common water containers in that community with the volumes pre-measured. All the households used jerry cans to collect water; these cans typically hold 20 liters. Children also used smaller jerry cans, up to 10 liters. Calculations for individual households were done and results are summarized in figure 4.7 below.

About 49 % persons in the sample used less than 20 liters per capita per day in midland (LM5). Almost all the persons in lowland (97 %) and highland (96 %) used less than 20 liters per person per day (Fig.4.7). This may be attributed to large family sizes in the two sites. It can be noted that only few individuals in LH2 (4 %) and IL6 (3 %) were within the minimum limit –the 20 liters per person per day set by WHO an indication that there is water shortage in Baringo County.

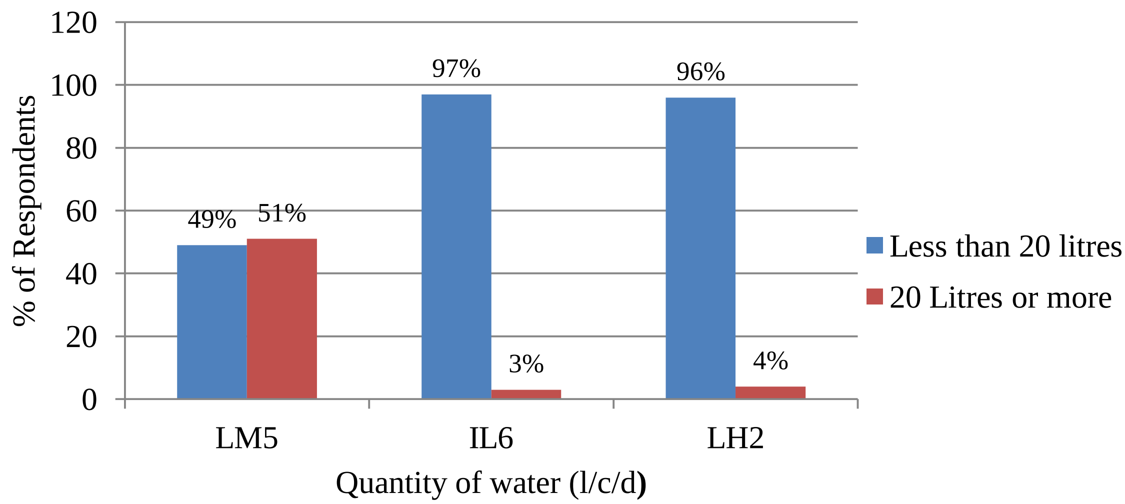


Figure 4.7: Quantity of water used per capita per day

Source: Field data, August 2015

Further insight into the households' access to domestic water sources was gained from an assessment of total collection time (Figure 4.8). More than half (55 %) of the sampled respondents in LH2 took less than half an hour, while only 17% in LM5 and 18 % in IL6 took less than 30 minutes to get into water source, get water and back. The percentage of the respondents who took more time in normal roundtrip collecting water was highest in midland (83 %) and lowland (82 %). These are arid and semi-arid lands (ASALS) where droughts are frequent and rains more erratic. Water quantity is lowest during times of drought and many of the improved sources dry up in some locations. It was noted that during the dry season, water levels drop taking too much time to access even the nearby sources due to queuing. Rainfall variability results in decreased underground water discharge and surface water volume. With households in LM5 and IL6 relying on dams, streams and wells, this explains why the number of respondents were taking more time to fetch water.

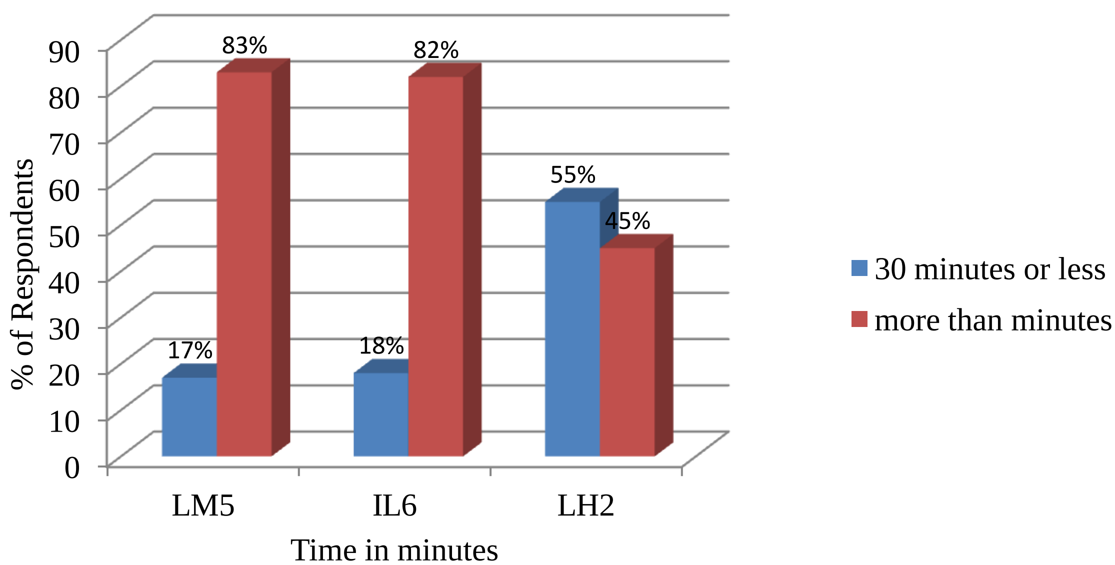


Figure 4.8: Time spent collecting water

Source: Field data, August 2015

Correlation analysis was performed to establish if there was a significant relationship between perceptions on rainfall variability and water access variables (Table 4.4). Results show that there was no statistically significant relationship between rainfall amount and any of the access variables. This means that the amount of rainfall received does not affect access to water.

Rainfall variability is a frequent recurrence in the area and residents have learned to live with it hence its variation does not affect type of source used, location of water source, quantity of water used, time spend and distance covered collecting water. The results are in line with Adetayo (2015) findings who observed a weak but positive correlation between public water availability and rainfall in Nigeria. However, Onyenechere *et al.* (2011) in Nigeria observed a significant relationship between rural water supply and rainfall amount/variability pattern. Eldredge, Ktialii, Nrcholds, Abdalla & Rydjeski (1988) in Western Sudan reported that a relatively dry condition had persisted in the region since 1966 due mainly to a decline in rainfall.

Table 4.4: Relationship between rainfall variability and access to water

		Amount of rainfall over the last 5 years	Source of water for domestic use	Location of Water source	Time spend in round trip to fetch water	Quantity of water used per capita	Approximate Distance to water source
Amount of rainfall over the last 5 years	Pearson Correlation	1	-.054	-.007	.093	-.032	.091
	Sig.(2-tailed)		.293	.892	.072	.532	.077
	N	376	376	376	376	376	376

**Correlation is significant at the 0.05 level (2-tailed).

Results of rainfall trend analysis revealed that rainfall is not only low but highly variable and unpredictable over time in Baringo County. The County experiences spatial rainfall variability-differences in total rainfall received across the agro-ecological zones. Variable rainfall can cause of water scarcity. According to Oki and Shinjiro (2006), uneven distribution of rainfall in space and time is one of the causes of water scarcity worldwide. Ngongondo (2006) in Malawi also reported that there is vast problem of access to potable for an average household especially during the dry season when there is decline in rainfall with alternating wet and drier years. This is because a deficiency of rainfall can possibly lead to a depletion of stream discharge and reservoir storage, which would in turn affect sectors such as public utilities (power and water supply) sector (Tarhule, 1997). Water scarcity is likely to become even more severe as climatic impacts and increasing water demand combine. According to USEPA (2013), climate change exacerbates weather Oscillations and generally impact water quality as well as quantity. In many regions, changing precipitation is altering hydrological systems affecting water resources in terms of quantity and quality (IPCC, 2014).

From figure 4.9, it can be observed that sampled respondents concur with various aspect(s) of water access affected by rainfall variability. Fifty-three percent of the sampled respondents agreed that quantity of water was the aspect of water access that was most affected by rainfall variability. A total of 25 % of the sampled households agreed that distance covered collecting water has generally increased due to rainfall variability. Few of the households agreed that reliability of source (9 %), type of source (6 %), time spent fetching water (4 %) and location of water source (3 %) was mostly influenced by rainfall variability. The nature of effects of rainfall variability varies across the year. The end of the dry season is the most uncertain period because none of the available sources is dependable. More frequent and severe droughts were perceived to be responsible for the reduced water level in Lake Baringo and intermittency of most rivers that were previously permanent (see plate 4.3). River Endao which is one of the major sources of water in the area was reported to have changed its course several times in the recent past and has since become seasonal because of climate change.

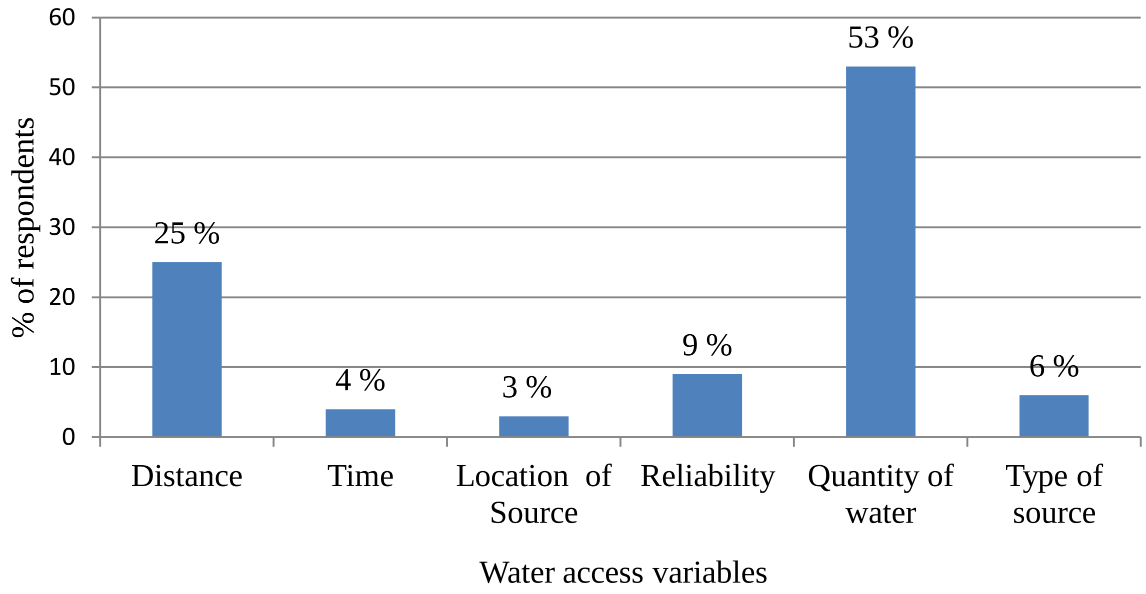


Figure: 4.9: Aspect(s) of water access affected by rainfall variability

Source: Field data, August 2015

Plate 4.3 (a) Dried river (Endao) in Salabani

Plate 4.3 (b) Lake Baringo

Plate 4.3: Water sources affected by rainfall variability

Source: Field survey, August 2015

The reasons cited by respondents interviewed for observed change in rainfall variability over the last 5 years in Baringo County are given in Figure. 4.10 below. Among the households interviewed, 58 % of the respondents were of the view that deforestation is responsible for rainfall variability over the last 5 years in Baringo County while 30 % of the respondents were of the opinion that climate change caused rainfall variability. Finally, 12 % of the respondents said that they had no idea about climate change. The results implicate deforestation as the main cause of rainfall variability. This could be as a result of an increased awareness by extension officers on importance of vegetation. To the few respondents, there was complete lack of awareness of the issues involved in rainfall variability in Baringo County hence there is need to increase awareness on rainfall variability. The findings are in agreement with those of Masese, Raburu, Mwasi & Etiegni (2012) and Jenny and Svensson, (2002) who observed deforestation as the main cause of climate variability.

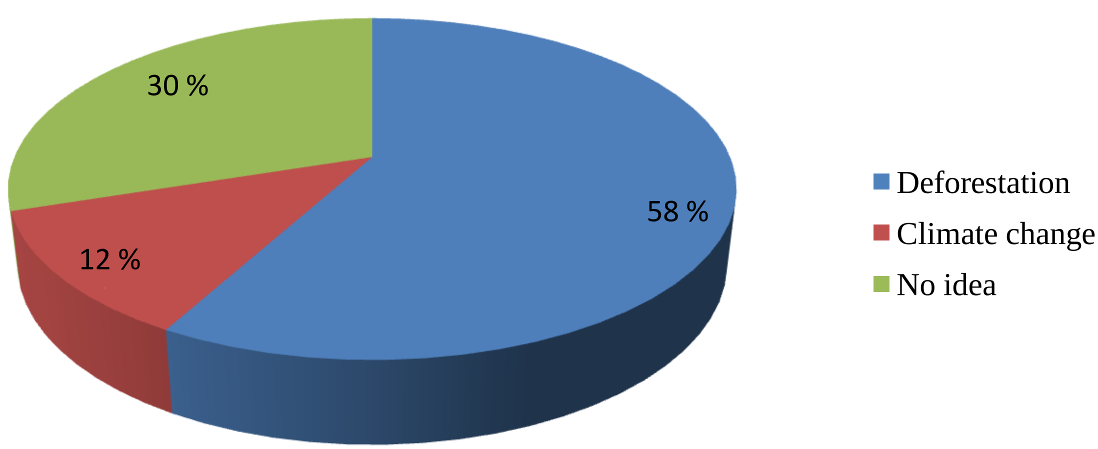


Figure 4.10: Reasons for observed change in rainfall variability over the last 5 years in Baringo County

Source: Field data, August 2015

Most of the forest in Baringo is located in the highlands. It was established that logging is the main cause of deforestation in Baringo County. More of Baringo's woodland is being cut down for charcoal and wood-based industries. Farmers also fell trees to increase space for farming (Jenny and Svensson, 2002). Both cutting and burning of trees are practiced as shown in Plate 4.4d. Charcoal stacks are often seen right next to the cleared areas. Aerial photos from 1969 and 1979 over a highland area were also available (Plates 4.4e and 4.4f), confirming that areas with cultivated land are increasing while areas of forested and uncultivated land are decreasing. Large patches of open land surrounded by forest are visible even on very steep slopes. Researcher field observations of the situation today verified a continued decrease of the forests the latest decades (Plates 4.4e). Only small forest lands remain in the highlands due to an expansion of cultivated land (Plates 4.4c and 4.4d). Deforestation in Baringo County is also evidenced by many sawmills in the area (Plate 4.4b) and open areas west of Lake Baringo such as the Njemps flat in Salabani. Some trees have been flushed away and the areas affected by gully erosion have both expanded and increased in number as illustrated in plate 4.4a. Here the open ground has expanded much during the analyzed time. The vegetation cover is very sparse and the overgrazing is severe (Plate 4.4a).

Plate (a)

Plate (b)

Plate (c) Plate (d)

(a) Open ground in Salabani location (b) Sawmill processing logged trees in Lembus Central

(c) Large patches of open land surrounded by forest (d) Cut trees in Lembus Central

Source: Field data, August 2015

(e) Highland area with small terraced fields (f) Steep slopes with burnt land in the highland

Plate 4:4; Deforestation in Baringo County

Source: MALDM (1994)

From Table 4.5, it can be observed that only 3 % of the respondents agreed that negative effects of rainfall variability was very severe on distance covered collecting water. These were the households whose water source was located within a kilometer of their dwelling. This implies that the effects were very severe to most of the households (29 %) who walked long distances in search of water. These respondents had their water source located more than a kilometer away from their dwelling. The quantity of water collected decrease with increase in distance covered collecting water. Cairncross and Feacham (1993) found that once distance covered collecting water exceeds 100 meters from the dwelling, the quantities of water-collected decrease significantly.

Table 4.5 shows results on perception of effects of rainfall variability on access to water. Survey results revealed that effect of rainfall variability was very severe on type of water source used by household. It was severe to some respondents (23%) who used borehole as their main source of water. Respondents gave an example of water table that normally falls whenever drought sets in resulting to drop in water level. These force them to utilize more than one type of water source. To most of those who used surface water (24 %) the effect was moderately severe while to those who used tap water (15 %), the effect was not severe. The effect was also was very severe on location of source. According to the study findings, the effect was very severe to the few of the respondents (23%) whose source was located in own plot or yard. the impact was moderately severe to the 30 % of respondents whose source was located elsewhere. WELL (1998) found that when water is outside the home or plot, the quantity of water that is available for use in a household is less than that of household with water piped into the home.

Research findings indicated that most of the respondents (30 %) who agreed that negative effect of rainfall variability was very severe on time spend fetching water spent more time. They spent thirty minutes or more in normal roundtrip collecting water. The effect was not severe to those who took less time (less than 30 minutes) fetching water. The study established that the negative effects of rainfall variability were also severe on quantity of water used per capita per day. The effect was very severe to those who consumed less than 20 liters per day. To those who were within the minimum limit –the 20 liters per person per day (16 %), the effect was less severe.

Table 4.5: Percentage distribution of respondent’s perception of effects of rainfall variability on access to water

	Effects of rainfall variability		
Water access variables	**Very severe (%)**	**Moderately severe (%)**	**Not severe (%)**
Distance to water source			
1 Kilometer or Less	3	15	21
more than 1 Kilometer	29	26	6
Source of water for domestic use			
Rainwater	0	1	0
Tube well or borehole	23	4	5
Spring water	0	1	0
Surface water	8	24	6
Bottled water	0	0	1
Tap water	2	10	15
Location of water source			
In own dwelling	1	1	2
In own yard or plot	21	10	18
Elsewhere	10	30	7
Time spent fetching water			
30 minutes or less	3	14	21
more than minutes	30	27	5
Quantity of water used per capita			
Less than 20 litres	32	28	11
20 Litres or more	1	12	16

Source: Field data, August 2015

4.4 Adoption of Rainwater Harvesting Technologies as an Adaptation Strategies to Rainfall Variability

In this study, the adoption scale to measure the adoption of Rainwater Harvesting Technologies (RWHT) was constructed using percentage of adopters. Some researchers such as Rogers (2003) and Vijayabhjinandana (2007) agreed that adoption of innovations followed hierarchical stages namely: awareness, interest, evaluation, trial and usage. These five stage processes of adoption were used to develop a framework for measurement of adoption in the present study. Respondents were asked to tick yes or no against stages of adoption of rainwater harvesting technologies. The percentage yes or no were calculated. Adopters were further asked to indicate the number of years they have made use of the technology. A five-year period was considered long enough for households to have fully adopted the technology. The findings (Table 4.6) revealed that most of the households in Baringo County had awareness (90 %), interest (96 %), evaluated (92 %), tried (79 %) and used (91%) the technology. However, most of them had made use of the technology for few years (less than five years). From Table 4.6, about 68 % of the households sampled had used RWH technologies for five years or more. About 32 % had practiced the technology for only few years; 4 years (13 %), 3 years (9 %), 2 years (6 %) and 1year (4 %).

Table 4.6: Percentage and frequency distribution for stages of adoption (N=376)

Adoption stages	Response categories	Frequency	Percentage
Awareness	Yes	342	91
	No	34	9
Interest	Yes	362	96
	No	14	4
Evaluation	Yes	347	92
	No	29	8
Trial	Yes	298	79
	No	78	21
Usage	Yes	342	91
	No	34	9
Duration of use			
1 year		14	4
2 years		19	6
3 years		32	9
4 years		43	13
5 years or more		235	68
Non -users of RWHT		33	9
Total		376	100

Source: Field data, August 2015

In the survey locations, about 50 % of the respondents have adopted RWH techniques in their households. This is not good enough because relatively 50 % of the respondents have not adopted the technology. According to Floyd, Harding, Paddle, Rasali, Subedi K.D. & Subedi P.P. (1999), adoption greater than 60 % is good. On the basis of this, there is low adoption of RWHT in Baringo County hence there is need to increase awareness. Adoption of rainwater harvesting technologies in this case meant that the household had gone through the adoption process that is awareness, trial, evaluation, interest stage and had finally accepted to practice the rainwater harvesting technologies for five years or more. The survey established that even non-adopters utilized RWHT to some extent. Some of them had some knowledge or awareness while others had tried, assessed or used the technology for a short period (less than five years) of time. Those non adopters were asked as to why they are not adopting RWHT and most of them responded that they lacked adequate rainwater harvesting structures. Some of the respondents also reported that they are not interested with the technology. Respondent households practicing this technique reported improved access to water in their households.

Households in Baringo County were engaging in various rainwater harvesting techniques to adapt to climate variability. From the total sample of adopters households (Table 4.7), 33 %, 65 % and 2 % of the respondents were using rain water only during rainy season, rainy season and dry season, and dry season respectively. Only few adopters of RWHT used rainwater only during rainy season. There is higher percentage (65%) of use of rainwater harvesting technologies during rainy and dry season. Least percentage (2 %) use rainwater harvesting technologies during dry season because it is a dry spell.

Table 4.7: Use of rainwater technology by seasons

Category	**% Technology users**
Rainy season only	33
Dry season only	2
Rainy season & dry season	65
Total	100

Source: Field survey, 2015

During the study, respondents were asked to list the rainwater harvesting technology (RHT) they know. From Table 4.8, Most of the respondents (42 %) knew a variety of both Roof top RWHT (such as storage tanks and wells) and Surface runoff RWHT (such as water pans, ponds and dams). About 35 % of the respondents knew only Roof top RWHT while 17 % knew Surface runoff RWHT only. The remaining 6% knew none of the technologies. Roof water harvesting is a system of collecting rainfall water from the roof of a building and storing it in some storage facilities for future use when there is shortage of water (Haile and Merga, 2002). Surface run-off harvesting - is a system of collecting run-off from a catchment using channels or diversion systems and storing it in a surface reservoir- (Rockstrom, 2000).

Adopters have good knowledge about roof top rainwater harvesting technologies because many roof water tanks have been implemented by NGOs in rural areas of Kenya. These roof water tanks were regarded to be of the best quality and increasing water quantity and availability at the implemented site (Aroka, 2010). The technology has been exploited in Kenya for many years with most focus on the arid and semi-arid areas (ASALs) and rural areas (Otieno, 1994). The technology is also flexible and adaptable to a very wide variety of conditions (Worm and Hattum, 2006). It is used in the richest and the poorest societies, as well as in the wettest and the driest regions in the world.

Table 4.8: Rainwater harvesting technologies known

Type of RWHT	**Frequency**	**Percentage**
Surface runoff RWHT (water pans, dams)	65	17
Roof top RWHT (storage tanks, wells)	130	35
All of the above	159	42
None of the above	22	6
Total	376	100

Source: Field data, August 2015

About 90 % of the households in Baringo County were aware of water harvesting techniques that existed within their local context. A small proportion of households (10%) were not aware of the rain water harvesting techniques and this may be attributable to inadequate dissemination of information and skills with regard to rain water harvesting techniques. The distance to be covered (Figure 4.6) and times spend (Figure 4.8) collecting water in the event of water scarcity further amplified the awareness of and the need for water harvesting technologies. The distance covered in search of water is relatively far during water scarcity period. This makes people, especially women and children whose work is to ensure that there is water in the household (Gok, 2006), spend a lot of energies and time as well as travel longer distances in search of water during this period. According to Worm and Hattum (2006), collecting and storing water close to households improves the accessibility and convenience of water supplies and has a positive impact on health.

The research sought to find out how awareness was created. Figure 4.12 illustrates four major channels used to sensitize households on rainwater harvesting technology and practices. Majority of the governmental and non – governmental officers said that they created awareness through group meetings. This can be the very reason why majority of the households (71 %) revealed that such awareness is created by fellow villagers. In addition, school training and other sources such as radio, television and own initiatives were also mentioned. However, the finding that a section of the respondents not using rain water harvesting technologies had some knowledge of RHWTs implies that some of the technologies are not new in the sampled locations. The NGOs, and to a limited extent government extension staff, are just trying to revitalize utilization of RWHT and training residents in better ways of constructing rainwater harvesting structures. Barghouti and Le Moigne (1990) found that NGOs with few private sectors played an important role in implementing and adopting water harvesting techniques all over Kenya. These organizations were well appreciated by the community and were considered to be most efficient compared to government driven programs. According to Masuki, Mutabazi, Tumbo, Rwehumbiza & Hatibu (2005), awareness exposes someone to information and therefore creates knowledge which is a very important stage in the adoption of rain water harvesting technologies.

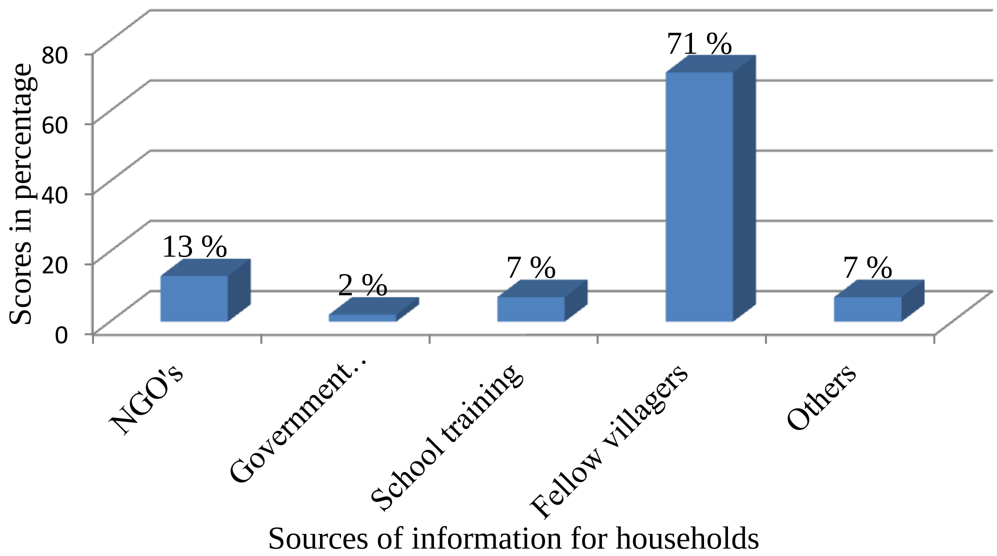


Figure 4.11: Sources of information and knowledge on RWHT

Source: Field data, August 2015

About (57 %) of the households in Baringo County practiced rooftop water harvesting techniques followed by dams (18 %,) and wells (12 %) with minority of the households using water pans (1%) (Table 4.9). Some of the technologies practiced in Baringo County are shown in Plate 4.5. Most of the households practiced rooftop water harvesting techniques -with rooftop catchment (storage tanks) being the most commonly used technique where communities use gutter-to-tank technology. All those who harvest water at their homesteads use gutter-to-tank technology. The findings concur with those of Kimani *et al*., (2015) in Makueni County, Kenya which observed that various rainwater harvesting technologies were used including rooftop harvesting techniques with rooftop catchment being the most commonly used technique. Rooftop water harvesting techniques was also the most adopted technology in Yatta, Kenya (Onwonga, Ahmed, Mburu & Elhadi, 2013). The ease of implementation of the said technique may have made it popular to the communities. Mati, De Bock, Malesu, Khaka, Nyabenge & Oduor (2007) found that rooftop harvesting technologies have the advantage to collect relatively clean water. Rooftop rainwater harvesting has also shown a high degree of reliability especially to the households who have invested in substantial rainwater harvesting systems (Kimani *et al*., 2015).

The second most widely practiced water harvesting technique was the dam. This is the case in other places of Kenya such as Yatta sub-County of Machakos County (Onwonga *et al.*, 2013), Makueni County (Kimani *et al*., 2015) and Kitui West, Lower Yatta and Matinyani sub-Counties of Kitui County (Luvai *et al*., 2014) where adoption of dams technique is pronounced. Despite its poor quality, water collected from earth dams is used to cater for livestock and domestic purposes (Kimani *et al*., 2015). Adoption of other techniques such as water pans (1 %) and wells (12 %) were found to be low in this area. This however is not the case in other places of Kenya such as Lare Sub-County of Nakuru County, where adoption of water pans technique is pronounced (KARI, 2000).

Table 4.9: Type of water harvesting techniques practiced by household

Type of water harvesting techniques	**Frequency**	**Percent**
Water pans	5	1
dams	69	18
storage tanks	216	57
Wells	44	12
storage tanks & wells	20	1
All of the above	17	6
None of the above	5	5
Total	376	100

Source: Field data, August 2015

Majority of the households (85 %) in Baringo County lack adequate rainwater harvesting structures (Figure 4.13). Only few households (15 %) have adequate structures. The study established that most (over 70%) of the respondents especially those using rooftop RWH systems have storage facilities of less than 150 litres capacity which cannot hold enough water throughout the year. Kimani *et al*., (2015) reported that households that have invested in sizable rainwater harvesting systems ranging from 1 to 10 m^3 capacity hardly experience water shortage problems and waterborne diseases. Several studies have been done on different issues pertaining to rainwater harvesting. For example, with respect to storage, Biswas and Mandal (2014) observed that a 4,000 L concrete tank installed with a roof area of 40 m^2 was adequate to take care of water demands of four-member household for five-month dry period. While Mwenge Kahinda, Taigbenu and Boroto (2010) recommended an optimum tank size of 0.5 m^3 which achieved water savings of 10-40%. In order to achieve a good water-saving efficiency and limit financial losses. Roebuck, Oltean-Dumbrava & Tait (2012) recommended storage tank size limit of 1.2-1.5 m^3. Pictures of some of the rooftop rainwater storage facilities are shown in plate 4.5 below.

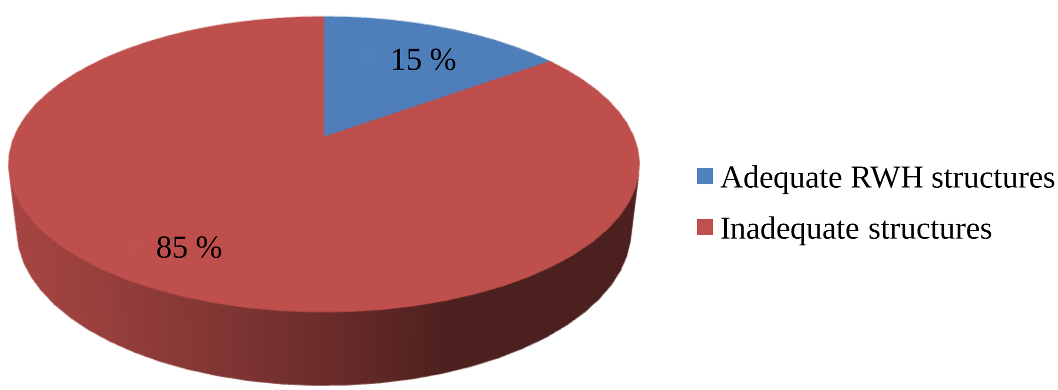


Figure 4.12; Adequacy of Rainwater harvesting structures

Source: Field data, August 2015

(a) Cement tank in Lembus Central (b) Plastic tank in Salabani

(b) Jerry can storage facilities in Salabani (d) Dug well in Ribkwo

Plate 4.5: Various Rooftop Rainwater storage facilities used in Baringo County.

Source: Field data, August 2015

4.5 Variation in Adoption of RWHT among the Three Agro-Ecological Zones

From the total sample households in Baringo County, 16 %, 64% and 47 % of the respondents had adopted rainwater harvesting technologies in Agro-Ecological zones LM5, LH2 and IL6 respectively. More than half of the in LM5 (84 %) and IL6 (53 %) had not adopted the technology (Table 4.10). Adoption of RWHT varies widely among the three agro-ecological zones.

To test for the statistical significance of the cross-tabulated relationships a null hypothesis $H_0 4c_{iii}$ posited that there *is no statistically significant variation in levels of adoption of RWHT among the three agro-ecological zones* was generated. A chi-square test statistic was conducted to test the null hypothesis (Table 4.10). The results, as shown in Table 4.10, show that, there is a significant variation in levels of adoption among the three agro-ecological zones.

Table 4.10: Variation in levels of adoption of rainwater harvesting technologies

Agro-Ecological zone	Adopters		Non adopters		Total	
	Freq	%	Freq	%	Freq	%
LM5	12	16	64	84	76	20
LH2	134	64	77	36	211	56
IL6	42	47	47	53	89	24

Chi-Square Test

	LM5	LH2	IL6
Observed frequencies	12	134	42
Expected frequencies	62.7	62.7	62.7
$(O-E)^2 / E$	40.997	81.08	6.834

Degrees of freedom=2; Calculated X^2=128.911; Significance level=0.05;
Table X^2=5.991

It can be observed that only few households in LM5 and IL6 have adopted the technology yet these are arid and semi-arid lands (ASALS) where droughts are frequent and rains more erratic. According to Amha (2006), RWHT is more suitable in arid and semi-arid areas where the average annual rainfall is from 200 to 800 mm (rarely exceeding 800 mm). Respondents in the two agro-ecological zones attributed their lack of harnessing rainwater to inadequate finances, information and design of the house. A fact that is supported by key informant interviews; namely local administrators (chiefs), NDMA, water and NGO extension officers. It was established that most households live in grass-thatched houses which are not suitable for rainwater harvesting and lack information and extra income to purchase water harvesting structures. Awareness creation has concentrated on the use of basic methods and technologies and most of the households were using small containers such as drums, buckets and jerry cans to harvest water. Very few had water tanks.

Results on socioeconomic characteristics of households (Table 4.2) showed that income and education status in LM5 and IL6 is generally low. Majority of the household heads have attained only primary education in LM5 while in IL6, majority have no formal education. According to Lloyd and Baiyegunhi (2015), educated household heads are more likely to adopt rainwater harvesting technologies. Links between education and technology adoption have also been identified (Tesfaye, 2006; Kimani *et al*., 2015; Murgor, Owino, Cheserek & Saina, 2013; Onwonga *et al*., 2013). Education would expose one to information and therefore creates awareness and enhances adoption of water harvesting systems. The source of income for majority of households in LM5 and IL6 was crop and livestock sales respectively. It was noted that majority entirely depended on farming activities for survival and generation of income and/or depended on farming activities to supplement their main sources of income. This, together with the low levels of education, may perhaps explain why the adoption of the water harvesting technologies in the two agro-ecological zones is low. The meager agricultural income may not be sufficient to implement some of the water harvesting techniques with regard to other competing uses; health, education and nutrition. High household income implies a greater incentive for investment in rainwater harvesting technologies and ability to bear the risks that can be associated with its adoption (Lloyd and Baiyegunhi, 2015).

Most of the households (92%) in highland (Lembus Central) and in midlands (Salabani) (68%) of Baringo practiced rooftop water harvesting techniques (storage tanks) because they have corrugated roof houses (Figure 4.14). Water harvested from rooftops is mainly for domestic uses including drinking and household chores. This technique is so important in the rural highland areas where the terrain is rugged and the villages and hamlets are scattered because it is difficult and expensive for communities to be served by centralized water supply schemes (Binyam and Desale, 2015). The roof water harvesting also has the advantage of being low cost, relatively simple in design (household technology), less laborious and time saving (Alem, 1999). The emergence of this technique these days is due to the increasing shortage of water from the conventional sources, shallow wells, perennial springs, rivers/streams. Binyam and Desale (2015) noted that roof water harvesting practices were confined to urban areas only in the past. However, its use in the rural areas are increasingly becoming important these days as more people in the rural areas are having corrugated roof houses.

The study revealed that only few of the households (29 %) sampled in lowland (Ribkwo) practiced rooftop RWHT. This may be attributed to more households having grass roof houses. Majority of the households (60 %) used surface runoff water harvesting techniques (dams). Earth and sand dams are constructed to collect water from river valleys for livestock and domestic purposes. Surface runoff occurs mostly on flat to gently sloping terrains and hardly contributes river flows due to low rainfall intensities in this part hence it is either captured in dams or re-infiltrates before reaching the river. The presence of luvisols in lowlands is suitable for surface runoff water harvesting because the subsurface layer lying at 1 to 3 m depth is clayey, favorably minimizing seepage losses (Pachpute, Tumbo, Sally & Mul, 2009). Land evaluation of RWH in a surface reservoir in the four Great Horn of African countries (Ethiopia, Kenya, Tanzania and Uganda) revealed that, it was slowly being adopted with high degree of success (Kiggundu, 2002). There are many dams in arid areas of Baringo constructed by NGO's (e.g. INTEX construction company and ACTED) in liason with the Government of Kenya. However, earth dams and other open water storage facilities including water wells in Baringo County face the problem of evaporation just as in all other open water storage facilities in ASALs. Erratic rainfall and shortages leading to frequent drought spell, high evapo-transpiration rates have resulted to unreliability and unsuitability of earth dams (Kimani *et al*., 2015).

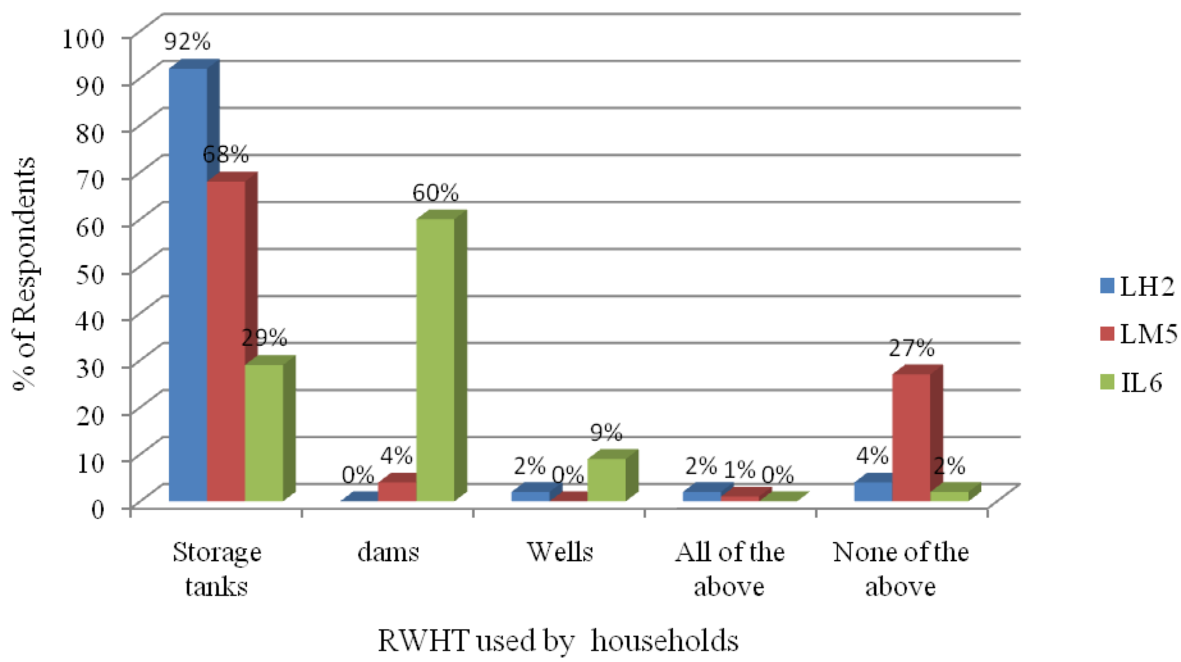


Figure 4.13: RWHT practiced by households in LM5, LH2 and IL6

Source: Field data, August 2015

4.6 Constraints to Adoption of Rainwater Harvesting Technologies

It emerged from the study that Baringo County faced a host of challenges that limited their capacity to devise effective adaptation strategies to rainfall variability. As shown in Table 4.11, households in Baringo County experienced challenges such as financial constraints (72 %), lack of information (40 %), inadequate rainwater harvesting structures (27%) and lack of technical skills and knowledge (26%) among others. During the interview, it also emerged that finances are critical to rain water harvesting and adaptation to climate change in general. Baringo residents observed that, even with basic skills and knowledge of adaptation, they are just helpless due to poverty. A fact that is supported by key informant interviews with chiefs and NDMA officers which revealed that most households in Baringo County lack diversified sources of income. Poverty is particularly high in the arid and semi-arid lands (ASALs) affecting 80-90 percent of the population (NEMA, 2010).

Table 4.11: Constraints to adopting rainwater harvesting technologies in Baringo County

Limiting factors	Yes		NO	
	F	%	F	%
Lack of information	150	40	226	60
Illiteracy	26	7	350	93
Traditional beliefs	5	2	371	98
Financial constraints	272	72	104	28
Unavailability of credit	52	14	324	86
Lack of RWH structures	64	17	312	83
Age of household head	5	2	371	98
Gender related disadvantages	10	3	366	97
Rainfall variability	65	17	311	83
Lack of technical skills and knowledge	96	26	280	74
Labour demanding	30	8	346	92
Inadequate RWH structures	100	27	276	73
Remoteness	5	2	371	98

Source: Field data, August 2015

The findings corroborate the results of a study conducted by Mburu *et al.,* (2015) in Yatta sub-County, Kenya where more than 70 % of the respondents designated lack of finance as the main barrier to adoption of rainwater harvesting technologies. Bryan *et al*. (2011) also revealed that lack of money or access to credit was a significant barrier to adaptation. Other findings by Bryan *et al*. (2011) corroborate the outcomes of this research notably; lack of credit, lack of adequate structures and lack of information are significant impediments to adaptation to climate change. Related studies have also found that households' income level was an important factor affecting adoption of water harvesting techniques (Shikur & Beshah, 2013; He, Cao & Li, 2007; Onwonga *et al.,* 2013). These findings also concur with those of Gbetibouo (2009) in the Limpopo River Basin, South Africa where most of the respondents cited lack of access to credit, poverty and lack of savings as the main barriers to adaptation. However, according to Gbetibouo (2009), few respondents cited lack of information or knowledge of appropriate adaptation measures as barriers to adaptations. On the other hand, lack of knowledge on climate change is considered by Nzeadibe *et al*. (2011) to be one of the major constraints to climate change adaptation in the Niger Delta while in Botswana, lack of labour was cited by most of the respondents as the main barrier to adoption (Bunclark & Lankford, 2011). Households were reluctant to dedicate their labour to implementing the systems.

According to Rutten (1992), there is need for diversified income sources in arid and semi-arid lands (ASALs) as a strategy to enhanced adoption of water harvesting techniques. Income improves household's financial capacity and increases the ability to adopt new technology. Access to formal credit facilities can relax households' financial constraints & expected to make households willing to participate in water harvesting activities (Molla, 2005). The respondents in

Baringo County gave mixed opinions regarding the influence of the availability of financial capital on rainwater harvesting technologies but the majority stated it to be a barrier to the initial adoption of the technology even when systems are heavily subsidized by the government. Income might be the biggest contributor to the water scarcity in Baringo County since majority of the population are poor with over 70% of the County's population living below the poverty line. These households cannot afford materials to construct water storage facilities or buy the ready-made facilities. The two main types of costs associated with RWH technologies are the initial investment costs and operating costs. These cover the cost of tools, labour, training which might be needed and other costs associated with investment and operating the techniques. Lloyd and Baiyegunhi, (2015) noted that high household income implies a greater motivation for investment in rainwater harvesting technologies and ability to bear the risks that can be associated with its adoption.

Lack of technical skills and knowledge among the farmers can be attributed to the wide-ranging low levels of education in the County whereas lack of information can be attributed to inadequate training on rainwater harvesting systems. In most adoption studies, household heads with higher levels of education attainment are more likely to adopt or to practices rainwater harvesting techniques compared to less educated heads (Chianu & Tsujii, 2004). According to KRA (1998) major technical constraints towards the adoption and success of rainwater harvesting systems include; inadequate guidelines on the construction of RWH systems especially in the rural areas, inadequate technological transfer to the beneficiaries (in cases of donor funded projects) and lack of training programmes on rainwater harvesting for stakeholders (beneficiaries artisans). Poor technical selection and usage of local materials in construction of

RWH systems and improper sizing of rainwater storage systems also limits adoption of RWHT (Wanyonyi, undated). Other factors include among others: inadequate water quality improvement structures, and limited technological transfer in rainwater harvesting at project level due to inadequate trained personnel in RWH.

Rainfall variability could be a limitation to adaptation in the sense that it can lead to the drying up and flooding of technologies such as wells, dams and water pans. Hence during extreme drought years, very little can be done to bridge a dry spell. Erratic rainfall and shortages leading to frequent drought spell, high evapo-transpiration rates have resulted to unreliability and unsuitability of many technologies. The open water storage including dams, pans and ponds, cannot sustain water for a long time due to the high rates of evaporation (Kimani *et al*., 2015). According to Campisano, Gnecco, Modica & Palla (2013), frequent precipitation increases the performance of rainwater harvesting and that the water saving efficiency depends on storage tank size, demand fraction, storage fraction and climate. Also, Chao-Hsien and Yu-Chuan (2014a) observed that rainwater harvesting potential depends on climatic factors; quantity of precipitation being the most crucial factor.

The study further sought to establish whether there was a relationship between socioeconomic factors and adoption of rainwater harvesting technologies (RWHT) by households in Baringo County. To find out the role played by socioeconomic factors on adoption of RWH technologies, a cross tabulation was run between adoption of RWHT and households' heads background characteristics. Table 4.12 indicates the results. Households' demographic and socio-economic characteristics play an important role in determining their technology adoption decisions and their livelihoods.

Table 4.12: Relationship between household heads' background characteristics and adoption of RWHT in Baringo County

	Adoption of RWHT	
Demographic characteristic	Yes	No
Age of the household head		
Below 18	0	1
18-30	12	19
31-40	14	14
41-50	13	10
51-60	8	4
61 and above	3	2
Education level of the household head		
No formal education	9	15
Primary and below	11	13
Secondary	18	17
Post-secondary	12	5
Gender of the household head		
Male	34	30
Female	16	20
Source of income		
Wage employment	18	10
Self-employment	12	13
Business	12	15
Crop sales	8	12
Household size		
3 members &below	3	6
4 to 7 members	32	32
8 to 10 members	13	10
11 members & above	2	2

Source: Field data, August 2015

From Table 4.12, only 9 % of the household heads with no formal education and 11 % who attained primary education had adopted rainwater harvesting technologies. This implies that most of the households (30 %) whom their heads had acquired secondary and post-secondary education adopted rainwater harvesting technologies because low educational attainment leads to low incomes and economic status of households is closely linked with the affordability of services such as water. This indicates that the probability of adoption of rainwater harvesting techniques is higher among educated household heads than among uneducated household heads. This is in-line with previous studies such as Kimani *et al*., 2015, Tesfaye, 2006, Lloyd and Baiyegunhi, 2015, Murgor *et al*., 2013 and Onwonga *et al,* 2013. Education improves the capability for resourcefulness and invention. According to Dasgupta (1989), adopters tend to have higher level of formal education because educated people are more open to accept new innovations and technology interventions than uneducated ones.

About 18 % of the households whose main source of income was wage employment had adopted rainwater harvesting technologies. Only 8 % of the households whose main source of income was crop sales adopted the technology. This implies that household heads that mainly relied on income from farms had less likelihood of adopting the water harvesting techniques than those who had other sources of income apart from farms. This is in consistent with the findings of Kimani *et al*., 2015, Tesfaye, 2006, Lloyd and Baiyegunhi, 2015. Other studies in conclusion with this include that of Onwonga *et al*, (2013) in Yatta district, Kenya where amongst the factors that affected the adoption of rainwater harvesting techniques, the majority of the respondents had reported that the farm was the main source of their incomes. However, Herath and Takeya (2003) noted that the role of farm income on the decision to adopt is not clear. Hence, it is hard to predict the sign of farming as source of income.

Only 12 % of the household heads aged between 18 and 30 years adopted rainwater harvesting technologies. Majority of the respondents (35 %) aged between 31 and 60 years had adopted the technique. This indicates that the probability of adoption of rainwater harvesting techniques is higher among older household heads than among younger household heads. This is consistent with the findings of Onwonga *et al.,* 2013. According to Babbie (1973), as the person gets older he/she tends to intensify adoption of the technologies in his/her household. However, according to Kimani *et al*., 2015 and Lloyd and Baiyegunhi, 2015, older household heads are less likely to adopt rainwater harvesting technologies. Young members of a household have a greater chance of absorbing and applying new knowledge (Sidibe, 2005). DTU (2002) also reported that households headed by elderly people have no interest to participate in rain water harvesting.

About 34 % of male household heads adopted rainwater harvesting technologies. Only 16 % of the females adopted the technology. This indicates that the probability of adoption of rainwater harvesting techniques is higher among male household heads than among female household heads. Previous adoption studies have found that women are less likely to adopt new technology (Adesina and Chianu, 2002; Kimani *et al*., 2015; Lloyd and Baiyegunhi, 2015). Lawrence *et al.* (2002) also observed that gender of the household head is closely connected with the availability of water in household. According to Kimani *et al*. (2015), females can positively influence the adoption of rainwater harvesting technologies because they are more concerned with water issues while to Lloyd and Baiyegunhi (2015), males can positively influence the adoption of RWHT because of bias against rural women inheriting land or having secured land rights. Security of tenure is a necessity for households to be able to carry out long or medium term investment (Molla, 2005).

The study established that only few (3 %) smaller households (households with less than three family members) adopted rainwater harvesting technologies. 13 % households with 8 to 10 members adopted the technology. Majority of the households (32 %) with family members between 4 to 7 members adopted the technique. It can be observed that households that have large families are more likely to adopt rainwater harvesting technologies in their households. Senkondo, Mdoe, Hatibu, Mahoo & Gowing (1998) and Shikur and Beshash (2013) found the number of family members in a household to be one of the factors determining adoption of RWHT. As the number of family size increases, the demand for water also increases hence households decide to adopt rainwater harvesting also increase (Alemayohu, 2013). Applications of RWH techniques are sometimes labour intensive (Senkondo *et al*., 1998). Given that family labour is the main source of labour in Baringo County, families with a small number of members working in the household are likely to be non-adopters.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter covers the summary of the major findings of the study as derived from the analysis of the five research objectives in chapter four. Conclusions are also outlined based on the findings. The last part of the chapter explains the recommendations and suggestions for further research.

5.2 Summary

The purpose of this study was to analyze rainfall trends, establish the effects of rainfall variability on access to domestic water, determine adoption of RWHT, establish variation in levels of adoption of rainwater harvesting technologies and assess constraints to use of rainwater harvesting technologies (RWHT) in Baringo County, Kenya. To achieve the objectives, the study utilized three data sets, namely: rainfall data, household survey and interview schedules data. Rainfall data was analyzed to yield results of annual rainfall variability. Trend analysis was used to analyze rainfall variability. Household survey and interview data was used to evaluate perceptions on rainfall and adoption of RWHT. To establish whether there was a relationship between rainfall variability and household access to domestic water, correlation analysis was used. Adoption of RWHT was measured by calculating percentage of adopters. To determine whether there was a significant variation in levels of adoption among the three agro-ecological zones, chi-square statistic was used. This chapter therefore, presents the conclusions drawn from the findings and the recommendations necessary for policy formulation and further research.

5.2.1. Rainfall variability trends

The study found that rainfall trends varied by agro-ecological zones in Baringo County. Results of trend analysis showed that annual rainfall in Agro-ecological zones LH2 (Lembus central) depicts an increasing trend over the period of study while in Agro-ecological zones LM5 (Salabani) and IL6 (Ribkwo) depicted decreasing trends. The coefficients of variation for annual rainfall amount for IL6, LM5 and LH2 was 0.45, 0.33 and 0.70 respectively. The three locations exhibited very high coefficients of variation for annual rainfall (CV > 30%), indicating high rainfall variability. Highland areas showed increasing amounts and higher variability in rainfall as opposed to low lying areas which showed decreasing amounts and less variability within and between the years. Communities' perceptions of rainfall adequacy were in line with observational data, where they acknowledged decrease in the amount of rainfall and shorter rainy seasons. During the interview, respondents were able to associate climate change and variability with deforestation showing awareness on the role of man in varying climate.

5.2.2. Effect of rainfall variability on access to domestic water

Only few households (29 %) in Baringo County had access to domestic water. Baringo County residents are dependent on improved water sources; borehole, tap water, protected spring, rainwater and bottled water. To majority of households in Ribkwo (IL6) and Salabani (LM5), water points were beyond a distance of 1 kilometer. 85 % and 80 % of households respectively had their water source located more than a kilometer away from their dwelling. To more than half of respondents (56%) in Lembus Central (LH2), water points were within a distance of 1 kilometer. The percentage of the respondents who took more time in normal roundtrip collecting water was highest in midland (83 %) and lowland (82 %). These are arid and semi-arid lands (ASALS) where droughts are frequent and rains more erratic. Almost all the persons in lowland (97 %) and highland (96 %) used less than 20 liters per day. More than half of the respondents in midland were within the minimum limit –the 20 liters per person per day set by WHO. Respondents in Baringo perceived the impact of rainfall variability to be more severe on quantity of water used per capita per day. The study established that there was no significant relationship between rainfall amount and access to water. The amount of rainfall received does not affect access to water.

5.2.3. Adoption of Rainwater Harvesting Technologies

Households in Baringo practiced both rooftop water harvesting techniques (wells, storage tanks) and surface runoff RWHT (dams, water pans). About half (50 %) of the households had adopted Rainwater harvesting technologies in their households. Rooftop catchment (storage tanks) is the most commonly used technique where communities use gutter-to-tank technology while dam was the second most widely practiced water harvesting technique where households capture surface runoff. It was established that majority (90 %) of the respondents were aware of water harvesting techniques that existed within their local context. They obtained such information from fellow villagers. The government and non-governmental organizations created awareness through group meetings. To support adaptation, the organizations were engaged in implementing and training residents on use of rainwater harvesting technologies.

5.2.4. Variation in Adoption of Rainwater Harvesting Technologies

Analysis of adoption by agro-ecological zones yields an understanding that adoption of rainwater harvesting technologies varies among the three agro-ecological zones. There was a significant variation in levels of adoption of Rainwater harvesting technologies among the three agro-ecological zones. The study found that majority of the households (64%) in LH2 has adopted the technology while only few households in LM5 and IL6 have adopted. The low levels of education and income in LM5 and IL6 contributed to low levels of adoption. Majority of the households in highland (Lembus Central) and midlands (Salabani) practiced rooftop water harvesting techniques (storage tanks) while in lowland (Ribkwo), they practiced surface runoff water harvesting techniques (dams). Adoption of rooftop water harvesting techniques in IL6 (Ribkwo) was limited by the design of the house. Many households live in grass-thatched houses which are not suitable for rainwater harvesting.

5.2.5 Constraints to Adoption of Rainwater Harvesting Technologies

Baringo peoples' adaptive capacity is constrained by lack of information on RWHT, financial constraints, inadequate rainwater harvesting structures, rainfall variability, illiteracy and lack of technical skills and knowledge on RWHT. The study also established that demographic characteristics of households' heads such as education, income and age determined adoption of Rainwater harvesting technologies. Households in Baringo said that the greatest challenge that they faced was financial constraints. It was in their view that if the government or non-government institutions could support them financially by giving incentives, a faster and wide adoption of the practice would be realized.

5.3 Conclusions

On the basis of the findings of the study, the researcher made several conclusions which are related to the five research objectives of the study. These conclusions were generalized to all households in Baringo County. They are as follows:

Objective 1: *Analysis of rainfall variability trends in agro-ecological zones LM 5, IL 6 and LH 2 for the period 1981 -2010*. The findings of this study have established that there is variation in amount of annual rainfall within and between the years. Total annual rainfall also varied among the three Agro-ecological zones. Annual rainfall in LH2 (Lembus central) showed a positive trend whereas in LM5 (Salabani) and IL6 (Ribkwo), it showed negative trends. Nearly all the years in IL6 showed below normal mean rainfall. All the locations showed higher variability in rainfall. This is attributed to increase in extremes of rainfall on the annual scale such as high intensity rainfall and droughts thus affecting the variability. Significance of the variations varies by agro-ecological zones and this is attributed to variations in altitude and land use intensity in the specific locations. There is climate variability in Baringo County which in the long term would constitute climate change. This has implications on hydrological systems and water resources.

Objective 2: *Effects of rainfall variability on access to domestic water in Baringo County*. It was established that there was no statistically significant relationship between rainfall variability and any of the water access variables. The amount of rainfall received does not affect access to water although households implicated rainfall variability on reduced access to water. Only few households (29 %) have access to domestic water in Baringo County. Households in the area reported recent increase in distance covered and time spend collecting water. Decrease in quantity of water used per capita per day and change in location and type of source were also reported. However, they have accepted rainfall variability as a frequent recurring characteristic of rainfall regime in that area and thus they have learned to live with it. The coping strategies identified are simple survival strategies (vendor, dug well, water pan), which may not meet the required standard for optimal use of water. Water storage, in its various forms, provides a mechanism for dealing with variability which, if planned and managed correctly, increases water security and adaptive capacity. Badly planned and designed water storage is a waste of financial resources and, rather than mitigate, may exacerbate unpleasant climate change impacts.

Objective 3: *To determine the adoption of rainwater harvesting technologies (RWHT) as an adaptation strategy to climate variability in Baringo County*. About half (50 %) of the households in Baringo have adopted Rainwater harvesting technologies in their households as an adaptation to rainfall variability. There is slow adoption of RWHT in Baringo County irrespective of their potential to improve household access to water. Half of the households do not use the technology due to lack of adequate rainwater harvesting structures and interest. Households in Baringo knew a variety of Rainwater harvesting technologies. They obtained such information from both governmental and non-governmental sources through fellow villagers. There are institutions – government and NGOs working towards enhancing adaptive capacity in Baringo County by creating awareness and training residents in better ways of constructing rainwater harvesting structures. The households practiced both Roof top Rainwater harvesting technologies (such as storage tanks and wells) and Surface runoff RWHT (such as water pans and dams) in their homesteads. Storage tanks were found to be the most widely practiced technique. However, many households used tanks with a capacity of between 200 and 500 liters which cannot hold enough water throughout the year. It has been evident that where water harvesting has been adopted for household water, there has been increased access to water especially during the dry period. Hence, Baringo residents see water harvesting as part of the solution to enhancing their water security.

Objective 4: *To determine variations in adoption of rainwater harvesting technologies (RWHT) among households by agro ecological zones in Baringo County*. There was observed statistically significant variation in levels of adoption of Rainwater harvesting technologies among the three agro-ecological zones. Adoption of RWHT significantly varied among the households in LH2 (Lembus central), LM5 (Salabani) and IL6 (Ribkwo). More than half of the households have adopted RWHT in LH2 while in LM5 and IL6, less than half the households have adopted. There is low adoption of RWHT in midland and lowland yet these are arid and semi-arid lands (ASALs) where droughts are frequent and rains erratic. Although this is well selected to cope with arid and semi-arid lands (ASALs) environment, households continue to suffer from the extreme events. Low levels of education and income in LM5 and IL6 contributed to low levels of adoption. They entirely depended on farming activities for survival and generation of income which may not be sufficient to implement some of the water harvesting techniques with regard to other competing uses. There is need for alternative income sources, like markets for other products. It was also established that majority of the households in highland (Lembus Central) and midlands (Salabani) practice rooftop water harvesting techniques (storage tanks) while in lowland (Ribkwo), they practice surface runoff water harvesting techniques (dams). The variations are attributed to the design of the house. Many households in LM5 and LH2 have corrugated roof houses while in IL6, many have grass-thatched houses hence limiting their use of rooftop RWHT. Although there are attempts to support rainwater harvesting for domestic use, stakeholders in the water sector need to double efforts to ensure water accessibility to a majority of people in Baringo.

Objective 5: *Constraints to use of rainwater harvesting technologies (RWHT) at household level in Baringo County*. The people of Baringo face a host of challenges that limited their capacity to devise effective adaptation strategies to rainfall variability. They experience the following challenges: lack of finances, inadequate rainwater harvesting structures, rainfall variability, illiteracy, lack of technical skills and knowledge on RWHT, age, source of income and education level of the household head. Household demographic characteristics: age, income and education level of the household head are other key factor explaining the decision behavior of households for participation in water harvesting practices. Educated, elderly and male household heads are more likely to adopt RWHT. Lack of finance is the main barrier to adoption of rainwater harvesting technologies in Baringo County. Those households facing financial constraints were not willing to participate in water harvesting activities. Many households especially in lowland and midland lack diversified sources of income. Farming activities is their main source of income. Household income determines adoption of RWHT. Income improves household's financial capacity and increases the ability to adopt new technology. Finances are critical to rain water harvesting and adaptation to climate change in general. Even with basic skills and knowledge of adaptation, people are still vulnerable due to poverty. Income improves household's financial capacity and increases the ability to adopt new technology. Improving access to formal credit facilities can relax households' financial constraints. Thus, to address adaptation to climate variability, one has to first address the high poverty levels in the area.

5.4 Recommendations

Based on the research findings, the study recommends the following:

i) It was observed that highland areas showed increasing trend of rainfall amounts as opposed to mid lying and low lying areas which showed decreasing rainfall amounts within and between years. High annual rainfall variability was observed in all the locations. Therefore, there is need for increase in awareness on rainfall variability and use of early warning tools by stakeholders.

ii) There was no significant relationship between rainfall variability and access to water. This implies that residents of Baringo County have lived with rainfall variability and devised ways of accessing water, including adoption of RWHT. The study therefore recommends that the existing rainwater harvesting technologies be up scaled to guarantee enough and quality water for domestic and livestock use.

iii) The study established that about half of the households in Baringo adopted Rainwater harvesting technologies in their households. Therefore, sensitizing residents on the potential socioeconomic benefits of adopting rain water harvesting technologies and improving existing techniques which are already practiced can promote wide adaptability.

iv) Since adoption of rainwater harvesting technologies varied significantly among the three agro-ecological zones, there is need for a greater understanding of best storage utilized under specific agro ecological and social conditions and much more systematic planning in order for many water storage investments to deliver the intended benefits. There is also need to strengthen adaptation capabilities of households in the areas that are weak.

v) Adoption of rainwater harvesting technologies in Baringo County has been constrained by lack of finances, inadequate rainwater harvesting structures, rainfall variability, illiteracy, lack of technical skills, lack of knowledge on RWHT and household demographic characteristics such as age, source of income and education level of the household head. Lack of finance is the main barrier to adoption of RWHT. Working to alleviate the financial constraints of users is, therefore, essential for policy makers and other NGOs to promote rain water harvesting practices in the long run. This can be carried out using various means, one of which is provision of adequate loan with possible minimum interest rates. Income sources should also be diversified to improve household's financial capacity and increase their ability to adopt new technology.

5.5 Suggestions for Future Research

Following the findings of this study, the following are possible research areas that need to be undertaken to better understand the rainfall variability and use of Rainwater harvesting technologies as an adaptation strategy in Baringo County:

i) This study analyzed annual mean rainfall variability in agro-ecological zones LM5, IL6 and LH2 of Baringo. There is need for an analysis on seasonal mean rainfall variability, number of rainy days per year and yearly distribution patterns across the main agro-ecological zones.

ii) Because adoption of rainwater harvesting technologies by households takes time, there is a need for collecting a series of data (separated in time) about adoption rather than depending on single season static data.

iii) Water loss through evaporation and seepage from open reservoirs is a challenge within the arid and semi-arid lands. Research on the ways of reducing this need to be done.

iv) It was established that many households in Baringo depend surface water sources. There is need for a study on how rainfall variability in Baringo affects stream flow.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE FOR HOUSEHOLDS

Preamble

I am Ednah Koskei, a graduate student from Kabarak University, pursuing Doctor of Philosophy Degree in Geography. I am involved in conducting a research study whose main purpose is to help me understand how rainfall variability affects access to water and use of rainwater harvesting technologies in Baringo County, This questionnaire contains a number of questions that will assist me to gain understanding and write a report that will be handed over to university. It is my sincere hope and request that you will kindly provide the necessary answers to the respective questions here presented. May I take this opportunity to assure you that any information you volunteer will be treated with utmost confidentiality and be used for academic purposes only.

Please tick the appropriate response or give a brief comment where applicable

SECTION A: Respondents' personal information

1. Name of Respondent: ……………………………………………………………

2. Gender of the household head: [1] Male [2] Female

3. Education level:

[1] No formal education [2] Primary and below [3] Secondary [4] Post-secondary

4. Age bracket of household head:

[1] Below 18 [2] 18-30 [2] 31-40 [3] 41-50 [4] 51-60 [5] 61+

5. Source of Income: [1] Wage employment [2] Self employment [3] Business [4] crop sales

6 Household size: ……………………..……………………………………….

7. Respondent's relation to household head

[1] Household head (Self) [2] Wife [3] Other (Specify)**…………**

SECTION B: Household's access to water

1. What is the main source of water used by your household for cooking, drinking and personal hygiene?

   [1] Rainwater [2] Tube well or borehole [3] Dug well [4] Spring water [5] Surface water (river, stream, pond, dam) [6] Bottled water [7] Others

2. Where is water source located?

   [1] In own dwelling [2] In own yard or plot [3] Elsewhere

3. How long does it take to go there, get water and come back?

   [1]30 minutes or less [2] more than 30 minutes

4. How much water does each member of your household use per day?

   [1] Less than 20 liters [2] 20 liters or more

5. What is the approximate distance to the water source?

   [1] 1 KM or less [2] more than 1 KM

6. In which month of the year are you able to obtain at least 20 liters per day?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]
[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]

7. In which month do you spend 30 minutes or less in a (normal) round trip to fetch water,

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]
[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]

8. In which month of the year do you have your water source located within one kilometer of your home?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]
[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]

9. In which month of the year do you use the following water sources classified as improved (rainwater, borehole, tap water, protected spring) ?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]
[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]

SECTION C: Rainfall variability

10. . Describe the rainfall trend in this area over the last five years

	Tick appropriate trend over the last 5 yrs			Reasons for observed change
	Increasing	Decreasing	No change	
a. Amount of rainfall				
b. Distribution of rainfall				

11. What specific aspect of water access is most affected by rainfall variability? (Tick one)

Access	**Tick**
a. Distance	
b.Time	
c.Location of source	
d.Reliability	
e.Quantity of water	
f.Type of source	

12. . Kindly use the options below to rank the negative effects of rainfall variability in the last 5 years:

1–Very severe, **2**-Moderately severe, **3**–Not severe

Negative effect	**Rank [1,2,or 3]**
a. Increased distance to water source	
b. Increased time spent fetching water	
c. Change in source location	
d.Water supply less than normal during dry period	
e.Decrease in quantity of water used per capita	
f.Reliance on unimproved source	

SECTION D: Rainwater Harvesting Technology

13. Are you aware of Rainwater Harvesting Technologies?

[1]Yes [2] No

14. Which Rainwater Harvesting Techniques do you know?

[1] Surface runoff harvesting (water pans, dams) [2] Roof top rainwater harvesting (storage tanks, recharging of bore wells, recharging of dug wells) [3] All of the above [4] None of the above

15. Which Rainwater Harvesting Techniques are you interested in?

[1] Surface runoff harvesting (water pans, dams) [2] Roof top rainwater harvesting (storage tanks, recharging of bore wells, recharging of dug wells [3] All of the above [4] None of the above

16. . Of the technologies you have mentioned, which ones have you tried?

[1] Water pans [2] dams (check dams, earthen dams) [3]Storage tanks(polyethylene, cistern, Ferro-cement tanks) [4]Wells(tube well, bore well, dug well). [3] All of the above [4] None of the above

17. . For how long have you tried it?

[1] 1 year [2] 2 years [3] 3 years [4] 4 yrs [5] 5yrs [6] Not applicable

18. Of the technologies you have mentioned, which ones have you used?

[1] Water pans [2] dams (check dams, earthen dams) [3]Storage tanks(polyethylene, cistern, Ferro-cement tanks) [4]Wells(tube well, bore well, dug well). [3] All of the above [4] None of the above

19. For how long have you used it?

[1] 1 year [2] 2 years [3] 3 years [4] 4 yrs [5] 5yrs[6] Not applicable

20. When do you use rainwater harvesting technologies you have mentioned?

[1]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]
[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]	[No]

[2] Not applicable

21. Of the technologies you have mentioned, which ones have you evaluated?

[1] Water pans [2] dams (check dams, earthen dams) [3] Storage tanks(polyethylene, cistern, Ferro-cement tanks) [4]Wells(tube well, bore well, dug well). [3] All of the above [4] None of the above

22. Are you satisfied with the water harvesting technologies you are using?

[1]Yes [2] No

23. Which of the existing water technologies would you want to use?

[1] Water pans [2] dams (check dams, earthen dams) [3] Storage tanks(polyethylene, cistern, Ferro-cement tanks) [4]Wells(tube well, bore well, dug well). [3] All of the above [4] None of the above

24. Do you have adequate Rainwater Harvesting structures in your household?

[1] Yes [2] No [3] Not applicable

25. Who are the major sources of information on rainwater harvesting technologies?

[1] NGO's [2] Government officers [3] School training [4] Fellow villagers [5] Others (specify)………….

26. What are the main limitations in using Rainwater Harvesting Technology?

Factor	**Response categories**	
Lack of information	Yes [ ]	No [ ]
Illiteracy	Yes [ ]	No [ ]
Traditional beliefs on rainwater harvesting	Yes [ ]	No [ ]
Formal & informal institutions	Yes [ ]	No [ ]
Lack of diversified sources of income	Yes [ ]	No [ ]
Unavailability of credit	Yes [ ]	No [ ]
Lack of water harvesting technologies	Yes [ ]	No [ ]
Age of household head	Yes [ ]	No [ ]
Gender related disadvantages	Yes [ ]	No [ ]
Rainfall variability	Yes [ ]	No [ ]
Lack of technical skills	Yes [ ]	No [ ]
Labour demanding	Yes [ ]	No [ ]
Lack of awareness	Yes [ ]	No [ ]
Water distribution problems	Yes [ ]	No [ ]
Inadequate rain water harvesting structures	Yes [ ]	No [ ]
Remoteness	Yes [ ]	No [ ]

Thank you, for providing this information

APPENDIX II

KEY INFORMANT INTERVIEW SCHEDULE

Interview schedule No. ………… … Location ……………………. Date………………

The Key Informants (Health officers, Meteorologists, Chiefs, NGO's)

1 .Based on your activities/experience in your area, kindly explain the rainfall pattern in the area in terms of rainfall distribution and amount.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………………………………………

2. What is your opinion on water situation in your area?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………..

3What is your opinion about water supply today compared to 10 years ago?

[1]Better than before [2] about the same [3] Worse than before

4. Based on your activities/experience in the area, is rainfall variability a constraint to water availability? (Explain)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………

5. In your area, what needs to be done in this area to improve water situation?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………….

6. What is the place of rainwater harvesting in your area?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………

7. What is the role of your institutions in improving water accessibility?

[1] Implementing RWHT [2] Offering credit [3] Piping water [4] Training [5] RWHT extension services [6] Others specify…………….

8. What are the best strategies that can be implemented in order to enable households adapt to rainfall variability in Baringo County?

……………………………………………………………………………………………

……………………………………………………………………………………………

………………………………………………………………….

9. What activities is your institution currently engaged in to ensure provision of clean water during the dry season?

....

....

10. What in your view is the level of adoption of Rainwater Harvesting Technology in this area?

[1] Low [2] Medium [3] High

11. What challenges do you experience in promoting Rainwater Harvesting Technologies in your area?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

12. Are there any fora or workshops that have been used to educate people about the use of Rainwater Harvesting Technology? Yes [ ] NO [ ]

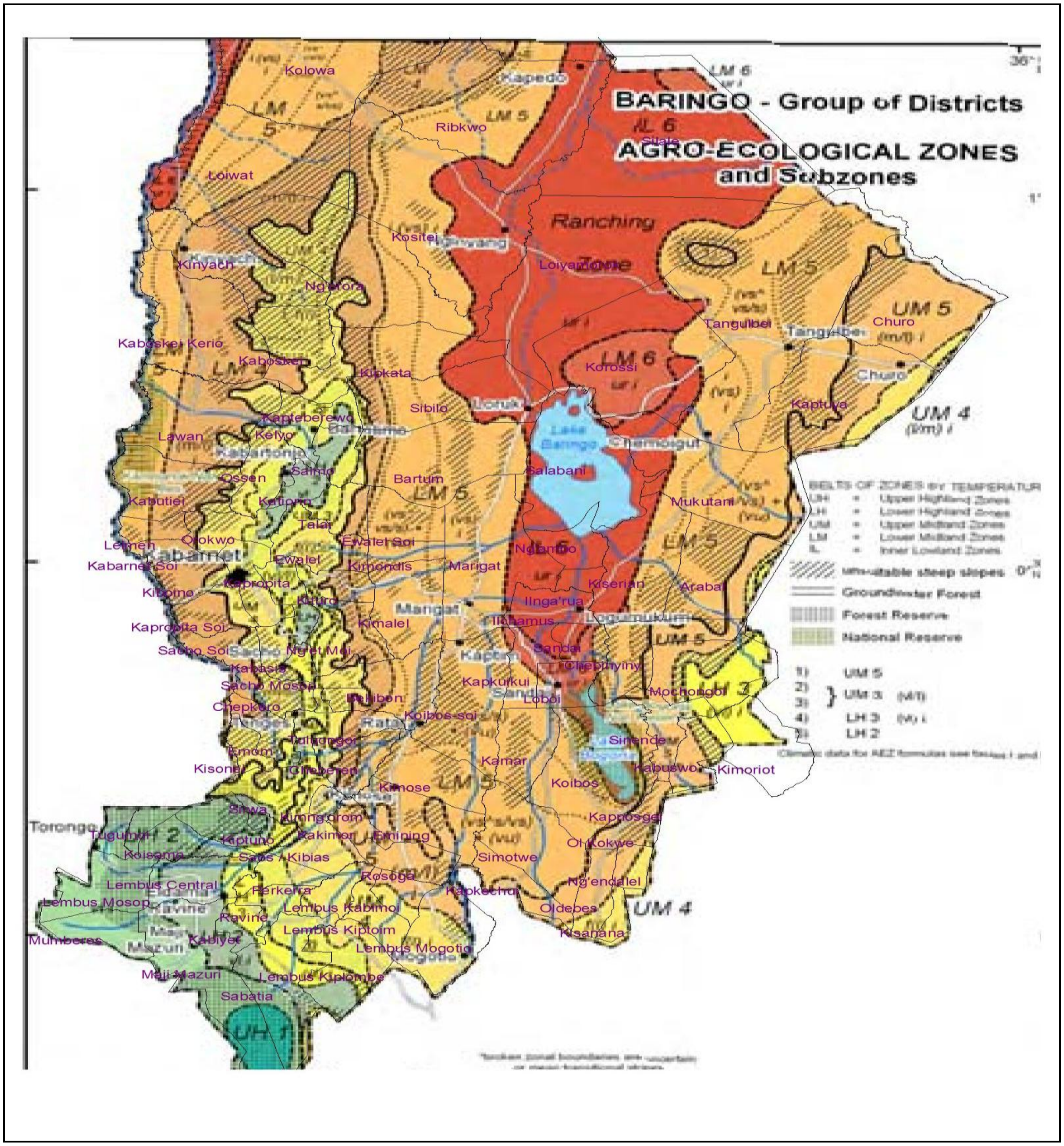
13. What can you recommend to help improve dissemination, access and use of Rainwater Harvesting Technology?

……………………………………………………………………………………………

Thank you, for providing this information

APPENDIX III

AGROECOLOGICAL ZONES OF BARINGO COUNTY



APPENDIX IV

RESEARCH AUTHORISATION FROM KABARAK UNIVERSITY

INSTITUTE OF POST GRADUATE STUDIES AND RESEARCH

Private Bag - 20157
KABARAK, KENYA
E-mail: directorpostgraduate@kabarak.ac.ke

Tel: 0203511275
Fax: 254-51-343012
www.kabarak.ac.ke

30th July, 2015

The Director General
National Council for Science and Technology
P.O Box 30623-00100
NAIROBI

Dear Sir/Madam,

RE: RESEARCH BY EDNAH CHEMUTAI KOSKEI - REG. NO. GDES/M/1198/09/13

The above named is a Doctoral student at Kabarak University in the School of Science, Engineering & Technology. She is carrying out a research entitled **"Rainfall Variability and Use of Rainwater Harvesting Technologies as an Adaptation Strategy in Baringo County, Kenya".** She has defended her proposal and has been authorized to proceed with field research.

The information obtained in the course of this research will be used for academic purposes only and will be treated with utmost confidentiality.

Please provide the necessary assistance.

Thank you.

Yours faithfully,

KABARAK UNIVERSITY POSTGRADUATE STUDIES & RESEARCH DEPT. 30 JU_ 2015 PRIVATE BAG - 20157, KABARAK

Dr. Betty J. Tikoko
DIRECTOR - POST-GRADUATE STUDIES & RESEARCH

Kabarak University Moral Code
As members of Kabarak University family, we purpose at all times and in all places, to set apart in one's heart, Jesus as Lord. (1 Peter 3:15)

APPENDIX V

RESEARCH AUTHORISATION FROM NATIONAL COMMISSION FOR SCIENCE TECHNOLOGY AND INOVATION

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email:dg@nacosti.go.ke
Website: www.nacosti.go.ke
when replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No.
NACOSTI/P/16/90080/9583

Date:
17th June, 2016

Ednah Chemutai Koskei
Kabarak University
Private Bag - 20157
KABARAK.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on "***Rainfall variability and use of rainwater harvesting technologies as an adaptation strategy in Baringo County, Kenya,***" I am pleased to inform you that you have been authorized to undertake research in **Baringo County** for the period ending **13th June, 2017.**

You are advised to report to the **County Commissioner and the County Director of Education, Baringo County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Baringo County.

The County Director of Education
Baringo County.

National Commission for Science, Technology and Innovation is ISO 9001: 2008 Certified

CONDITIONS

1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit
2. Government Officers will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two(2) hard copies and one(1) soft copy of your final report.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No. A 9606

CONDITIONS: see back page

APPENDIX VI

PUBLISHED RESEARCH PAPER 1

Koskei EC *et al.*; *Sch. J. Arts. Humanit. Soc. Sci., May 2016; 4(5B):583-592*

Scholars Journal of Arts, Humanities and Social Sciences **ISSN 2347-5374 (Online)**
Sch. J. Arts Humanit. Soc. Sci. 2016; 4(5B):583-592 **ISSN 2347-9493 (Print)**

Adoption of Rainwater Harvesting Technologies as an Adaptation Strategy to Climate Variability in Baringo County, Kenya

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Abstract: The study sought to investigate the adoption of rainwater harvesting technologies (RWHT) as an adaptation strategy to climate variability in Baringo County, Kenya. The study employed a descriptive survey design. Purposeful sampling and stratified proportionate random sampling procedures were used to obtain the sample. The respondents comprised of 376 households. Questionnaire, key informant interview schedule and observations were the main instruments of data collection. Analysis of data was done using the SPSS. Adoption was measured by calculating percentage of adopters. The results showed, about half (50 %) of the households in Baringo County adopted rainwater harvesting technologies in their households with storage tanks being the most widely practiced technique. However, many households use tanks with a capacity of between 200 and 500 liters which cannot hold enough water throughout the year. There is slow adoption of RWHT in Baringo County irrespective of their potential to improve household access to water. Half of the households do not use the technology due to lack of adequate rainwater harvesting structures and interest. Therefore, improvement of the existing rain water harvesting techniques which are already practiced will be of great advantage to the residents and can also promote wide adaptability. To promote interest in RWHT, residents should be sensitized on the potential socioeconomic benefits of adopting them.
Keywords: Adoption, rainwater harvesting technologies, adaptation, Climate variability.

INTRODUCTION

Water is life and is an essential component for the proper functioning of human settlements. However, the population at risk of increased water stress in Africa is projected to be between 75-250 million and 350-600 million people by the 2020's and 2050's respectively [1]. Despite considerable improvements in access to freshwater in the 1990s, only about 62% of the African population had access to improved water supplies in 2000 [2,3]. People living in rural areas are the worst affected, with only 41% of the rural population of Sub-Saharan Africa having access to clean water [4]. The food and Agriculture Organization reported that 48 countries in Africa, including Kenya, would face water shortage by 2025. About seventeen million (about 43%) Kenyans currently lack access to improved water supply [5]. Climate change is an additional threat that puts increased pressure on already stressed hydrological systems and water resources in Kenya [6]. Water resources such as streams, rivers, lakes and groundwater that are mainly rain-fed are adversely affected by climate change [7]. In Kenya, climate change has had far reaching effects since majority of the population depend on rain-fed water sources.

Climate change and climate variability are already taking place in Kenya and their effects are being felt [8]. Arid and Semi-Arid Lands (ASALs) and the poor in society are the most vulnerable and likely to be hit hardest by climate change due to their low adaptive capacity [9]. The climatic factors of greatest economic and social significance are temperature and rainfall with the latter, eliciting more concern than the former. Rainfall in Kenya is variable, especially in ASALs [10]. Climatic variations in Kenya have been associated with global climatic systems such as the El-Niño/South Oscillation (ENSO) phenomenon and Quasi-Biennial Oscillation (QBO) [11, 10]. They have also been associated with shifts in dry land or desert margins and the rise or fall of water levels in lakes and rivers. For instance, lakes Turkana, Baringo, Bogoria, Elementaita, Nakuru, Naivasha and Magadi are estimated to have occupied much larger area in the Holocene period [8]. As in the rest of the tropical regions, droughts and floods are common phenomena in Kenya. The two are triggered by the same factors and can be either mild or disastrous. They are more common in the arid and semi-arid regions. The main causes/sources of floods are storm surges, El niño/La niña events, and other extremes of climate variability, land terrain, poor drainage systems and regulation of dams [12]. The intensity of drought also seems to be increasing over the years as a result of the changing climate [13]. Notable ones are the 2000/2001 and 2006 droughts which were the worst in at least 60 years (since 1940's) [13].

Approximately 80% of Kenya's land mass is arid and semi Arid (ASAL) characterized by average annual rainfall of between, 200mm to 500mm per year, and is prone to harsh weather conditions according to [14]. Some areas in the northwest and east receive only 200 mm per year [10]. Kenya has a population estimated at 38.6 million. 80% of Kenya is classed as ASALs, and these areas are home to approximately 30% (~12 million) of Kenya's people [15]. The principal climatic hazard in the ASALs is drought. Most of the droughts exhibit such characteristics as false and late onset of the rains, pronounced breaks during the rainy season, and early cessation of the rains, leading to drastic alterations in the pattern of seasonal rainfall distribution [16-18]. Many areas in Baringo County in mid-west Kenya are in the ASAL's region. While Kenya, like countries in other parts of the world, have considerable experience in dealing with climate variability, climate change is likely to present them with new and tougher challenges. Consequently, the country needs to adopt new strategies to cope with new situations. The current technologies and approach especially in water are unlikely to be adequate to meet projected demands, and increased climate variability will be an additional stress [9]. Innovations that may help to increase the availability of water are of major importance. Effective rainwater harvesting systems can decrease the risk of flooding during extreme rainfall events while providing access to clean water during the expected prolonged dry seasons expected because of climate change.

Rainwater harvesting refers to all technologies where rainwater is collected to make it available for domestic purposes and agricultural production [19]. By convention, Rainwater Harvesting Technology (RWHT) is a technique used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams. It is considered as the single most important means to increase agricultural productivity and provide a source for domestic supply in drought prone areas [20]. Various rainwater harvesting technologies have been in use for millennia and new ones are being developed all the time [21]. These can be classified as: rooftop water harvesting and surface runoff water harvesting. Many communities and countries facing water shortages because of climate change could significantly boost supplies by collecting and storing rain falling freely from the clouds [22]. Throughout the ages, this has been a traditional way of enhancing domestic water supply [23]. Effective RWH systems can decrease the risk of flooding during extreme rainfall events while providing access to clean water during the expected prolonged dry seasons expected because of climate change.

Rainwater harvesting is a very old practice and has been in parts of the world for more than 4000 years [24]. The technology is popular in rural Australia, parts of India, Africa and parts of the United States [25]. The importance of traditional, small scale systems of rainwater harvesting in sub-Sahara Africa has recently been recognized [26] and is gradually being adopted with high degree of success in the four Great Horn of African countries (Ethiopia, Kenya, Tanzania and Uganda) [27]. The technology has been exploited in Kenya for many years with most focus on the arid and semi-arid areas (ASALs) and rural areas [28]. Rainwater harvesting (RWH) has been proposed as one of the options to improve water supply especially in rural and peri-urban areas of low-income countries [29-30] as well as in all agro climatic zones [31]. However, the technology is more suitable in arid and semiarid areas (ASALs) [32-33] to ensure water availability especially during prolonged dry season and drought [34]; [35] and [36]. Improving domestic water supply by rainwater harvesting saves ASALs women and children more time who spend 3-5 hours per day collecting water and more in periods of drought [10].

Baringo County suffers from intensive floods, severe droughts combined with short rainy seasons and drought related losses like any other County situated in the northern regions of Kenya. Given that many households in Baringo County are poor, they are vulnerable to rainfall variability. Household water needs in the County are met from nearby surface water sources or withdrawn from traditional wells [37]. However, in the dry season, wells, streams and rivers dry up forcing women and children who do the considerable labor involved in water collection to travel longer distances in search of water for domestic use from unprotected sources. High rainfall variability negatively impacted on household access to improved water sources. Many households find it difficult to store quantities of rain falling in very short periods so that it can be used over the entire year. This study therefore seeks to determine adoption of rainwater harvesting technologies (RWHT) as an adaptation strategy to climate variability in Baringo County in order to provide them with relevant and appropriate information that can inform their adaptation appropriately and reduce vulnerability to rainfall variability. Domestic Rainwater Harvesting, which provides water directly to households, would enable a number of households in rural areas to access water that conventional technologies cannot supply.

MATERIALS AND METHODS

A descriptive survey was carried out on the sample of Baringo households to explore and describe use of rainwater harvesting technologies as at the time of study. The study used purposeful sampling and stratified proportionate random sampling procedures to obtain the sample. Within Baringo County, the locations were stratified according to the agro-ecological zones. These are LM 5 (lower Midland), LH 2 (Lower Highland) and IL 6 (Inner Lowland). Lembus Central, Salabani and Ribkwo locations was purposefully selected for the study. They were selected because of having Agro-ecological zones LH2, LM5 and IL6 respectively to ensure that the researcher picks extreme climates only and ensure proper representation of the respondents within the whole Baringo County area coverage. Lastly, random selection of the respondents within locations was made proportionate to the population of each location as per the household census report of 2009 [38]. The study targeted 376 households which constituted 7.9 % of the total number of households in the three agro ecological zones. The selection of respondents was informed by household population by location level. This information was acquired from the County Development Officer at Kabarnet, the County headquarters. Lembus Central location has a population of 2,668 households while Salabani has a population of 963 households and Ribkwo 1128 households. These were the three strata where proportional representation was obtained. 211 households in Lembus Central, 76 in Salabani and 89 in Ribkwo location was selected. A total of 376 respondents were selected for the study. Their participation during the interviews was however based on random sampling.

As for the key informants, purposive sampling was used to select those to be interviewed. These were selected from among meteorologists, NGO officers, chiefs, NDMA officers and water officers based on their positions of authority. These key informants were selected for the interview in consideration that they have insights on the subject of climate and water and use of RWHT by the households in the County.

The data were obtained from households and key informants through personal interviews by use of structured questionnaire, key Informant interview schedule and observations. The study focused mainly on household heads for interviewing to ensure uniformity of data collection process. The questionnaire was used to collect data from households on use of RWHT and levels of adoption of RWHT. The questionnaire was administered to all the 376 households in the study area. Key Informant Interview Schedule was used to collect in-depth data on use of RWHT.It was used to collect valuable data that was used to check the validity of responses obtained through use of questionnaires. Observations were made of the various water sources, water harvesting structures and the nature of their construction. Information obtained through observation enabled comparing of the reported information with the actual occurrences in the study area. Additionally, photographs in the study area were taken by researcher. The photographs have helped to illustrate the various water sources and RWH technologies that were used by the households. The use of photographs augmented findings from other data collection procedures.

The data collected was analyzed using descriptive statistics. Adoption was measured using one of the procedures mentioned by Agbamu [39]; calculating percentage of adopters. The use of percentage involved asking respondents to respond yes (1) or No (0) to the technologies they have adopted. Five stage processes of adoption were used to develop a framework for measurement of adoption. The five stages are: awareness, trial, evaluation, interest and usage. The respondents were asked to tick yes or no against stages of adoption of rainwater harvesting technologies. The percentage yes or no were calculated. The adoption level was the summation of the numerical values of the Yes responses. This appears to be the commonest approach to the measurement of adoption [40-43]. Adopters were further asked to indicate the number of years they have made use of the technology. A five-year period was considered long enough for households to have fully adopted the technology.

RESULTS AND DISCUSSION

In this study, the adoption scale to measure the adoption of Rainwater Harvesting Technologies (RWHT) was constructed using percentage of adopters. *Adoption of innovations followed hierarchical stages* namely: awareness, interest, evaluation, trial and usage. These five stage processes of adoption were used to develop a framework for measurement of adoption in the present study. Respondents were asked to tick yes or no against stages of adoption of rainwater harvesting technologies. The percentage yes or no were calculated. Adopters were further asked to indicate the number of years they have made use of the technology. A five-year period was considered long enough for households to have fully adopted the technology.

The findings (Table 1) revealed that most of the households in Baringo County had awareness (90 %), interest (96 %), evaluated (92 %), tried (79 %) and used (91%) the technology. However, most of them had made use of the technology for few years (less than five years). From Table 1, about 68 % of the households sampled had used RWH technologies for five years or more. About 32 % had practiced the technology for only few years; 4 years (13 %), 3 years (9 %), 2 years (6 %) and 1year (4 %).

In the survey locations, about 50 % of the respondents have adopted RWH techniques in their households and equally 50 % have not adopted (Figure 1). Adoption of rainwater harvesting technologies in this case meant that the household had gone through the adoption process that is awareness, trial, evaluation, interest stage and had finally accepted to practice the rainwater harvesting technologies for five years or more. The survey established that even non-adopters utilized RWHT to some extent. Some of them had some knowledge or awareness while others had tried, assessed or used the technology for a short period (less than five years) of time. Those non adopters were asked as to why they are not adopting RWHT and most of them responded that they lacked adequate rainwater harvesting structures. Some of the respondents also reported that they are not interested with the technology. Respondent households practicing this technique reported improved access to water in their households.

Table-1: Percentage and frequency distribution for stages of adoption (N=376)

Adoption stages	Response categories	Frequency	Percentage
Awareness	Yes	342	91
	No	34	9
Interest	Yes	362	96
	No	14	4
Evaluation	Yes	347	92
	No	29	8
Trial	Yes	298	79
	No	78	21
Usage	Yes	342	91
	No	34	9
Duration of use Freq. Percent.			
1 year	14	4	
2 years	19	6	
3 years	32	9	
4 years	43	13	
5 years or more	235	68	
Non -users of RWHT	33	9	
Total	376	100	

Source: Field data, August 2015

Table 1 shows the adoption process (awareness, trial, evaluation, interest and use) that households undergo before they finally accept to practice the technology in their households and that number of years they have practiced the technology.

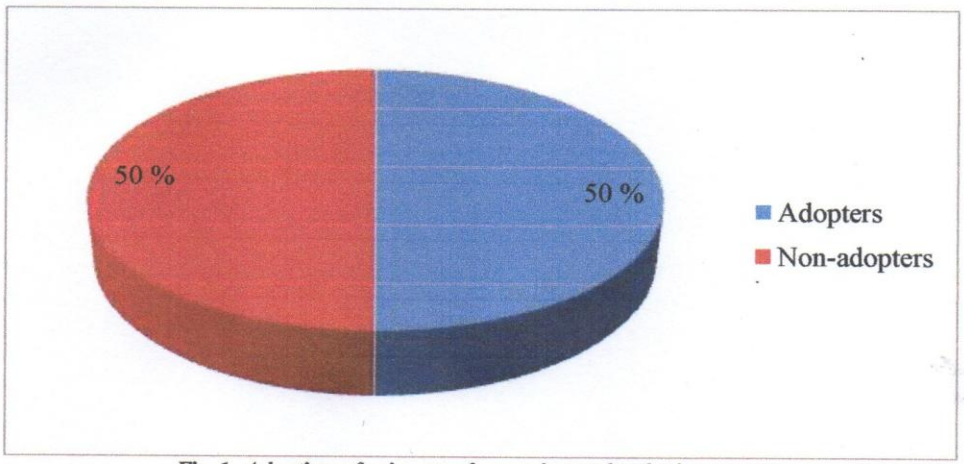


Fig-1: Adoption of rainwater harvesting technologies
Source: Field data, August 2015

Figure 1 shows percentage of adopters and non-adopters of rainwater harvesting technologies. Adopters are aware, interested and have evaluated, tried and used the technology in their households for five years or more.

Households in Baringo County were engaging in various rainwater harvesting techniques to adapt to climate variability. From the total sample households (Table 2), 2 %, 65 % and 33 % percents of the respondents were using rain water only during rainy season, full rainy season and partial dry seasons, full rainy and dry seasons respectively. Full rainy & full dry season, and full rainy & partial dry season was mainly indicated by the adopters of the technology. Only few adopters of the technology indicated only rainy season consumption of rain water.

Table-2: Use of rainwater technology by seasons

Category	% Technology users
Rainy season only	2
Full rainy & partial dry	65
Full rainy & full dry seasons	33
Total	100

Source: Field survey, 2015

During the study, respondents were asked to name/list the rainwater harvesting technology (RHT) they know. From Table 3, Most of the respondents (42 %) knew a variety of both Roof top RWHT (such as storage tanks and wells) and Surface runoff RWHT (such as water pans, ponds and dams). About 35 % of the respondents knew only Roof top RWHT while 17 % knew Surface runoff RWHT only. The remaining 6% knew none of the technologies. Roof water harvesting is a system of collecting rainfall water from the roof of a building and storing it in some storage facilities for future use when there is shortage of water [44]. Surface run-off harvesting - is a system of collecting run-off from a catchment using channels or diversion systems and storing it in a surface reservoir [45].

Adopters have good knowledge about roof top rainwater harvesting technologies because many roof water tanks have been implemented by NGOs in rural areas of Kenya. These tanks were regarded to be of the best quality and increasing water quantity and availability at the implemented site [46]. The technology has been exploited in Kenya for many years with most focus on the arid and semi-arid areas (ASALs) and rural areas [28]. The technology is also flexible and adaptable to a very wide variety of conditions [24]. It is used in the richest and the poorest societies, as well as in the wettest and the driest regions in the world.

Table-3: Rainwater harvesting technologies known

Type of RWHT	Frequency	Percentage
Surface runoff RWHT (water pans, dams)	65	17
Roof top RWHT (storage tanks, wells)	130	35
All of the above	159	42
None of the above	22	6
Total	376	100

Source: Field data, August 2015

About 90 % of the households in Baringo County were aware of water harvesting techniques that existed within their local context. A small proportion of households (10%) were not aware of the rain water harvesting techniques and this may be attributable to inadequate dissemination of information and skills with regard to rain water harvesting techniques. The distance to be covered and time spend collecting water in the event of water scarcity further amplified the awareness of and the need for water harvesting technologies. The distance covered in search of water is relatively far during water scarcity. This makes people, especially women and children whose work is to ensure that there is water in the household, spend a lot of energies and time as well as travel longer distances in search of water during this period. Collecting and storing water close to households improves the accessibility and convenience of water supplies and has a positive impact on health [24].

The research sought to find out how awareness was created. Figure 2 illustrates four major channels used to sensitize households on rainwater harvesting technology and practices. Majority of the governmental and non – governmental officers said that they created awareness through group meetings. This can be the very reason why majority of the households (71 %) revealed that such awareness is created by fellow villagers. In addition, school training and other sources such as radio, television and own initiatives were also mentioned. However, the finding that even non-adopters have some knowledge of RHT implies that some of the technologies are not new in the sampled locations. The NGOs, and to a limited extent government extension staff, are just trying to revitalize utilization of RWHT and training residents in better ways of constructing rainwater harvesting structures . NGOs with few private sectors played an important role in implementing and adopting water harvesting techniques all over Kenya [47]. These organizations were well appreciated by the community and were considered to be most efficient compared to government driven programs. Awareness exposes someone to information and therefore creates knowledge which is a very important stage in the adoption of rain water harvesting technologies [48].

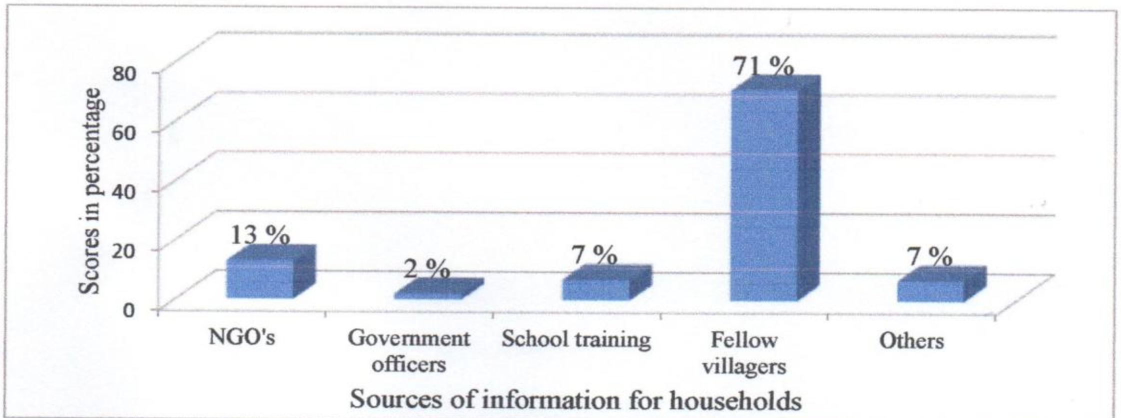


Fig-2: Sources of information and knowledge on RWHT
Source: Field data, August 2015

About (57 %) of the households in Baringo County practiced rooftop water harvesting techniques (storage tanks) followed by dams (18 %,) and wells (12 %) with minority of the households using water pans (1%). (Table 4). Most of the households practiced rooftop water harvesting techniques -with rooftop catchment (storage tanks) being the most commonly used technique where communities use gutter-to-tank technology. All those who harvest water at their homesteads use gutter-to-tank technology. The findings concur with those of Makueni County, Kenya where various rainwater harvesting technologies were used including rooftop harvesting techniques with rooftop catchment being the most commonly used technique [49]. Rooftop water harvesting techniques was also the most adopted technology in Yatta, Kenya [50]. The ease of implementation of the said technique may have made it popular to the communities. Rooftop harvesting technologies have the advantage to collect relatively clean water [20]. Rooftop rainwater harvesting has also shown a high degree of reliability especially to the households who have invested in substantial rainwater harvesting systems [49].

The second most widely practiced water harvesting technique was the dam. This is the case in other places of Kenya such as Yatta Sub-County of Machakos County [50], Makueni County [49] and Kitui West, Lower Yatta and Matinyani sub-Counties of Kitui County [51] where adoption of dams technique is pronounced. Despite its poor quality, water collected from earth dams is used to cater for livestock and domestic purposes [49]. Adoption of other techniques such as water pans (1 %) and wells (12 %) were found to be low in this area. This however is not the case in other places of Kenya such as Lare Sub-County of Nakuru County, where adoption of water pans technique is pronounced [52].

Table-4: Type of water harvesting techniques practiced by household

	Frequency	Percent
Water pans	5	1
dams	69	18
storage tanks	216	57
Wells	44	12
storage tanks & wells	20	1
All of the above	17	6
None of the above	5	5
Total	376	100

Source: Field data, August 2015

Table 4 shows the type of rainwater harvesting technologies practiced by households in Baringo County. These include Roof top RWHT such as storage tanks and wells and Surface runoff RWHT such as water pans and dams.

Majority of the households (85 %) in Baringo County lack adequate rainwater harvesting structures (Figure 3). Only few households (15 %) have adequate structures. The study established that most (over 70%) of the respondents especially those using rooftop RWH systems have storage facilities of less than 150 litres capacity which cannot hold enough water throughout the year. Households that have invested in sizable rainwater harvesting systems ranging from 1 to 10 m^3 capacity hardly experience water shortage problems and waterborne diseases [49]. Several studies have been done on different issues pertaining to rainwater harvesting. For example, with respect to storage 4,000 L concrete tank installed with a roof area of 40 m^2 is adequate to take care of water demands of four-member household for five-month dry period [53]. An optimum tank size of 0.5 m^3 is recommended to achieve water savings of 10-40% [54]. In order to achieve a good water-saving efficiency and limit financial losses, a storage tank size limit of 1.2-1.5 m^3 is recommended [55]. Pictures of some of the rooftop rainwater storage facilities used in Baringo County are shown in plate 1 below.

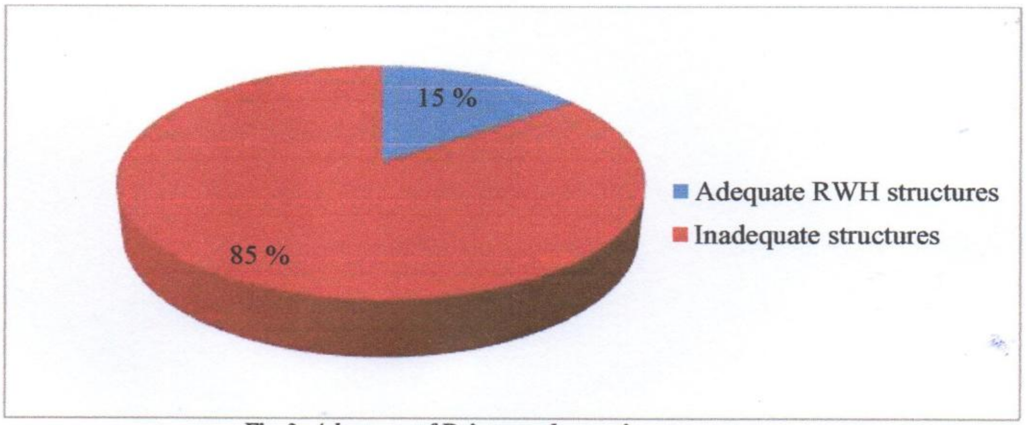
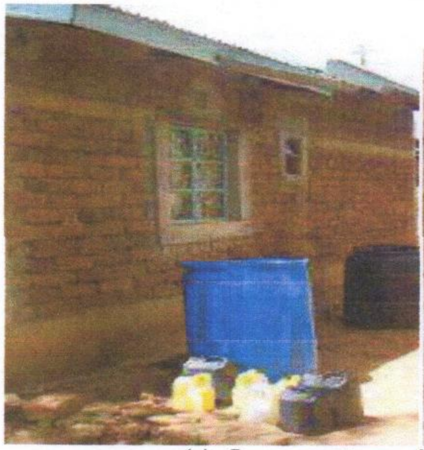
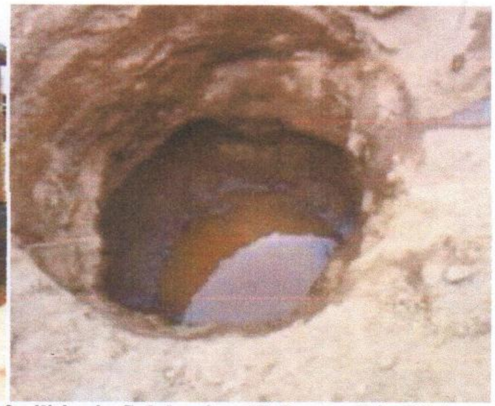


Fig-3: Adequacy of Rainwater harvesting structures
Source: Field data, August 2015

Figure 3 shows the percentage households with adequate structures of harvesting rainwater in their households and those with inadequate structures.

(a)Cement tank in Lembus Central **(b) Plastic tank in Salabani**





(a) Jerry can storage facilities in Salabani (d) Dug well in Ribkwo
Plate 1: Various Rooftop Rainwater storage Facilities used in Baringo County.
Source: Field data, August 2015

CONCLUSION

About half (50 %) of the households in Baringo County have adopted Rainwater harvesting technologies in their households as an adaptation to rainfall variability. There is slow adoption of RWHT in Baringo County irrespective of their potential to improve household access to water. Half of the households do not use the technology due to lack of adequate rainwater harvesting structures and interest. Households in Baringo knew a variety of Rainwater harvesting technologies. They obtained such information from both governmental and non-governmental sources through fellow villagers. The households practiced both Roof top Rainwater harvesting technologies (such as storage tanks and wells) and Surface runoff RWHT (such as water pans and dams) in their homesteads. Storage tanks were found to be the most widely practiced technique. However, many households used tanks with a capacity of between 200 and 500 liters which cannot hold enough water throughout the year. It has been evident that where water harvesting has been adopted for household water, there has been increased access to water especially during the dry period. Hence, Baringo residents see water harvesting as part of the solution to enhancing their water security. It is therefore important that more trainings and support programmes be increased in Baringo County in order to combat rising water insecurity. Therefore, improvement of the existing rain water harvesting techniques which are already practiced will be of great advantages to the residents and can also promote wide adaptability. To promote interest in RWHT, residents should be sensitized on the potential socioeconomic benefits of adopting them.

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APPENDIX VII

PUBLISHED RESEARCH PAPER 2

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Mara Research Journal of Environmental Sciences
Vol. 1, No. 1, November 2016, Pages 14 - 27

Effects of Rainfall Variability on Access to Domestic Water in Baringo County, Kenya

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Received: October 29, 2016
Published: November 4, 2016

Abstract

The study sought to investigate the relationship between rainfall variability and access to domestic water in Baringo County. The study employed a descriptive survey design. Purposive sampling and stratified proportionate random sampling procedures were used to obtain the sample. The respondents comprised of 376 households. Questionnaire, key informant interview schedule and observations were the main instruments of data collection. Analysis of data was done using the SPSS. Correlation analysis was used to establish the relationship between rainfall variability and access to domestic water in Baringo County. There was no statistically significant relationship between rainfall amount and any of the access variables. This means that the amount of rainfall received does not affect access to water. Rainfall variability is a frequent recurrence in the area and residents have learned to live with it, and hence, its variation does not affect type of source used, location of water source, quantity of water used, time spend and distance covered collecting water. However, the coping strategies identified are simple survival strategies (dam, dug well, water pan), which may not meet the required standard for optimal use of water. In the dry season, the sources dry up forcing women and children, who do the considerable labour involved in water collection, to travel longer distances in search of water for domestic use from unprotected sources. Therefore existing water sources should be up scaled to guarantee enough and quality water for domestic use in Baringo County.

Keywords: Rainfall variability, Access to water, Effects, Baringo County, Kenya

1. INTRODUCTION

Access to domestic water represents a day-to-day struggle for many citizens living in developing countries (Herischen *et al.*, 2002; Chapitaux *et al.*, 2002; UN-Water/WWAP, 2006). About 200 million of Africa's population corresponding to about 25%, currently experience high water stress (Boko *et al.*, 2007). The population at risk of increased water stress in Africa is projected to be between75-250 million and 350-600 million people by the 2020's and 2050's, respectively. Despite considerable improvements in access to freshwater in the 1990s, only about 62% of the African population had access to improved water supplies in 2000 (WHO/UNICEF, 2006; Vörösmarty, 2005). People living in rural areas are the worst affected, with only 41% of the rural population of Sub-Saharan Africa having access to clean water (UN-Water, 2014). The food and Agriculture Organization reported that 48 countries in Africa, including Kenya, would face water shortage by 2025. About seventeen million (about 43%) Kenyans currently lack access to improved water supply (USAID, 2011).

According to Dungumaro (2007), increased settlements, human population growth, ignorance, and pricing cause water shortage. Socio-economic status is a significant determinant of household access to water in households (Lawrence *et al.*, 2002). Other variables closely connected with the availability and accessibility of water include, among others, household size and gender of the household head (Dungumaro, 2007). Overdependence on secondary sources of water coupled with the increasing climate change, has made water to be a scarce resource in the world. Climate change and to an extent climate variability, is an additional threat that puts increased pressure on already stressed hydrological systems and water resources (Mwenge *et al.*, 2013). Hydrological resources such as streams, rivers and ponds that are mainly rain-fed are adversely affected by climate change (Onyenechere *et al.*, 2011). Boko *et al.*, (2007) noted that climate change and variability are likely to impose additional pressures on water availability, water accessibility and water demand in Africa. Eastern and southern African countries are characterized by water stress brought about by climate variability and wider governance issues (Ashton, 2002; UNESCO-WWAP, 2006). Several studies have found that climate change has altered not only the overall magnitude of rainfall but also its seasonal distribution and inter-annual variability worldwide (Easterling, 2000; Trenberth *et al.*, 2007; Zeng *et al.*, 1999).

Climate change and climate variability are already taking place in Kenya and their effects are being felt (Okoth-Ogendo *et al.*, 1995). The climatic factors of greatest economic and social significance are temperature and rainfall with the latter, eliciting more concern than the former. Rainfall in Kenya is variable, especially in ASALs (NCEA, 2015). Climatic variations in Kenya have been associated with global climatic systems; such as the El-Niño/South Oscillation (ENSO) phenomenon and Quasi-Biennial Oscillation (QBO) (Ogallo, 1992; NCEA, 2015). They have also been associated with shifts in dry land or desert margins and the rise or fall of water levels in lakes and rivers. For instance, lakes Turkana, Baringo, Bogoria, Elementaita, Nakuru, Naivasha and Magadi are estimated to have occupied much larger area in the Holocene period (Okoth-Ogendo *et al.*, 1995). As in the rest of the tropical regions, droughts and floods are common phenomena in Kenya. The two are triggered by the same factors and can be either mild or disastrous. They are more common in the arid and semi-arid regions. The main causes/sources of floods are storm surges, El niño/La niña events, and other extremes of climate variability, land terrain, poor drainage systems and regulation of dams (WHO, 2002). The intensity of drought also seems to be increasing over the years as a result of the changing climate (Orindi *et al.*, 2007). Notable ones are the 2000/2001 and 2006 droughts, which were the worst in at least 60 years (since 1940's) (Orindi *et al.*, 2007).

While Kenya, like many countries in other parts of the world, have considerable experience in dealing with climate variability, climate change is likely to present them with new and tougher challenges. Consequently, the country needs to adopt new strategies to cope with new situations. The current technologies and approach, especially in water, are unlikely to be adequate to meet projected demands, and increased climate variability will be an additional stress (IPCC, 2001). Baringo County suffers from intensive floods, severe droughts combined with short rainy seasons and drought related losses like any other County situated in the northern regions of Kenya (RoK, 2006). The Kenya government has introduced reforms in the water sectors, through the Water Act of 2002, with a view of conserving and improving water access in Kenya. The water sector reforms appear to have done well in the establishment of institutional framework, however, with little impact on improving water accessibility. There is also the National Climate Change Response Strategy (2010) and National Climate Change Action Plan (2012) – policy documents that provide guidelines on how to address the challenge of climate variability in Kenya. There are also efforts by development agencies to improve water accessibility, especially in ASAL areas of Kenya. Notable ones are CARE International, World Vision, Kenya Rainwater Association (KRA) and UNDP. The contribution of development agencies appear scattered in across the country.

Despite the efforts, households in Baringo County continue to suffer from water inaccessibility. The situation is usually exacerbated by climate variability. Little has been done at local level to safeguard against the uncertainties induced by rainfall variability and, even where there is contribution, there is no assessment on effect on households. In order to ensure safe and adequate water for all Kenyans, the country needs innovative technologies and proactive strategies that will empower its citizens in meeting their water demands. This study, therefore, sought to establish the effects of rainfall variability on household access to water in order to provide them with relevant and appropriate information that can inform their adaptation appropriately, and therefore, reduce vulnerability to rainfall variability.

1.1 Study Area

This study was conducted using household and meteorological data records from Nginyang, Chemususu and Perkerra stations, located in Baringo County northwestern part of Kenya. Geographically, Baringo is situated between Latitudes 00 degrees 13" South and 1 degree 40" North and Longitudes 35 degrees 36" and 36" degrees 30" East (Fig. 1). The County is cut across by the Equator at the southern part. According to the 2009 Kenya population and Housing census results, Baringo's human population stood at 555,561 people and 110,649 households (KNBS, 2013). This figure is projected to increase by about 5% in the next census. Baringo County covers a range of climatic zones, from semi-arid (zone iv), arid (zone v), and very arid (zone vi) through semi-humid (zone iii) and sub-humid (zone ii), to a small portion in the humid zone (zone 1). The mean annual rainfalls in these zones are 450 mm to 900 mm (semi-arid), 800 mm to 1,400 mm (semi-humid), 1,000 mm to 1,600 mm (sub-humid) and 1,100 to 2,700 mm (humid). The mean annual potential evaporation amounts for these areas are 1,650 mm to 2,300 mm (semi-arid), 1,450 mm to 2,200 mm (semi-humid), 1,300 mm to 2,100 mm (sub-humid), and 1,200 mm to 2,000 mm (humid) (Odada *et al.*, 2006). Baringo County is divided into three major agro-ecological zones namely the highlands, midlands and lowlands and the following sub- zones: UH 1, UH 2, LH 2, LH 3, UM 3, UM 4, UM 5, LM 4, LM 5, LM 6 and IL 6 (RoK, 2013).

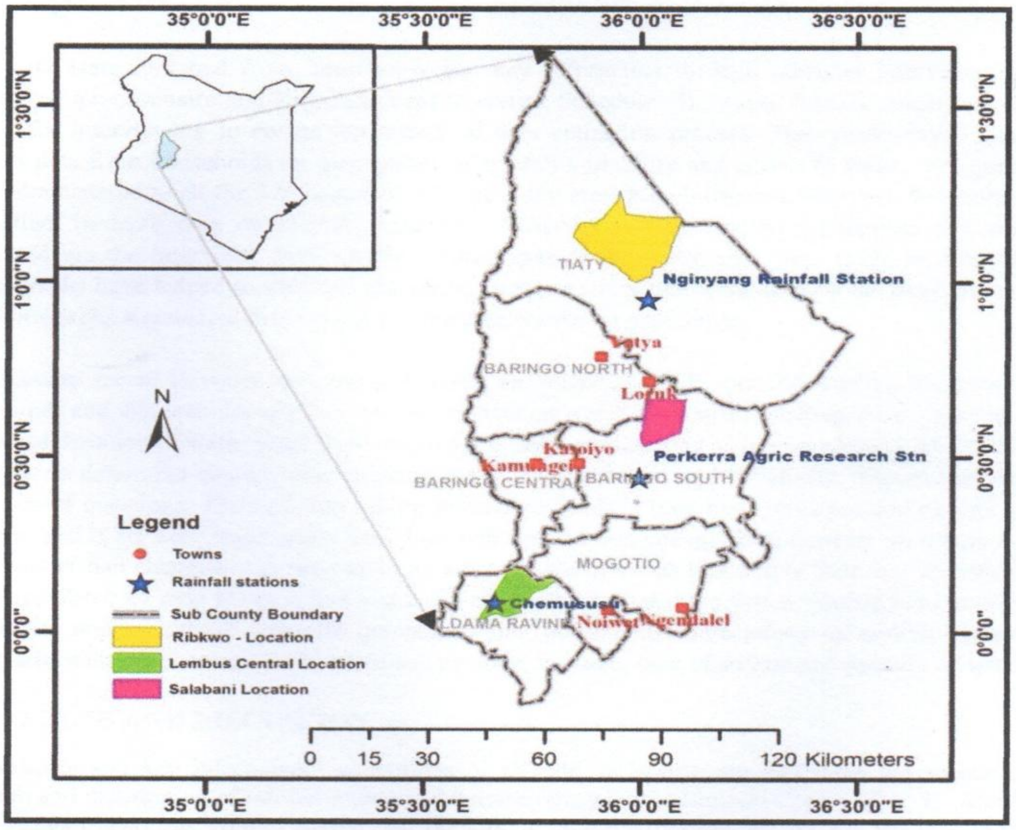


Figure 1: Location of the study area (Baringo County)
Source: Survey of Kenya (2014)

2. MATERIALS AND METHODS

The study used purposeful sampling and stratified proportionate random sampling procedures to obtain the sample. Within Baringo County, the locations were stratified according to the agro-ecological zones. These are LM 5 (lower Midland), LH 2 (Lower Highland) and IL 6 (Inner Lowland). Lembus Central, Salabani and Ribkwo locations was purposefully selected for the study. They were selected because of having Agro-ecological zones LH2, LM5 and IL6, respectively to ensure that the researcher picks extreme climates only and ensure proper representation of the respondents within the whole Baringo County area coverage. Lastly, random selection of the respondents within locations was made proportionate to the population of each location as per the household census report of 2009 (RoK, 2010). The study targeted 376 households which constituted 7.9 % of the total number of households in the three agro ecological zones. The selection of respondents was informed by household population by location level. This information was acquired from the County Development Officer at Kabarnet, the County headquarters. Lembus Central location has a population of 2,668 households, while Salabani has a population of 963 households and Ribkwo 1128 households. These were the three strata where proportional representation was obtained. 211 households in Lembus Central, 76 in Salabani and 89 in Ribkwo location was selected. A total of 376 respondents were selected for the study. Their participation during the interviews was, however, based on random sampling.

As for the key informants, purposive sampling was used to select those to be interviewed. These were selected from among meteorologists, NGO officers, chiefs, NDMA officers and water officers based on their positions of authority. These key informants were selected for the interview in consideration that they have insights on the subject of climate and water use of RWHT by the households in the County.

The data were obtained from households and key informants through personal interviews by use of structured questionnaire and Key Informant Interview Schedule. The study focused mainly on household heads for interviewing to ensure uniformity of data collection process. The questionnaire was used to collect data from households on perceptions of rainfall variability and access to water. The questionnaire was administered to all the 376 households in the study area. Key Informant Interview Schedule was used to collect in-depth data on rainfall variability. Observation was used to supplement and enrich data collected via the interview. Additionally, photographs in the study area were taken by researcher. The photographs have helped to illustrate the various water sources that were used by the households. The use of photographs augmented findings from other data collection procedures.

Households access to water was assessed based on WHO/UNICEF Joint Monitoring Programme (JMP) guidelines and this included distance covered collecting water, time spent fetching water, quantity of water collected, location of water source and use of water sources classified as improved (WHO/UNICEF, 2008). In order to determine communities' perceptions of rainfall trends and variability, respondents were asked two sets of questions. The first was asking household heads if they have observed any change in rainfall pattern, and if so, how many years back they had noticed this change. Respondents were also asked how the weather had changed over the years i.e., what the weather was like a long time ago and what changes they had observed over the past five years. To establish whether there was a relationship between rainfall variability and household access to domestic water, households' perceptions on rainfall variability was correlated with water access variables (distance, time, location, type of source and quantity of water).

3. RESULTS AND DISCUSSION

Households and key informants' perceptions of climate variability are that there are variations in the amount and distribution of rainfall within and between the years in Baringo County (Fig. 2). Almost all the households (98%) interviewed agreed that the amount and distribution rainfall has changed over the last five years (Fig. 2). They noticed a decrease in the amount of rainfall or shorter rainy seasons. All the key informants interviewed including chiefs, water officers, NGO's (ACTED) and NDMA officers, agreed that rainfall is changing and is no longer as it was years back. All the respondents that were interviewed believe that the climate is changing and is no longer as it was some years back. They indicated that these changes were mainly associated with rainfall amount and distribution. People's perception is that rainfall is lesser today than it was in previous years. This is a common finding from other studies on perceived and actual rainfall trends and variability; such as in Lower Eastern Kenya (Omoyo *et al.*, 2015), Eastern Uganda (Shisanya *et al.*, 2011), semi-arid central Tanzania (Slegers, 2008), Ethiopia (Tilahun, 2006) and Sudano-Sahelian regions (Sivakumar, 1991).

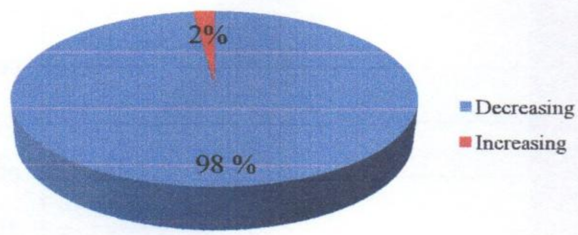


Fig. 2: Perceived Amount and distribution of Rainfall over the last 5 years
Source: Field survey, August 2015

In this study, an assessment of access to water was based on WHO/UNICEF Joint Monitoring Programme (JMP) guidelines; distance covered collecting water, time spent fetching water, quantity of water collected, location of water source and use of water sources classified as improved (WHO/UNICEF, 2008). All these variables are essential for a declaration of access to water. Access to water in this case meant that the household spent 30 minutes or less to fetch water, used water sources classified as improved, had their water source located within one kilometer of their home and were able to reliably obtain at least 20 liters per member of a household per day as recommended by WHO/UNICEF.

The results (Fig. 3) indicated that only 29 % of the households sampled in Baringo County had access to domestic water while 71% had no access.

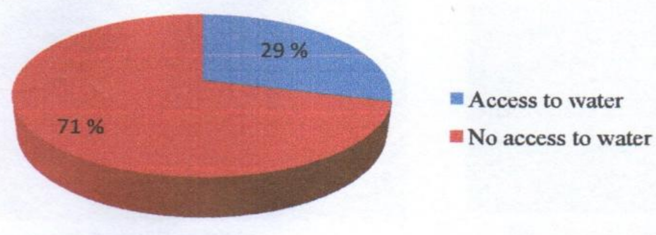


Fig. 3: Household access to domestic water in Baringo County
Source: Field survey, August 2015

Figure 4 and plate 1 present the types of water sources used among the sample households. As in other developing countries; households in the sample utilized more than one type of water source for drinking and other purposes. Only 37% of the households used unimproved domestic water sources; surface water. Majority of the households (57%) used improved water sources; borehole (32%), tap water (26%), protected spring (2%), rainwater (2%) and bottled water (1%). Improved water sources include sources that, by nature of their construction or through active intervention, are protected from outside contamination, particularly faecal matter and, are more likely to provide water suitable for domestic use than unimproved technologies. It was established that out of the 37% households that used surface water, majority used the worst drinking water source – a dam and this may limit the quantity of suitable drinking water. Streams and protected springs were almost exclusively mentioned in Lembus Central (LH2) while dams, boreholes and dug wells in Ribkwo (IL6). Most of the households in Salabani (LM5) mentioned lake, dam and streams as their main sources of water.

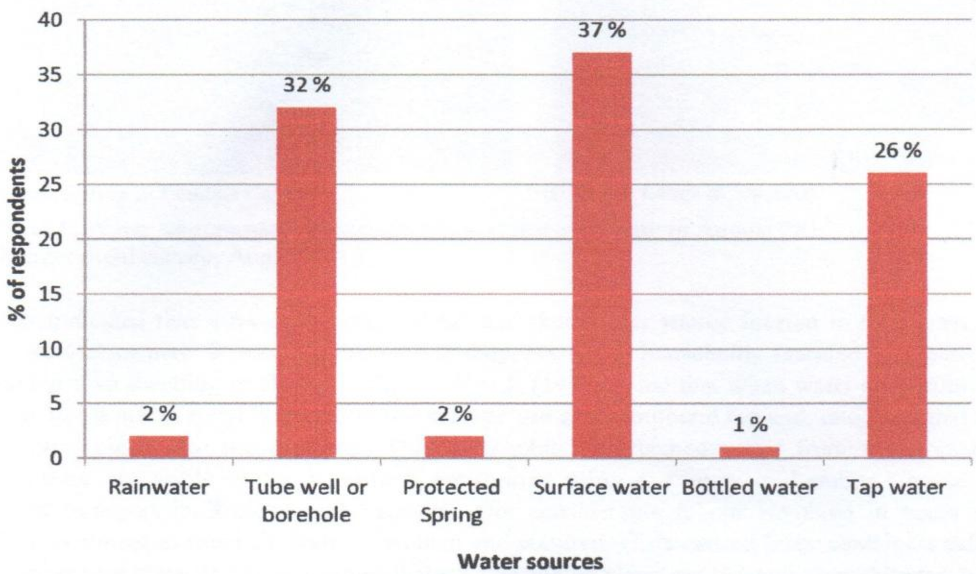
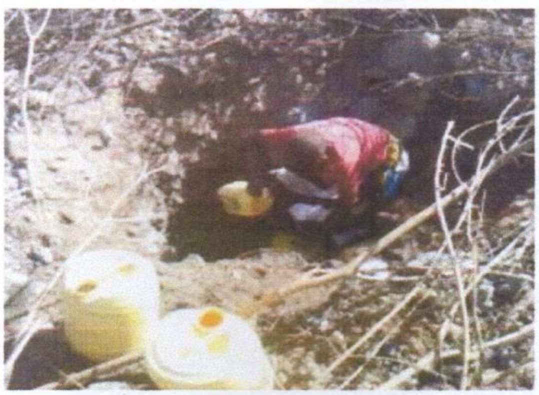
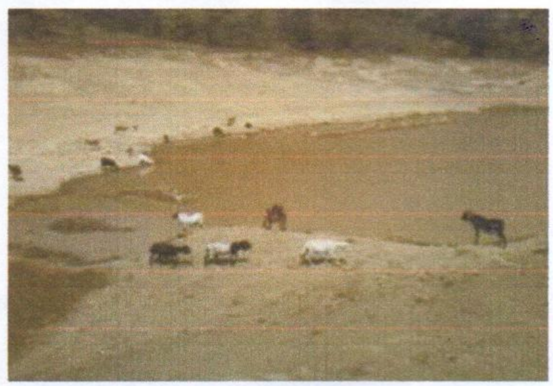


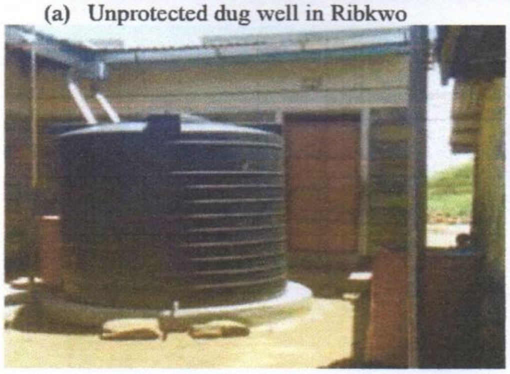
Fig. 4: Water sources used in Baringo County (Source: Field data, August 2015)



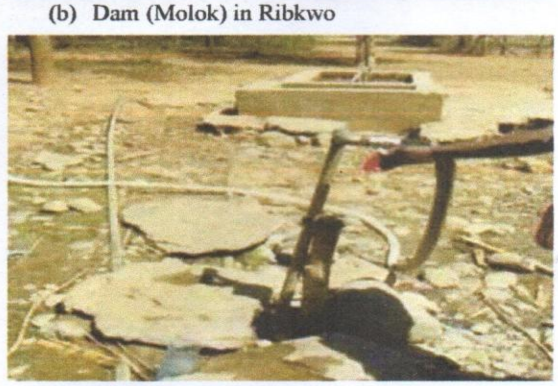
(a) Unprotected dug well in Ribkwo



(b) Dam (Molok) in Ribkwo



(c) Storage tank collecting rainwater in Lembus Central



(d) Tap water (public standpipe in Salabani

(e) Arama Spring in Lembus Central

(f) River Labos in Salabani

Plate 1: Water sources used by households in Baringo County in August 2015
Source: Field survey, August 2015.

Results indicated that 49% of the respondents had their water source located in their own yard or plot, while 48% elsewhere. It was established that only 3% of the households sampled had their water source located in own dwelling as shown in Fig. 5. WELL (1998) noted that when water is outside the dwelling, average use drops to roughly one third the average use at a compound tap and, one tenth that of household with water piped into the dwelling. The households that fetched water from a source that was not immediately accessible to the household transported using a donkey in Lembus Central and human-powered transport in Ribkwo and Salabani. The considerable labour involved in water collection in Baringo is almost exclusively done by women and children. Girls carried large containers full of water on their backs (see Plate 2). Water sources that are considered clean can become contaminated, between point of collection, storage and household use (KNBS, 2010). The extent and impact of this kind of water contamination is unknown in the area and calls for further investigation to be better understood.

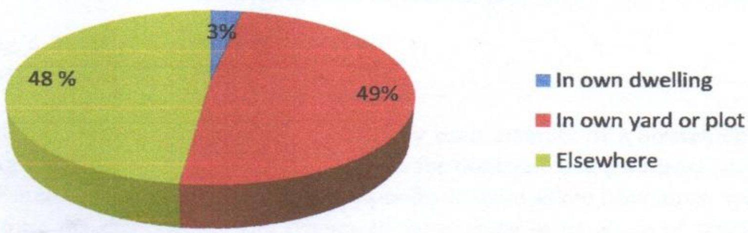
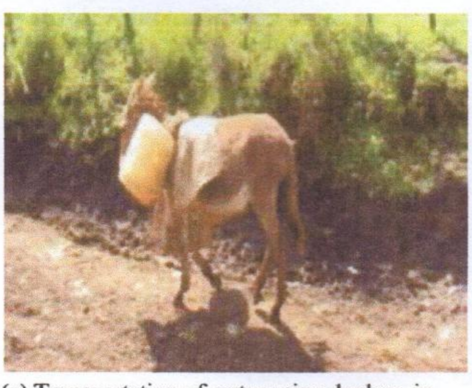
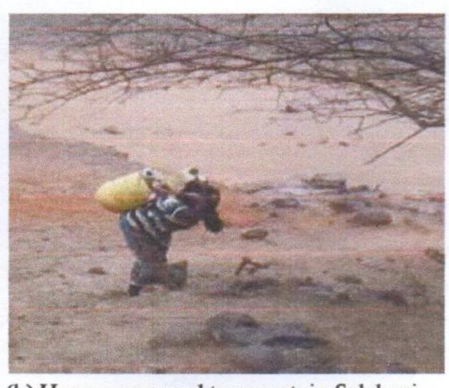


Fig. 5: Location of water source in Baringo County (Source: Field data, August 2015)



(a) Transportation of water using donkey in Lembus Central



(b) Human-powered transport in Salabani

Plate 2: Transportation of water (Source: Field survey, August 2015)

The percentage of respondents who covered long distance to watering points was highest (85%) in Ribkwo (IL6). In Salabani (LM5), 80% of the sampled population covered more than 2km to reach water points; while in Lembus Central (LH2) only 44% in of the sampled population had their water source located more than a kilometer away from their dwelling (Fig. 6). It was noted that a section of the households in Salabani depend on dam and rivers, which dry up during the dry season, forcing women and children to travel longer distances in search of water from other sources. The increase was less in Lembus Central and this can be attributed to rainwater harvesting, the sinking of boreholes and construction of a large community dam (Chemususu dam), which provide an additional source of water. It would be helpful if similar efforts were directed to other parts of the County to improve access to clean water.

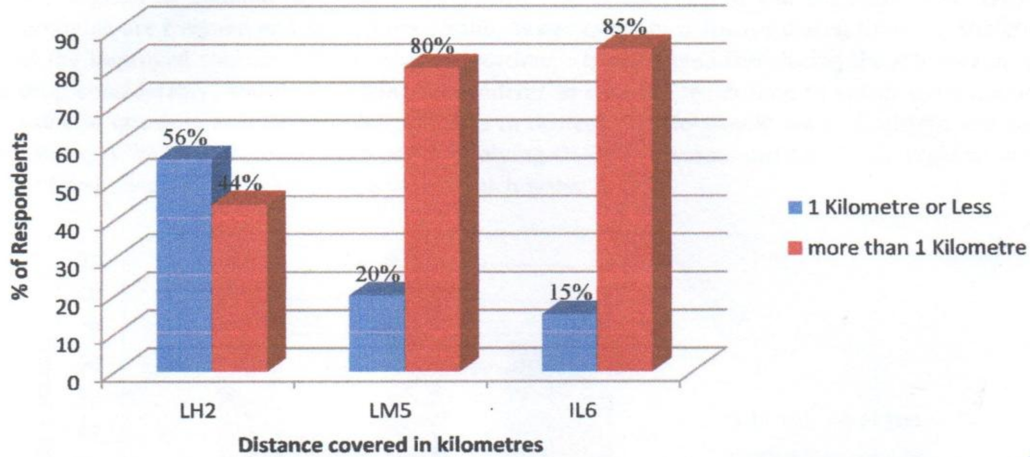


Fig. 6: Distance covered collecting water
Source: Field data, August 2015

The quantity of water used per capita per day by each member of a household in the sample was obtained by dividing the total volume of water collected for domestic use (in litres) per day in a household by total number of members in a household. The respondents were asked how much water had been collected since the same time the day before. The responses were given in numbers of containers rather than liters, and therefore, the researcher needed to have a series of pictures of the common water containers in that community with the volumes pre-measured. All the households used jerry-cans to collect water; these cans typically hold 20 liters. Children also used smaller jerry-cans, up to 10 liters. Calculations for individual households were done and results are summarized in Fig. 7.

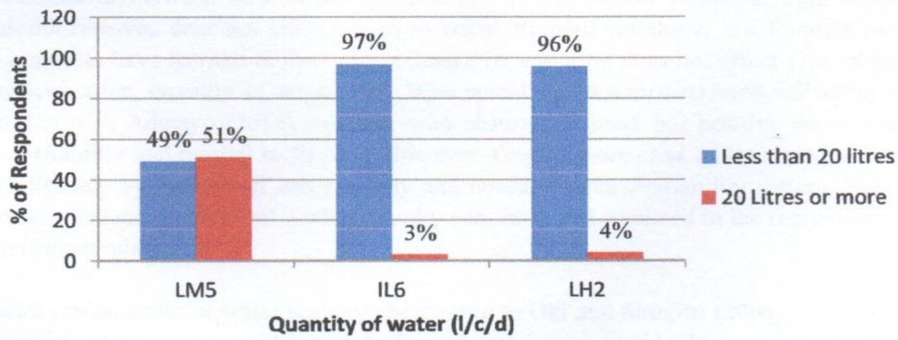


Fig. 7: Quantity of water used per capita per day
Source: Field data, August 2015

About 49% persons in the sample used less than 20 liters per capita per day in midland (LM5). Almost all the persons in lowland (97%) and highland (96%) used less than 20 liters per person per day (Fig. 7). This may be attributed to large family sizes in the two sites. It can be noted that only few individuals in LH2 (4%) and IL6 (3%) were within the minimum limit, the 20 liters per person per day set by WHO, an indication that there is water shortage in Baringo County.

Further insight into the households' access to domestic water sources was gained from an assessment of total collection time (Fig. 8). More than half (55%) of the sampled respondents in LH2 took less than half an hour, while only 17% in LM5 and 18 % in IL6; took less than 30 minutes to get into water source, get water and back. The percentage of the respondents who took more time in normal roundtrip collecting water was highest in midland (83%) and lowland (82%). These are arid and semi-arid lands (ASALS) where droughts are frequent and rains more erratic. Water quantity is lowest during times of drought and many of the improved sources dry up in some locations. It was noted that during the dry season, water levels drop considerably, and thus, making respondents to take too much time to access even the nearby sources due to queuing. Rainfall variability results in decreased underground water discharge and surface water volume. With households in LM5 and IL6 relying on dams, streams and wells, this explains why the number of respondents were taking more time to fetch water.

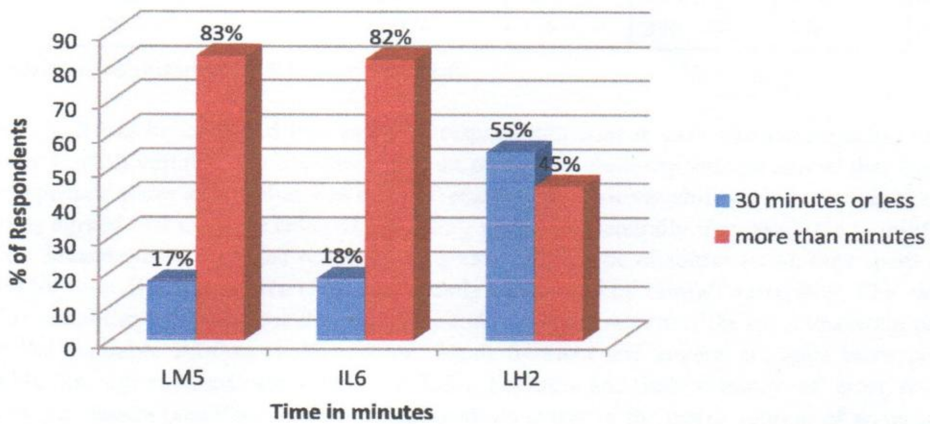


Fig. 8: Time spent collecting water
Source: Field data, August 2015

Correlation analysis was performed to establish if there was a significant relationship between perceptions on rainfall variability and water access variables (Table 1). Results show that there was no statistically significant relationship between rainfall amount and any of the access variables. This means that the amount of rainfall received does not affect access to water. Rainfall variability is a frequent recurrence in the area and residents have learned to live with it, hence its variation does not affect type of source used, location of water source, quantity of water used, time spend and distance covered collecting water. The results are in line with Adetayo (2015) findings, who observed a weak but positive correlation between public water availability and rainfall in Nigeria. However, Onyenechere *et al.* (2011) in Nigeria observed a significant relationship between rural water supply and rainfall amount/variability pattern. Eldredge *et al.* (1988) in Western Sudan reported that a relatively dry condition had persisted in the region since 1966 due mainly to a decline in rainfall.

Variable rainfall can be cause of water scarcity. According to Oki and Shinjiro (2006), uneven distribution of rainfall in space and time is one of the causes of water scarcity worldwide. Ngongondo (2006) in Malawi also reported that there is vast problem of access to potable water for an average household especially during the dry season, when there is decline in rainfall with alternating wet and drier years. This is because a deficiency of rainfall can possibly lead to a depletion of stream discharge and reservoir storage, which would in turn affect sectors such as public utilities (power and water supply) sector (Tarhule, 1997). Water scarcity is likely to become even more severe as climatic impacts and increasing water demand combine. According to USEPA (2013), climate change exacerbates weather Oscillations and generally impact water quality as well as quantity. In many regions, changing precipitation is altering hydrological systems affecting water resources in terms of quantity and quality (IPCC, 2014).

Table 1: Relationship between rainfall variability and access to water

		Amount of rainfall over the last 5 years	Source of water for domestic use	Location of Water source	Time spend in round trip to fetch water	Quantity of water used per capita	Approximate Distance to water source
Amount of rainfall over the last 5 years	Pearson Correlation	1	-.054	-.007	.093	-.032	.091
	Sig.(2-tailed)		.293	.892	.072	.532	.077
	N	376	376	376	376	376	376

**Correlation is significant at the 0.05 level (2-tailed).

From Fig. 9, it can be observed that sampled respondents concur with various aspect(s) of water access affected by rainfall variability. Fifty-three percent of the sampled respondents agreed that quantity of water was the aspect of water access that was most affected by rainfall variability. A total of 25% of the sampled households agreed that distance covered collecting water has generally increased due to rainfall variability. Few of the households agreed that reliability of source (9%), type of source (6%), time spent fetching water (4%) and location of water source (3%) was mostly influenced by rainfall variability. The nature of effects of rainfall variability varies across the year. The end of the dry season is the most uncertain period, because none of the available sources is dependable. More frequent and severe droughts were perceived to be responsible for the reduced water level in Lake Baringo and intermittency of most rivers that were previously permanent (see Plate 3). River Endao which is one of the major sources of water in the area was reported to have changed its course several times in the recent past and, has since become seasonal because of climate change.

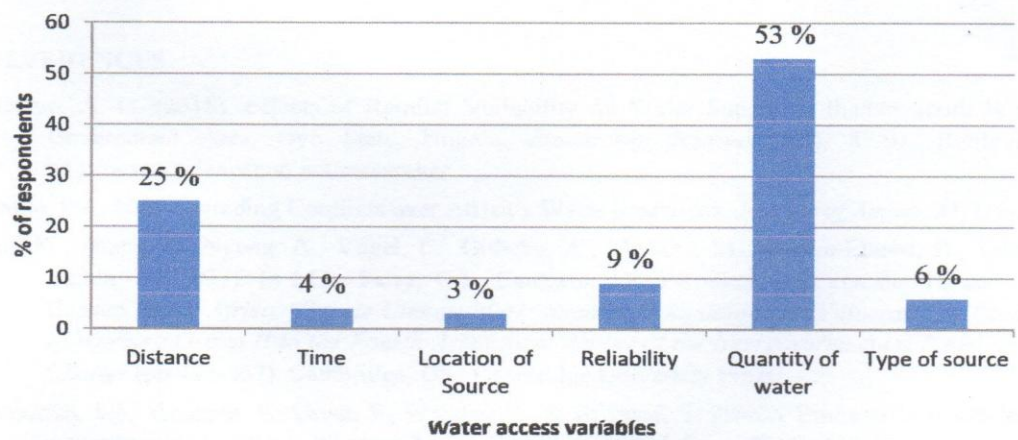
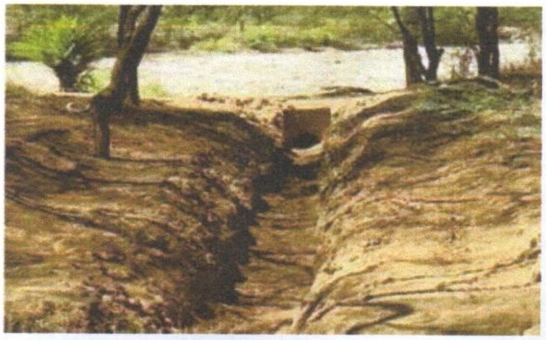


Fig. 9: Aspect(s) of water access affected by rainfall variability
Source: Field data, August 2015



(a) Dried river (Endao) in Salabani

(b) Lake Baringo

Plate 3: Water sources affected by rainfall variability
Source: Field survey, August 2015

4. CONCLUSION AND RECOMMENDATION

It was established that there was no statistically significant relationship between rainfall variability and any of the water access variables. The amount of rainfall received does not affect access to water; although households implicated rainfall variability on reduced access to water. Only few households (29%) have access to domestic water in Baringo County. Households in the area reported recent increase in distance covered and time spend collecting water. Decrease in quantity of water used per capita per day and change in location and type of source were also reported. However, they have accepted rainfall variability as a frequent recurring characteristic of rainfall regime in that area; and thus, they have learned to live with it. The coping strategies identified are simple survival strategies (vendor, dug well, water pan), which may not meet the required standard for optimal use of water. Water storage, in its various forms, provides a mechanism for dealing with variability which, if planned and managed correctly, increases water security and adaptive capacity. Badly planned and designed water storage is a waste of financial resources and, rather than mitigate, may exacerbate unpleasant climate change impacts. The study therefore recommends that the existing water sources be up scaled to guarantee enough and quality water for domestic and livestock use.

5. ACKNOWLEDGEMENT

The author would like to thank the postgraduate school, Kabarak University for supporting this study.

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Cite this article:

Koskei, E. C. (2016). Effects of Rainfall Variability on Access to Domestic Water in Baringo County, Kenya. *Mara Research Journal of Environmental Sciences*. Vol. 1, No. 1, pp. 14 - 27.