UNIVERSITY OF NAIROBI

ANALYSIS OF EFFECTS OF RAIN WATER HARVESTING TECHNOLOGIES ON LIVELIHOODS AMONG HOUSEHOLDS IN MATUNGULU SUB-COUNTY, MACHAKOS, KENYA

A Thesis Submitted to the University of Nairobi in Partial Fulfillment of the Doctor of Philosophy Degree in Environmental Governance and Management

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This thesis is my original work and has not been presented for a degree in any other university

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DEDICATION

This thesis is dedicated to my son, Ryan Isaac Muyaka. May you gain more knowledge than your father and be a great man in future.

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ABBREVIATIONS AND ACRONYMS

ASALs	-	Arid and Semi-Arid lands
BC	-	Before Christ
CBOs	-	Community Based Organizations
CDA	-	County Development Agenda
CWWA	-	Canadian Water and Wastewater Association
DRWH	-	Domestic Rain Water Harvesting
FAO	-	Food and Agriculture Organization
GDP	-	Gross Domestic Product
GWI	-	Global Water Institute
GWP	-	Global Water Partnership
HBF	-	House Builders Federation
HCSA	-	Human Coexistence with Semi-Aridity
IEBC	-	Independent Electoral and Boundaries Commission
IFAD	-	International Fund for Agricultural Development
IRWH	-	Infield Rain Water Harvesting
IWRM	-	Integrated water resources management
MDG	-	Millennium Development Goals
MCIDP	-	Machakos County Integrated Development Plan
NGOs	-	Non-Governmental Organizations
NPWRMD	-	National Policy on Water Resources Management and Development
RWH	-	Rain Water Harvesting
RWT	-	Rain Water Technologies

RWHT	-	Rain Water Harvesting Technologies
SAB	-	Semi-Arid region of Brazil
SD	-	Sustainable Development
SDGs	-	Sustainable Development Goals
SPSS	-	Statistical Package for Social Sciences
STI	-	Science Technology and Innovation
SWC	-	Soil and water conservation
TDS	-	Total Dissolved Solids
TSS	-	Total Suspended Solids
UN	-	United Nations
UNCCD	-	United Nations Convention to Combat Desertification
UNICEF	-	United Nations International Children’s Emergency Fund
UNDP	-	United Nations Development Programme
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
USAID	-	United States Agency for International Development
WFP	-	World Food Programme
WHO	-	World Health Organization
WHT	-	Water Harvesting Technologies

ABSTRACT

Green agricultural innovations and technologies, rain-water harvesting technologies (RWHTs) included have the ability to overcome the water related difficulties experienced by households in rural areas. RWHTs have since been utilized for decades. Previous studies have evidenced the benefits of RWHTs to rural livelihoods. However, there is scanty documentation that explains the effects of RWHTs to rural livelihoods in Arid and Semi-Arid Lands (ASALs). The overall objective of this research was to analyze the effects of utilizing RWHTs on rural livelihoods. The specific objectives were: to assess the barriers and enablers of utilization of RWHTs among households; to evaluate the livelihood difference of households with or without RWHTs; to examine the extent to which Machakos County Government integrates RWHTs in its programs, planning and budgeting. The research used both quantitative and qualitative methods. Primary data was obtained by a household survey, focus group discussions and key informants' interviews (Appendix V). Pretested household questionnaires (Appendix II) were used to collect data from a sample of 384 respondents and participants observations were used for data triangulation. Secondary data was obtained through literature review of peer reviewed papers, reports and existing legislations on RWH. Descriptive analyses, tabulations, percentages, inferential statistics (correlation and regression analyses) and exploratory analyses were used for data analysis. The study affirmed that barriers and enablers did not significantly affect the utilization of RWHTs among the households. RWH had a significant ($\beta= 0.703$, $t=19.207$, $p=0.000<0.05$) impact on household livelihoods. In addition, incentives from the County Government of Machakos encouraged RWHTs. Correlation analysis outcomes showed a positive but weak correlation on barriers (costs and a lack of expertise on the utilization of these technologies) and enablers (incentives, sensitizations and funding) had an impact on household livelihoods. Regression assessment showed that barriers and enablers had a confident but statistically insignificant effect (β= 0.036, t=0.700, p=0.484>0.05) on the influence on household livelihoods but on the other hand, RWHTs had a positive and significant effect on the influence on household livelihoods. Moreover, integration of RWHTs in County Development Agenda had enhanced household livelihoods. The findings indicated that overall, a composite mean of 4.04 and a standard deviation of 0.699 of the respondents agreed that incentives from the county government significantly promoted RWHTs. This was confirmed by a positively strong and significant correlation (β= 0.703, t=19.207, p=0.000<0.05) between the integration of RWHT in the county development agenda and the impact on household livelihoods Results of this survey indicate that RWHTs are financed mostly by household heads and county government initiatives have not been adequately felt. There is a strong indication from the study that RWHTs had a significant influence on the impact on household livelihoods. To ensure the sustainability of RWHTs, the study recommended that the County Government of Machakos and other counties needed to intensify campaigns on RWH and incentivize households to utilize these technologies. Additionally, there is a need to strengthen funding and sensitization on the best technologies to enhance water harvesting. To ensure sustainability of RWHTs, the study recommends that Machakos County Government need to give continuous support, strengthen stakeholder and community participation in water management practices.

CHAPTER ONE: GENERAL INTRODUCTION

1.0 Introduction

The current world population stands at 7.9 billion people (United Nations World Population Prospects, 2019) and out of this population, 1.2 billion cannot access drinking water that is clean and safe (Armah *et al*., 2018). Currently, water scarcity affects every continent (Global Water Institute (GWI), 2013). World Health Organization (WHO) report of June 14, 2019 indicates that, seven hundred and eighty five (785) million people globally lack basic water drinking services, including one hundred and forty four (144) million people dependentant on surface water. The WHO report notes that slightly above two (2) billion people use drinking water sources that are dirty or contaminated. Furthermore, it is estimated that by the year 2025, fifty (50%) percent of the world's population will be located in area with water-stress (WHO, 2019). Water remains a global challenge among other challenges like energy, oceans, cities, climate change, poverty, food, gender equality and health (Armah *et al*., 2018). The demand for water use has grown globally thus it was now outpacing population growth, and increasingly, many regions are currently reaching levels which water services are unsustainable, especially in arid regions (GWI, 2013). According to the report by International Resource Panel (IRP), 2016, under current trends, global demand for clean and safe drinking water will overshoot supply by forty (40) per cent in 2030.

Fresh and easily accessible water accounts for only 0.014% of all water on Earth leaving ninety seven (97%) water as saline and slightly less than three (3%) as inaccessible **(**United Nations Development Programme (UNDP), 2006). Clean, safe, affordable and accessible water is salient for the overall public health, be it for drinking, domestic, livestock use, irrigation or for purposes of recreation. Better water resources supply, sanitation and management boosts a countries' economic development and contributes immensely to poverty eradication (WHO, 2019).

Technically, according to UNDP, 2006, fresh water amounts are enough on a global scale. However, unequal distribution (due to climate change) results in wet and dry locations, with increases in global fresh and safe water demand in recent years from industries and human beings. Globally, in every six people, one or two people are water stressed, implying that they lack sufficient access to water (UNDP, 2006). Globally, about 1.1 billion people are water stressed with majority of them found in developing countries, Kenya included **(**UNDP, 2006; Hoekstra and Mekonnen, 2016).

In Sub-Saharan Africa, too much time is spent by women and school going girls in fetching water from213470 natural springs, rivers and wells which whose quality and quantity has been adversely affected by climate change besides anthropogenic factors. About forty one (41%) percent of Kenya's population still relies on unsecure water sources, which include ponds, water pans, wells, sand dams and rivers. Such challenges are common in rural areas and urban slums (GWI, 2013). In the rural areas, a large population depends on rain fed agriculture yet droughts and floods have expansive impacts on such communities. One of the adaptation and mitigation strategy to boost water availability has been rain water harvesting. However, it is not well documented how rainwater-harvesting technologies affect or influence livelihoods among households.

The arid and semi-arid land experience inherently unpredictable rainfall and frequent droughts due to climate change. Some of the local dynamics that would be expected includes water shortages, deterioration of land resources and forage as well as decline in livestock productivity.

In Kenya, for instance, government agencies as well as non – governmental organizations to some extent try to provide help on farm adaptation strategies like rain water harvesting technologies which in turn assist households to cope with climate hazards that affect agricultural production and food security in arid and semi – arid lands (Lutta A. *et al*., 2020). The varied water harvesting technologies that have been enhanced in such areas include zai pits for growing crops and tress, water pans and shallow impact of such interventions with regard to improvement of range productivity and therefore welfare of agro - pastoral and pastoral communities has not been felt due to low adoption rate by households (Kimani M. W. *et al.*, 2015 and Lutta A. *et al*., 2020).

In Kenya, Machakos County covers an area of 6,042.7 km^2 with a population of 1, 421, 982 people and a population density of 235 people per square kilometre (Kenya Population and Housing Census, 2019). It is one of the semi-arid lands in Kenya with annual rainfall below 1,000 mm. Matungulu Sub – County, the sample area is among the eight sub – counties of Machakos County and it represents the ASAL characteristics of the larger Machakos County. Integrated water resource management and similar works of RWHTs is also practiced in other counties like Embu, Kitui, Makueni as well as Laikipia even though on small scale.

1.1 Problem statement

The biggest problem is that fresh water is not easily accessible and therefore scarce. Water is a scarce resource in both urban and rural areas of developing countries. Approximately 785 million people globally lack basic water drinking services and about two (2) billion people use drinking water sources that are dirty or contaminated (WHO, 2019). About forty one (41%) percent of Kenya’s population still relies on unsecure water sources, which include ponds, water pans, wells, sand dams and rivers (GWI, 2013). Water scarcity has constraint agricultural activities thus contributing to vulnerability of rural livelihoods. RWHTs have been in use for decades but the utilization in Kenya has been too slow or limited. Rural households for several decades (Peters, E. J., 2017) have utilized green rain water harvesting technologies to counter water scarcity. About 36% of Kenya's population in Arid and Semi-Arid Areas still walk for several kilometres to fetch water for both domestic and livestock use which exacerbate inequalities (Mogaka, 2009). The livelihood benefits of Rain water Harvesting Technologies has been documented in many countries including India, Korea, Canada, Zimbabwe, Japan and Brazil where underground dams and drilled wells for Urban population in India, for instance, have improved livelihoods (Hodson, P. and Jarman, R. 2006), (Nishigaki *et al.,* 2004), (Mutekwa, V., and Kusangaya, S., 2006). Studies in Canada have been done to identify the barriers to sustainable water management in Canadian Urban Cities (Chantelle Leidl *et al*., 2010). Similar studies have also been carried out in Middle East, North Africa, Mexico and Korea on rainwater as an alternative source of water for domestic and livestock utilization (Angelakis, 2016), (Pacey and Cullis, 1986). While we can borrow lessons from these countries, the socio-cultural and political settings are different from those of Kenya. Although the importance of Rain Water Harvesting Technologies in improving household livelihoods is well known in Kenya both at the National and County levels, little is known and remains to be limited documented empirical evidence on how the use of rain water harvesting technologies affect livelihoods among rural households. This study was undertaken to fill this gap.

1.2 Objectives

1.2.1 Overall Objective

The overall objective of this research was to analyze of effects of utilizing rainwater harvesting technologies on livelihoods among households in Matungulu Sub-County, Machakos, Kenya.

1.2.2 Specific Objectives

i. To assess the barriers and enablers of utilizing RWHTs among households in Matungulu Sub-County, Kenya.

ii. To evaluate the livelihood differences of households with or without RWHTs in Matungulu Sub-County, Kenya.

iii. To examine the extent to which Machakos County Government integrates RWHTs in its programs, planning and budgeting among households in Matungulu Sub-County, Kenya.

1.3 Hypothesis

This study was based on the following hypotheses that were tested specifically as per the study objectives and discussed in separate chapters:

H_0: Barriers and enablers do not significantly influence the effects of rainwater harvesting technologies among households.

H_1: Barriers and enablers significantly influence the effects of rain water harvesting technologies among households in Matungulu Sub-County, Kenya.

H_0: Livelihood differences of households do not significantly influence the effects of rain water harvesting technologies and those without in Matungulu Sub-County, Kenya.

H_1: Livelihood differences of households significantly influence the effects of rain water harvesting technologies and those without in Matungulu Sub-County, Kenya.

H_0: Machakos County Government programs, planning and budgeting do not significantly influence the effects of rainwater harvesting technologies among households in Matungulu Sub-County, Kenya.

H_1: Machakos County Government programs, planning and budgeting significantly influences the effects of rainwater harvesting technologies among households in Matungulu Sub-County, Kenya.

1.4 Justification

Water is life and not having it diminishes the hopes of SDG 3 on good health and wellbeing. Access to safe, clean, reliable, adequate and fresh supply of water is one of the main pointers of socio-economic development. The percentage of people accessing safe drinking water services was sixty six point nine (66.9%) percent as at 2014 which is a clear indication that most of the Kenyan population are unable to access safe, clean, adequate, fresh and reliable drinking water sources (Ministry of Devolution and Planning, 2017). The said situation can be enhanced through construction, expansion and development of water supply systems or projects in urban as well as rural areas and; decentralization of water provision and distribution services to the county governments to enhance efficiency and effectiveness of the entire process. The findings would inform policies and practices on green rain water harvesting technologies for improved livelihoods. The findings were also core to informing sustainable development goals particularly of zero hunger (SDG 2), reduced gender inequalities (SDG 5), clean water and sanitation (SDG 6), and climate action (SDG 13). This study therefore, sought to establish why there was still prevalent lack of safe, clean, reliable, adequate and fresh drinking water in Machakos County despite all the initiatives put in place.

1.5 Scope and Limitations

The focus of the study was Matungulu Sub – County of Machakos County. This Sub – County was chosen due to its Pre- eminent position as one of the driest areas of Machakos County. The survey was limited to household heads as the major respondents for the attainment of the required primary data. Key informants (Appendix V), focus group discussions, observations as well as review of relevant secondary data were conducted. The main aim of the research was to assess the effects of utilization of RWHTs on household livelihoods in the research area. The research was carried out in Machakos County, Matungulu Sub-County in Kenya. The study focused on households as a major source of data for the research and mainly targeted the utilization of RWHTs and county government strategies to encourage utilization as the main focus.

1.6 Structure of the thesis

The thesis was systematically arranged in six chapters. Chapter one gave or provided a broad introduction of the study. Chapter two provided a comprehensive literature review. Chapter three reported the review and findings on the barriers and enablers of utilization of rain water harvesting technologies at County levels, a case study of Matungulu Sub-County, Kenya. Chapter four dealt with improving household livelihoods using RWHTs in the study area. Chapter five presented findings on integration of water harvesting technologies in County Government programmes and budgeting. Chapter six presented the overall discussion, conclusions and recommendations.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This section of the thesis entailed a detailed review of published and unpublished literature on the feasibility of using rain water harvesting technologies to improve livelihoods in the study area and generally Kenya as a whole. The section also considered the history of harvesting rain water, technologies to cope with water scarcity, barriers and enablers of utilizing rain water harvesting technologies among households, the impact of rainwater harvesting technologies on livelihoods among households, the extent to which Machakos County Government integrates rain water harvesting technologies in its programmes, planning and budgeting, the rain water harvesting framework, theoretical framework, conceptual framework as well as the research gaps identified.

2.1 Water Access, Sanitation and Health

The demand for water in most urban areas has continued to spiral due to worldwide urbanization as the world population continues to increase (Sharma, S.K. and Vairavamoorthy, K. 2009). Water resources that are available continue to shrink or become limited, while there is multiplying need for water for different uses as well as preferences (rural, urban, agricultural, industrial and environmental). This has led to decreasing access to reliable and safe water since most of the nearby or accessible, good-quality and reliable water sources are either misused, over utilized or depleted. The overall management water treatment costs, purification, transportation and supply have been increasing day after day. Regularly providing clean, adequate, safe, reliable drinking water of good quality to an ever increasing global population is thus an ever increasing problem for water supply companies worldwide (Sharma, S.K. and Vairavamoorthy, K. 2009).

Human, animal and natural activities overally influence all sectors of the global water cycle. Gradually, human activities like clearing of forests, afforestation and agriculture have extreme effects on the water cycle including evapo-transpiration, water flow levels, groundwater levels and fluctuations of sea levels (Céline N. and D. Whittington, 2010). In addition, human activities affect cloud formation through gas emissions. The main dangers to water resources that later on affect people include pollution, scarcity, climate change with results like redistribution of precipitation, sea level rising, carbon dioxide absorption changes of the oceans and increases in precipitation as well as flooding (Céline N. and D. Whittington, 2010).

According to Henri Smetz (2009), most countries in both developed and developing countries have legal requirements for providing easy and affordable access to clean water to its population, which is part of the Millennium Development Goals. The Kenya Government has been focusing on achieving the sustainable development goals through its Vision 2030 economic blueprint (Ministry of Devolution and Planning, 2017). Henri Smetz in 2009, further notes that the right to safe, clean and adequate drinking water is the consumption right to utilize water when consumers may even lack the means to purchase the resource.

The global effects of climate change as well as the ever increasing clean and safe water scarcity, coupled with growth in population, urbanization and the general changes in demography present major problems on supply structures of water as a resource (WHO, 2019). Other alternatives of water sources for drinking, irrigation, livestock rearing as well as other domestic uses will therefore, continue to emerge, which will eventually lead to a growing dependence on underground water and other water sources, rainwater harvesting and recycling and reuse of wastewater (Ibid, 2019).

Better global reach to safe, adequate, reliable and clean drinking water as well as better sanitation is among the less costly and most practical way to enhance the livelihood of an entire population (Montgomery and Elimelech, 2007). Purification of drinking water dates back to 350 B.C., when Hippocrates recommended boiling water to kill bacteria and other impurities. By the start of the 20th century, most countries in Europe and United states had almost eliminated hygiene related diseases through water purification and installation of sewerage systems. This is in contrast to the less developed countries in Africa, Asia and Latin America where satiation services are still un-established, poorly funded on not even in existence. This is evidenced by the prevalence of hygiene related diseases in the mentioned regions (WHO/UNICEF, 2004)

China, one of the most prosperous economies in the world is facing acute water shortage in its major cities (Sharma, S.K. and Vairavamoorthy, 2009). Beijing, which is one of the largest cities and the capital city of China, is experiencing barely sufficient water for its population and potentially reaching catastrophic levels in the future. Beijing has therefore developed mechanisms to balance water supply as well as water demand by doubling water resources and putting in place water consumption management practices such as price control, guota water use, water conservation and waste water reclamation in order to meet the ever increasing water demands (Ibid, 2009).

Smetz (2009) noted in his study that access to clean and safe drinking water in industrialized countries is cheaper compared to developing countries. On average, households in industrialized countries utilize approximately 1.1% of revenue for settling water bills and sanitation bills. Impoverished households generally utilize about 2.6% of their income. Smetz further notes that enhancing the ability to get affordable water needs critical examination of the affordability index and coming up with remedial plans to mitigate it. Remedial plans may include differentiated pricing, aid programmes and cross-subsidy components. Most less developed countries have put in place similar measures making them to be water sufficient.

Several countries in both developed and developing countries have developed laws and regulations that if implemented should make access to clean and safe drinking water available to all, even populations residing in arid and semi-arid areas at an equitable, fair, acceptable, accessible, affordable or reasonable way. An example is France where French water law provides for provision of water to all affordable prices and guarantees access to water as the right of every citizen (Bayu, T. *et al.*, (2020). Indonesia adopted a regulation in 2006 that sets the cost of getting safe and clean water for drinking at a maximum of four (4%) percent of the income of any given household (as per the set minimum wage) (Smetz., 2009). In my own view as a researcher, I tend to critically point out that most of such countries, Kenya included, have had laws and regulations but what lacks most is the implementation phase. Most countries keep on repealing the set regulations from time to time with little or no implementation. This makes many of such regulations to remain on shelves after being passed but then what next after the passing is what remains unanswered.

In reference to the Sustainable Development Goal target 6.1, which aims at achieving universal and equitable reach to safe and affordable water for drinking, it is pertinent to ensure that this target is achieved or realized to improve the livelihoods of the larger population (WHO, 2019). The WHO/UNICEF Programmee called Joint Monitoring of 2017 also indicated that about eight hundred and forty four (844) million people are still living short of the basic reach to water, and a population of almost 2.3 billion are not yet able to get the minimal sanitation services like bathing, washing and or washroom flashing. Dirty or contaminated water can lead to disease transmissions. Poorly managed services for water are likely to expose households, individuals or even the entire population to preventable health risks, which is in the long run costly to many (WHO, 2019).

Bayu, T. *et al.,* (2020) in their research found out that inequalities in the access to sanitation is seen to exceed the access of water inequality in less developed countries. When regional comparison is carried out, therefore, it is noted that countries in the sub-Saharan Africa have tended to show a high level of access inequality for sanitation as well as water. In their research, they went ahead to state that for water inequality specifically, countries with relatively poor living standards were likely to suffer extreme levels of inequality for the basic services. It is, however, clear that even less developed countries with fairly high living standards per capita, for instance, countries like Gabon and Namibia, are likely to experience a high indication of inequality for basic sanitation (Ibid, 2020).

Inadequate drinking water, sanitation and hygiene basically referred to as WASH are pertinent risk factors, especially in low-income settings. Globally, in 2012, for instance, about 502, 000 deaths caused by diarrhea were seen to be due to inadequate drinking water and 280 000 deaths by inadequate sanitation (Prüss-Ustün, A. *et al.,* 2014). It is also noted that inadequate hand hygiene led to about 297 000 deaths per year in the whole world. This gives an estimated total of 842 000 deaths caused by diarrhea in this cluster of risk factors, which totals to about 1.5% of the total disease problem and 58% of all the diarrheal diseases case documented globally. On the other hand, in children under 5 years old, about 361 000 deaths could be prevented, representing 5.5% of deaths in that age group (Ibid, 2014).

Enhancing water storage via good rainwater harvesting technologies can help many families to utilize little time and the energy of physically fetching it, and thus communities, especially women and girls can be productive in other ways and even allows the young girls to go to school. Improvement of water storage mechanisms can also result in bigger personal safety by lessening the need to make long or even risky trips to fetch water in most arid and semi-arid lands (WHO, 2019). Improved water sources through improved rainwater harvesting technologies can also result in less expenditure on health in many communities, since people are less likely to fall sick, which will in turn lead to reduced medical costs, and communities can generally remain economically productive, literate and with sustainable livelihoods. It is quite important to note that globally, children are particularly at a major risk of acquiring water-related diseases due their active life that requires much care (Sharma, S.K. and Vairavamoorthy, 2009). It is therefore, important to ensure that children can access improved sources of water which, in the long run can result in better child health, and thus improved school attendance, which will in turn lead to them having better living standards in future (Ibid, 2019).

2.2 Water Sources

The water management approach that is supply-driven as the traditional way of doing things see the requirements for water of any particular household as ‘requirements’ or ‘needs’ which should be fulfilled and not as ‘demands’ which can changed (Sharma, S.K. and Vairavamoorthy, 2009). It thus places emphasis on the development of new premises and structures which uses the readily available sources to attain the perceived ‘increasing’ water requirements. This ancient method has resulted into the over-use of the resources, over-capitalization, as well as water pollution (Ibid, 2009). Thobani M. (1998) indicated in his study that there were changing trends in water sources utilization as opposed to previous traditional mechanisms to meet the growing demand for water that were based on voluntary means of water conservation and reallocation to various uses instead of coming up with new water sources.

Studies have found out that developed countries have in most occasions experienced consistent water source for households. However, in developing countries the observed trend has shown that households use two or more sources of water like piped water, wells, public taps, water sellers, water bowsers, supply of water from neighbouring households, rainwater harvesting, or rivers water, stream water, or lake sources (Céline N. and D. Whittington, 2010).

Different communities and households around the world use varied types of water sources basically depending on their geographical location. There exists different types of water sources around the world that have for a long time served humanity in different ways depending on those communities' or households' day to day needs as outlined and discussed below:

2.2.1 Surface Water Resources

These type of resources are the kind of water bodies that we witness on the earth surface. Such water bodies are varied in nature and they include: rivers, runoff, streams, wetlands, reservoirs and creeks which have fresh water as opposed to salty water. They comprise of both still and moving water bodies (Mers, T., 2020). They form part of the water hydrologic cycle that involves movement of water from the earth as well as to the earth's surface. Surface water resources and ground water resources replenish each other in that surface water can seep into the ground to form ground water and groundwater on the other hand can surface to replenish surface water through springs (National Geographic 2021). These sources of water are among the easiest water sources to filter and therefore, they happen to produce the highest quality of clean and safe drinking water for the general public. This kind of water resources are used by most people due to their easy accessibility. It is important to note that most people or even entire communities settle close to large lakes, rivers and streams where they can readily and easily fetch and use water. This makes surface water to be seen to be the most reliable alternative in terms of access for providing households and urban centres with the water that they require to operate normally. Some population to a large extent utilize river resource as well as lake resource for purposes of recreation that include swimming mostly by children and small scale or commercial fishing. The water is commonly used for farming through irrigation as well.

Generally, surface water can be classified into three major types: ephemeral, man-made and perennial. Perennial surface water are available on permanent basis and are replenished by ground water when there is some little rain. Surface water referred to as ephemeral are temporary and are available for small parts of the year. They include lagoons, creeks and water holes. On the other hand, artificial creations like dams, ponds or 'silanga' and created wetlands form the man-made surface water sources (Ibid, 2021).

Surface water resource accounts for over seventy (70%) percent of the water used Africa, south of Sahara (DWAF, 2004). Even though surface water resource is the most widely used water source, it is in most cases prone to contaminants from human activities making it unfit or even poisonous for both land and aquatic animals (Ochieng et.al, 2010). Surface water resource has been exploited for many years and generations and it serves as a source of both treated and untreated water source. Surface water resource is also an economic resource that has been exploited for tourism, fish farming, irrigation, domestic and livestock use and recreational activities among others, therefore, becoming an important resource to human kind in many households. Urbanization and increase in industrial waste has led to pollution of surface water resources mostly in less developed nations where water treatment technologies as well as systems have largely not been developed to manage such issues when the frequently crop up (Ochieng et.al, 2010).

Water is a basic need in any homestead and one of the most important resources that is spatially spread across the globe. Intensive research, therefore, needs to be carried out on hydrologic observations that can be made to identify spatial variations in reservoirs such as lakes, rivers, floodplains and wetlands. This is extremely important in trying to understand the spread of surface water and how best to conserve it (Alsdorf *et al.*, 2007). Surface water is prone to contamination from runoff and waste water and may need to be treated before they are used for domestic or industrial purposes. Contaminants pose health risk to people living near these water sources and in some occasions have led to environmental hazards (Craun, G.F., 1988).

In most countries, for instance, the law regulates surface water extraction. However, regulation sometimes are not adequately enforced due to weak or poor governance which leads to misuse and pollution of these resources. Since it is the most accessible water resource, it is relied upon for many uses, both domestic, farming and industrial. There is need for monitoring stream flow rates since it aids in the determination of the influence of activities done by man and changes in climate and how they impact on the already existing surface water sources. With proper management and good governance there is need to keep track of flora around surface water bodies. The clearance of flora and fauna, either through activities by human like deforestation or natural activities like fires, can have severe negative effects on surface water. Deforestation can also cause soil erosion through increased surface runoff that can in turn result in flooding (National Geographic 2021).

2.2.2 Groundwater Resources

It is estimated that nearly half of the worlds' population has settled within coastal regions (IPCC and UNEP, 1997, Jahanshahi and Zare, 2016, Sonkamble *et al*., 2014), majority of these population, especially in the less developed countries are subjected to high population growth leading to higher groundwater demand for domestic and industrial use. In these areas, groundwater is an important resource for human needs for fresh water (Ketabchi *et al*., 2016) and the entire population by acting as the exchange zones that separate marine and terrestrial hydro-biogeochemical cycles (Colombani *et al*., 2015, Post and Werner, 2017). There is thus, more water underground than all river and lake water resources combined. This implies that the amount of ground water globally is more than surface water. The only big challenge that hampers utilizing the ground water resource has been the difficulty involved in accessing it and also purifying it (Mers, T., 2020). These sources in some areas lead to soil saturation and on the other hand, they contain a lot of sediments which, the water needs therefore, undergo a thorough the process of filtration before it can be deemed fit for human consumption, for livestock use or even for farming activities through irrigation be it ground or overhead. That groundwater resource is the major source of plant hydration, even if it is most of the time not a reliable source of water for mankind. Their significance is seen since many of the groundwater resource supply some of the surface water resources via underground springs (Ibid., 2020).

According to Oiro *et al*., 2019, Aquifers along the coast remain significant sources for the socio-economic development of urban centres along the coastal strip (Kenyan coast included) as water requirements are realized through the exploitation of ground water. Keeping in mind the issues that influence the sustainability of groundwater resources of the coast that are fresh is, therefore, critical. The integrative approach considered under this study in mapping out the extent of seawater intrusion and examining its driving forces is key. Widespread issues of seawater intrusion is becoming a big problem in coastal aquifers (Ibid, 2019). Oiro made a conclusion that increase in population along the Kenyan coast which is also coupled with increasing demand for water for domestic and industrial utilization in the area as well as along the whole of East African coast from Somalia to Mozambique, is mostly achieved through the exploitation of the coastal groundwater resources. This has forced the government as well as the coastal communities to dig more wells ranging from open wells to hand-pumped wells and electric power-driven boreholes for use.

Okello, C., Antonellini, M., Greggio, N. *et al*., (2015) noted that salinization that happens in coastal groundwater systems results in a severe degeneration in the amount as well as quality of fresh groundwater resources. To enhance the reliable utilization and management of fresh groundwater, quantification and characterization of such coastal resources are key in view of the population growth that is likely to be witnessed in many African countries.

Demand for water is driven by the ever-increasing population, increased irrigation practices and the rapid economic development through urbanization. In some cases, surface water resource is able to meet this demand, however, regional variations in climatic conditions lead to overuse of surface water resources and/or lack of it altogether. This leads to utilization of ground water especially in regions with severe water stress (Wada *et.al*, 2008). Over exploitation of ground water resources in many parts of the world may lead to depletion of the resource especially if the extraction of these resource exceeds ground water recharge. This can cause severe effect on the natural stream flow and wetlands ground water fed ecosystems (Wada *et.al*, 2010).

In northwest India, for instance, there are increasing concerns over sustainability of ground water exploitation for the current and future generations because of sustained growth in agriculture driven by the use of irrigation from ground water resources. This is one of the challenges facing aquiver systems worldwide which is evidenced by the decline in ground water levels in northwest parts of India over the past two decades (Lapworth *et al.*, 2015).

2.2.3 Storm water/Rainwater Resources

This kind of water source or resource is also referred to as runoff water that comes from heavy weather such as rain, snow, and hail (Mers, T., 2020). This water flows on land as runoff and can be captured or harvested for different domestic uses including washing, drinking for both domestic and livestock as well as farming through irrigation. Much of this water runs back into the oceans, lakes, seas, rivers and swamps and thus, capturing it beforehand is a major way to enhance the overall water supply on land and for the greater use by households. Due to this, majority of experts that focus on sustainability have tried to research the different ways or methods to harvest such runoff and filter it before it drains away into other water bodies (Ibid., 2020).

Storm water harvesting (SWH) which is also known as rainwater harvesting (RWH) is an alternative water resource that has not been adequately exploited and could be utilized as an alternative source to urban water supplies, as well as acting as a better ways to manage flooding and offer recreational sites (Fisher-Jeffes L. *et al*., 2017). It has been proven that storm water harvesting is one of the mitigating measures against erosion of the fertile top soils and land degradation in many parts of the world (Ibid, 2017).

That practice of collecting rainwater dates back to over 6,000 years ago and has always been the main water source for domestic use even though water harvesting systems were not yet developed. In the modern times however, rainwater harvesting systems have evolved and it is now the responsibility of water boards to harvest and properly utilize storm/rain water through structured and elaborate water distribution systems (Che-Ani, *et al.*, 2009).

There exist several benefits of rainwater especially when the correct rainwater harvesting method is used. Rainwater is viewed in Colombia as an alternative source of water for domestic consumption but extremely few actually use it (Morales-Pinzón, *et al.*, 2012). Rainwater is the cleanest water source but acquires acidity because it dissolves impurities such as carbon dioxide and nitrogen in the process of raining and collection. It is thus, noted that rainwater is part of a continuous exchange of water between the atmosphere and the ocean (Che-Ani, *et al*., 2009).

Studies have also proven that the quality of rainwater is greater than surface water and can be compared to ground water as it does not dissolve minerals and metals found in soil and rocks (Ibid, 2009). However, this quality is often influenced by location, human activities and the type of storage employed but, can be purified for use if properly treated and stored.

2.2.4 Wastewater Resources

This resource is referred to as a mixture of rainwater runoff, industrial, commercial and domestic waste carried by water. Wastewater is mainly determined by human activities that bring about environmental pollution that end up in water runoff. Such human activities may lead to industrial effluents, domestic waste discharge and wastewater released from varied farming activities as well as chemical use. The type of pollutants realized determine the type of water treatment needed to purify waste water to be fit for reuse by both human and animals (Naidoo, S., and Olaniran, A., 2013).

There are four main source of waste water namely: domestic, industrial, agricultural and urban. Urban wastewater combines domestic, industrial, rainwater and sewer leaks while processes from agricultural activities from nearby farms and in some cases, contaminated ground water forms agricultural wastewater (Naidoo, S., and Olaniran, A., 2013).

Wastewater resource is a water source for human and animal use that is rarely utilized due the difficulties in purifying it to render it clean and safe for human or animal consumption. This is the water used in households, in manufacturing industries, and in many agricultural activities all over the world. The water ends up being disposed off through the drains and sewage systems (Mers, T., 2020). Some of such water is treated while some is just released to join other water bodies untreated hence dangerous to human and animal life. Since this is already used water, it may be a combination of toxic substances which may require proper filtering and purification for it to be recycled back for utilization.

The major concern associated with the use of wastewater is the risk of human and livestock related diseases as a result to exposure to pollutants and microbial organs existing in wastewater. There is also a risk of environmental degradation from leakages of toxic wastewater in water treatment plants (Naidoo, S., and Olaniran, A., 2013).

Treatment and re-use of wastewater has been necessitated by the increasing need for water resulting from the ever increasing population, urbanization, industrialization and increased agricultural activities. Waste water has therefore become one of the sources of usable water through recycling (Morales-Pinzón, *et.al*, 2012).

It is necessary to treat wastewater to remove impurities before they are discharged to aquifers or other natural water bodies such as oceans, lakes, rivers, lakes, ponds, swamps among others. All water found in nature has some level of impurities and the distinction between clean and polluted water depends on the concentration of impurities found in the water. Proper tests and water treatment are therefore, necessary before and water is utilized. Water can only be classified as polluted when it is not fit for use for a particular purpose (Som, I. *et al*., 2020).

Pollution can originate from various sources, including point and dispersed sources. Pollutants that reach aquifers from a single channel are point source pollutants and are normally discharges from cities, manufacturing plants, leakages among others. Dispersed pollutant sources include discharges from broad unconfined sources such as water run-off that carry animal and human wastes, pesticides and silts among others. Run-off storm water from urban drainage systems are also considered as dispersed pollutant sources because it carries several pollutants and enters the water aquifers from varied entry points. It is , therefore, easy to control point source pollutants since they flow to a particular point where they can be treated before being released into other nearby water bodies (Ribeiro, A. *et al.*, 2015).

2.2.5 Salt water Resources

It is estimated that only three (3%) percent of the total earth's water resources are fresh water and can readily be use for both domestic and industrial purposes. However, 97% of the world's water resource is found in oceans and is too salty for human use (Zhou, Y., and Tol, R. S. J., 2005). Since fresh water as a commodity remains scarce, several technologies have been developed to purify salt water for human use. The process of desalination has been in use all over the world for decades now. However, the process of desalination has not been adequately adopted in developing countries because of the cost implication. The desalination technologies are also not readily available, leaving the salt water resource largely untapped in almost all developing countries (Ibid., 2005).

Sharqawy, Lienhard and Zubair (2010), define Saline water (also most commonly referred to as salt water) as water that has a high percentage of dissolved salts (sodium chloride being the main component). The concentration such salt is normally measured in parts per thousand (permille, %) and parts per million (ppm). It is important to note that oceans contains over seventy (70%) percent of the planet (Mers, T., 2020). Due to their salty and abrasive nature, salt-water resources are too hard to utilize and also extremely expensive distil.

Membrane-based distillations to purify water and desalination have been in constant utilization to address the global problems of water scarcity as well as pollution of aquatic bodies. It is, however, noted that advancement in water purification membranes has been prevented by the persistent limitations of conventional membrane materials (Werber, J. *et al*, 2016).

2.2.6 Ice Cap Water Resources

Glaciers and ice caps cover about 10% of the world's land mass and are mostly found in the Nordic countries (parts of Europe and northern Atlantic). Glaciers and ice caps have a major role in the world's water cycle and generally, affect the quality of water, variability and run-off volume in areas where they occur (Gardner, A. S. *et al*., 2011).

Glaciers are frozen ice flowing downhill and normally begin as snowflakes. Glaziers start to form when snowfall far exceeds the summer melting. They can greatly vary in size and sometimes dangerous to any form of life when they start moving. Some glaciers have been measured to be 161 kilometers long. Glaciers are the largest storehouses of fresh water (Rastner, P. *et al*., 2012).

In some of the world's mountains, for instance, ice and snow are some of the physical features that are witnessed. These are actually important fresh water sources (Gardner, A. S. *et al*., 2011). In the Nordic countries, water from glaciers has been utilized for hydropower production, especially in the European Alps, Canada and New Zealand. They have also been utilized for agricultural purposes in some mountainous regions of the world. Among the main concerns of ice cap resources is the effect of changes climate due to global warming which is leading to melting at a faster rate. It is believed that there is a real danger of these resources disappearing, therefore, causing a climatic disaster (Thorsteinsson, T. *et al*., 2013).

The contribution of glaciers and ice cap to sea levels have not been adequately studied but reliable information from studies point to ice melting as one of the key contributions to rising sea levels (Björnsson, H., *et.al.* 2013). There is need to implement sound environmental measures to mitigate against the global warming in order to preserve this extremely important water resource in the world (Ibid, 2013).

Ice cap water resource is found in the polar regions of the world. It is possible to collect a substantial amount of water from the polar ice caps and glaciers for human as well as for livestock consumption (Mers, T., 2020). These versed bodies of ice float on oceans which are salty but they themselves consist of fresh water. This makes ice caps to be among the most important water resources for human and animal use provided that a reliable method to harvest them is identified. The glaciers exist in areas where there is little human settlement for them to regularly utilize them, and mankind has needs to develop better ways of melting them. Better methods of reaching such regions is extremely expensive and unsustainable. Furthermore, polar ice caps are important in regulating the temperatures of the Earth's surface (Ibid, 2020). The processes of melting them, on the other hand, would disrupt our global temperatures leading to harm that would affect most of the worlds' population.

People living in large glaciated inhabited areas of North Atlantic have abundant supply of water. Most of these areas, located in Greenland and Iceland have substantial ice cover. Glaciers and ice caps make up about eleven (11%) percent of the total surface area of Iceland with Sweden and Norway having smaller glaciers. The Nordic countries have tapped this resource for generation of renewable energy such as hydroelectric power (Thorsteinsson, T. *et al*., 2013).

In East Africa, several researches in the mid-1900s and towards the end of the 1900s indicated that the alpine glacier regions had in a period of seven years declined by 6.5 km^2 just on the Rwenzori Mountains alone (Nsubuga *et al.*, 2014). During the same period, Rwenzori ice caps had retreated by forty (40%) percent (Sector Performance Report, 2011). This major shifts in the trends identified warrants further research to further guide the decision makers (Ibid, 2014).

2.3 History of Harvesting Rain Water

Rain water Harvesting is a process of fetching and preserving storm water using different methods for varied future use by mankind (Mays *et al.*, 2013). Rain water from roofs is collected and channeled to containers, to pits like wells or boreholes, to a reservoir with percolation, to a water tank, water pan or a dam for varied future usage (Ibid, 2013). Its varied uses include water for kitchen gardens, livestock, washing, cooking, irrigation, drinking, longer-term storage and for ground water recharge (Nsubuga *et al.,* 2014).

Throughout generations, humans have been living in water scarce areas where collection of rainwater from rooftops and rainwater runoff from the hills were major sources of domestic water. This water collection technique, though simple, enabled early farmers to practice agriculture in the Arab countries, Northern parts of Africa and even Mexico (Pacey and Cullis, 1986).

Rain water harvesting technology is among the oldest methods of fetching water among households, which is in most cases financed by the user or reliant to the usage of locally available materials. The construction and use of rain water storage cisterns or containers has been in existence since the New Stone Age (the final stage of cultural evolution or technical development among prehistoric humans). In this stage, humans were no longer dependent on hunting, fishing and gathering wild plants). By the late 4000 BC, for instance, cisterns were useful water storages mostly utilized during dry-land farming (Mays *et al.*, 2013). Many ancient cisterns like containers for water storage were discovered in Israel with large capacities for storing water and with specialized features like carved rocks, lined with stones, and clay to avoid water leakages (Mays *et al.*, 2013). Similar cisterns were also found in Greek island of Crete (Everson *et al.*, 2011).

As early as 300 BC, farming communities in Pakistan, Afghanistan, Iran, India and Roman Empire were using rainwater harvesting technologies for agriculture (irrigation) (Everson *et al.*, 2011). In Pompeii, for instance, roof top water harvesting technologies and storage were common as early as the 1st century BC. (Everson *et al.*, 2011). The town of Venice, for example, also collected rain water using wells that were used in times of war (Everson *et al.*, 2011). These types of water harvesting technologies were seen to positively impact on household livelihoods then (Mays *et al.*, 2013).

Agricultural practices originated in the Middle East where climatic conditions were severely dry and may have depended on rain water harvesting for irrigation of their farms. There was minimal evidence of water harvesting in these regions however, until much later when evidence was uncovered on the use of rainwater applications in the Negev desert in the period between 200 BC and 700AD (Pacey and Cullis, 1986). One of the most striking discoveries was evidence of collecting runoff water from the hills using channels to intercept water during storms and redirect them to the fields in the Negev that were properly leveled and carefully enclosed by bunds. In Morocco, steeper hillsides were to collect runoff water which would flow to flat terraces organized behind stone containment walls where cultivation of crops was done. This technique was replicated in Tunisia where French travelers witnessed horticultural activities being practiced in the slope end of bunded rainwater catchments (Kutsch, 1982).

Modern water harvesting technologies, however, started appearing towards the end of the 19th century and early 20th century. The technologies were largely borrowed from the ancient water harvesting methods with addition of supply systems such as water pumps, pipes, drilling of deep wells among others. After the First World War, the utilization of cisterns for water supply expanded across several parts of the developed world. Other developing countries have since adopted these water harvesting technologies and have now been seen to be the main sources of water for domestic, industrial and agricultural use (Angelakis, 2016).

In Korea, new innovations have been developed and implemented for rainwater harvesting in star City. One such concept is the multipurpose concept which serves three purposes; conservation of water, flood control and preparation for unforeseen emergencies. Star city has also installed modern remote control systems to control water levels in reservoirs and hence controlling and mitigating against flooding. The Korean government has a robust incentive programme that supports interested persons to build water harvesting technologies and hence providing solutions to the expanding population (Angelakis, 2016).

2.4 Technologies to Mitigate Water Scarcity

Agricultural production in the African dry lands if put in context, soil and water conservation (SWC) usages like rainwater harvesting (RWH) give a great chance to strengthen agricultural practices in semi-arid lands which makes such areas become extremely productive and self-sustaining in reference to severe changes in climate (Vohland and Barry, 2009). Soil or water preservation methods are varied in nature but rainwater harvesting as a method is much supported by Governmental Organizations and agricultural extension agencies at national levels in Africa as well as in India (Batchelor *et al*., 2002), where such utilization have had a long tradition in terms of their usages (Pandey *et al*., 2003). Harvesting of rain water as a collection practice has been among the utilized ways that is supported by United Nations Convention to Combat Desertification (UNCCD) to curb desertification. Rain water harvesting methods are to a large extent seen to be of benefit even though with notable issues like the low levels of utilization which may result because of less or lack of farmers' involvement as the key stakeholders (Aberra, 2004).

Rain water harvesting practices collect surface water and also reduce runoff. In situ RWHTs have to a large extent had a positive effect on landscape activities overally. The recharge of aquifers as well as the positive progress in soil water is the main concern of hydrologists. However, competitions emerge in households due to varied water usages (Falkenmark and Rockstro M, 2004). Rain water harvesting systems focuses on minimizing changes that may affect different seasons like droughts and dry spells which in turn, affect the availability of water (Rockstro M. *et al*., 2002). In situations with unpredictable rainfall indications in the dry lands of sub-Saharan Africa, for instance, a great boost to the enhancement of crop production can be expected from enhanced SWC and RWH protection measures. Encouraging and promoting such methods in a more sustainable manner and at the same time taking into considerations the aspects of biodiversity offers a better avenue of mitigating the effects of drought and crop production failures. The preservation and utilization of RWH methods generally relies on the extent of farmers' involvement and the overall households in any given community. This might be where the main problem lies in terms of sustainability matters in rain water harvesting (Botha *et al*., 2004). If, for instance, most members of a household or even the entire community are involved in planning, then it will be highly expected that RWH frameworks will be sustained and benefits accruing from such frameworks will be shared (Bangoura, 2002).

The overall findings of this review that focuses on Africa display similar research results on the impact of rainwater harvesting methods in other parts of the globe. In Rajasthan, India for instance, where RWH utilizations have a long tradition, Pandey (2003) noted that RWH methods enhanced landscape diversity by an progressive growth of flora and fauna providing for human requirements. However, Pandey accepts that natural ecosystems might still contain more biodiversity resources. Other effects might emerge that are likely to compete for water between upstream and downstream users. There is also likelihood of some competitions and conflicts that RWH utilization could cause between pastoralists and sedentary farmers. RWH can influence large-scale changes of land use patterns as well as converting rangeland and natural vegetation into cropland. This might strengthen conflicts between pastoralists and sedentary farmers like what happens in Darfur, Sudan (Nyong, 2005b).

There are basically three techniques of harvesting rain water according to the Indian Railway Works Manual (2000) as outlined below:

(a) Storing rain water in tanks, water pans or dams.

(b) Recharging of ground water reservoirs using roof top collected water.

(c) Recharging of ground water reservoirs or aquifers with runoff.

Varied water harvesting technologies have however, been utilized in different parts of the world and they include: slab cistern, production cistern, stone tank, underground dam, trench dam, dams and drilled wells. Each of these technologies is discussed in the following sub-sections:

2.4.1 Slab Cistern

Since time immemorial, cisterns remain to be an important section in water distribution method for the survival of mankind and mankind’s well-being in order to achieve global water resource sustainability. The use of water cisterns for water harvesting dates back in time to the third millennium. Cisterns were utilized to store water runoff as well as storage for seasonal variations. The ancient cisterns included the uneven holes that were curved in rocks and others were complicated constructions like the Crete created by Minoans. In the developed world for instance, the utilization of water cisterns is fading and being replaced by modern technologies but, developing countries still utilize this water harvesting and storage technology to mitigate the lack of this important resource (Mays, L., Antoniou, G., and Angelakis, A., 2013).

The modern day cistern employs technology whereby roofs of houses are constructed in a way to collect rainwater (Vohland K. and Boubacar B., 2009). The harvested water is then channeled by gutters, and collected in cistern. The slab cistern, on the other hand, aims at providing water for domestic needs (drinking and cooking). Due to proper management involved in the process of harvesting water, the use of chlorine tablets or equivalents, the water quality is guaranteed. This kind of water harvesting technology has been utilized successively in Egypt where it has been seen to improve its livestock and crop productivity (Ibid, 2009).

2.4.2 Production Cistern

These rainwater cisterns were utilized by Greeks, Romans and the Pacific island people before the western civilization. The same basic technics of modern-day methods were utilized in the roof-catchment cisterns of these earlier times (Mays, L., Antoniou, G., and Angelakis, A., 2013).

Production cisterns is a concrete tank that has a top cover that is partly underground for ease of rainwater collection (Vohland K. and Boubacar B., 2009). The top cover is generally utilized to dry harvested grains. The collected water is used irrigation of different types of crops for household use, and basically, for animal drinking. Eventually, the surplus water is sold to generate household income. This system of harvesting water has been practiced with significant success in Poland and Italy to provide for safe drinking water (Ibid, 2009).

In areas with regular rainfall, collection of rainwater for household use is practical. Roof catchment cisterns have become common and may be used both for domestic and agricultural irrigation purposes. They are sometimes during emergencies for various purposes, even though care needs to be taken to ensure that water quality is maintained throughout its use. Rainwater may contain contaminants which may be a health risk if used for drinking without proper treatment (Mays, L., Antoniou, G., and Angelakis, A., 2013).

2.4.3 Stone Tank

The British East Africa Railways, for example, constructed one of Kenya's earliest known stone water tanks in Makindu River in 1907. The tank was connected to a Hydrant which pumped water to the tank to be used by steam railway engines at the time. (De Vrees, L. 1987). The design enhances the natural capacity of rocks to collect storm water through wall construction in the lower areas or around the tanks. This method of rain water harvesting has been utilized in Egypt but with little success since basically and largely depends on porosity of the rocks.

2.4.4 Underground Dam

This refers to a unit constructed to collect beneath the ground water movement from an aquifer that is constructed with a water proof embarkment (de Oliveira Lima, *et.al*, 2020). Underground dams are thus of two types, namely: underground dams and submerged dams. Simple technology is used when building underground dams and generally the construction requires no training to operate and maintain. However, during construction, there is always need for some degree of care. Some factors must be considered including the rainfall patterns, river flows, drainage lines, soil texture, salinity and storage capacity (Dos Santos Gomes *et al.*, (2018).

Many parts of the world have realized the development of new groundwater technologies for underground water conservation. One of such technologies is the underground dam that has attracted much attention from Japan, Brazil and India since the 1970s. Underground dams are constructed on a relatively impermeable sub-stratum in the soil and fractured rocks. This blocks the flow of underground water and water level rises so that these water can be utilized continuously in any household or in entire communities (Nishigaki *et al.,* 2004). There are basically two types of underground water dams; a sand-storage dam or sub-surface dam. Sand storage dams are built across riverbeds with the dam crest at a desired height above the ground level. The accumulation of sand behind the dam impounds water, therefore providing a safe aquifer utilization by animals and humans (Ibid, 2004).

A sub-surface dam entails the building of water proof, vertical structures which are created at identified points inside the river bed. Such structures will in turn, raise the water table level, that will lead to an increase in the amount of water collected upstream. This will result in a big accumulation of micronutrients and will create fertile sites for crop production and fruits production. Several tests in the SAB have shown such areas can be as big as one hectare and that they can hold a variety of crops including millet sorghum and nappier grass among others (Ibid, 2004).

2.4.5 Trench Dam

Trench dams are reservoirs that are dug into the ground that are long and narrow in nature. Their bases and their linings are often covered by a water proof materials and they have a storage capability of up to 150,000 litres. The dam is constructed in a way that its shape and coverage to a large extent minimizes water losses through evapotranspiration of the collected water. Conventional trench dams are frequently constructed using a variety of local materials, including soils, which can be time consuming and technically problematic. Achieving uniform soil compaction around the trench dam can be difficult, which can lead to worker safety issues. In addition, without quality materials and sound installation methods, achieving the required low permeability can be challenging and sometimes impossible (Day, S. R. *et al*, 2001).

2.4.6 Dams

The use of ground-water dams is one of the oldest ways of storing water in tropical climates (Kingsford, R., 2000). This method has a merit of reducing high evaporation rates and may also be a good source of clean water, with few diseases and water pollution. Dams are critical in the prevention of excess water runoff and erosion that transport soil and siltation downstream. In some instances, construction of dams may cause negative effects to the environment. In Australia, for instance, construction and diversion of water channels have disrupted flooding in the wetlands causing death of aquatic life in the wetlands. It has also led to reduction of bird population, plants and the entire ecological system has been altered (Kingsford, R., 2000). The beginning of the 20th century witnessed the explosion of mega water related projects. These projects included construction of dams to mitigate against flooding, for generation of electricity and for crop irrigation. Dam construction enhanced the ability of governments to develop policies and strategies for water management and distribution as well as enhancing food security through irrigation practices. It also greatly reduced the likelihood of natural disasters caused by flooding and water runoffs (Chen, J. *et al*, 2016). Reservoirs of little sizes in nature are placed on two rainwater collection structures which are interconnected. To avoid on evaporation, the second tank is allowed to receive water after the first collection tank is totally filled. The two tanks basically are constructed in a little collection basin, in an elevated place adjacent to the agricultural areas so as to avoid the cost of water transportation. The tanks holding capacity can be up to eight (8) million litres, which can sustain up to 4 hectares of land on irrigation (Ibid, 2016).

Embankment dam is another type of dam that has been used widely in many communities. This can be cheaply built using less sophisticated model processes and normal farm implements. Small size earth dams need less maintenance (unless in difficult locations or in extraordinary climatic situations), and that they can withstand foundation and abutment movements than other structures (Aristeidis, K., and Dimitrios, S., 2015). In constructing earth dams, it is of value to be careful when it comes to the choice of site, local conditions and the set regulations. This will allow for safe construction and utilization of the embankments. Expert engineers must also be consulted when there is doubt about the safety in the designs of dams. Poorly constructed dams can be dangerous for human and wildlife especially for those households or communities that live down the stream. The selection, designing and building of dams needs to be strictly adhered to in order to make sure that the highest standards are achieved (Safavian, A., and Amani, M., 2015).

Many countries have come up with policies that give directions in construction and management of dams. However, in some instances, these regulatory measures are rarely put into use or implemented and thus they have led to disasters and loss of life. Environmental regulations have also been put in place in most African countries for the construction of dams in order to mitigate against the impact of environmental degradation (Stephens, T., 2010).

The rights to access to water and licenses to abstract water exist in most countries which can be applied for and attained before any dam construction commences. These regulates the volumes of water which can be preserved within or abstracted from a river catchment and also permits for inspection and control of dam building to ensure the standards of safety and construction are maintained (Kamtukule, S. L., 2012).

The use of water for irrigation therefore, provides an avenue to supplement or to increase rain-fed crop production during the dry season. This leads to optimization of productivity for domestic consumption, as well as a provision of some surplus for sell. This is a common practice of rainwater harvesting technology in most parts of Kenya and East Africa in general (Kamtukule, S. L., 2012). It has been a successful technology even though expensive to most households. It is a technology that has for a long time improved the livelihoods of most populations as well as boosting their economic status in terms of agricultural and livestock production.

2.4.7 Drilled Wells

Drilled wells are among the most common water sources in rural and municipal areas including people living in large urban communities. Water from drilled wells is either pumped or pulled out manually using tailor made pulleys, solar o electric pumps. Even though drilled wells are common, they pose greater danger to human life and animals because they are always left open or are loosely designed posing danger mostly to animals and children (Hodson, P. and Jarman, R. 2006).

In Ontario, for instance, many rural households utilize ground water resource almost exclusively from private wells for their daily supply of potable water (Hugh S., 2004). Water from drilled wells may be the only water source especially where rain water and surface water are limited. Drilled wells therefore, need proper care, management and protection from contaminants. Contamination of ground water mostly emanates from movement of contaminated runoff water to wells especially where they are poorly constructed or decommissioned (Canadian Climate Impacts and Adaptation Directorate (CCIAD), 2002). It is, thus, the responsibility of owners of private wells to ensure that water is protected to avoid groundwater contamination and ensure good quality water is available for use by both animals and humans. Too little precipitation affects private wells negatively (Hugh S., 2004). Water supply is greatly affected when precipitation is low and water demand will not be met when ground water recharge is not sustainable. Under such situations the water level in the aquifer will reduce and expose the pump, and in some incidences, the well just dries up. Shallow wells tend to dry up during the time of low precipitation leading to severe water shortages for most households (AAFC and OMAF, 2003).

Another threat to water quality in wells is flooding resulting from severe precipitation compromising the well's ability to provide safe water supply. There is a possibility of surface water mixing with ground water during flooding, especially where there is poor construction of the wells. Flooding may to some extent enhance the rate of movement of flood water and contaminated substances in the soil. This can result in contamination of ground water sources especially in areas with shallow aquifers (Simpson, H. 2001).

Hydrologic cycle changes are believed to also affect ground and surface water systems which in turn adversely affect the integrity of drilled wells (CCIAD, 2002). Reduction of snow accumulation during shorter and warm winters would decrease snow accumulation, in effect increasing ground water levels, decreasing snow collection in the winter could end up in declined groundwater recharge in the spring and early summer, which could constraint shallow aquifers through lowered groundwater levels particularly during the summer season (Ibid, 2002). The drilled wells were used to reach confined aquifer's water for varied household needs. In Kenya, for instance, drilled wells are a common feature even though costly to majority. Several methods are applied during the process including:

2.4.7.1 Hand Dug Wells

Since the ancient times, the most simple and common wells have been dug by hand. They are on average fifty feet deep or even more and they are mostly utilized when there is a lot of ground water. The wells are to a large extent too dangerous to construct in regions with loose soils and have caused loss of many lives of labourers who lack the skills to build them. Since in most cases, such wells are left open, they are contaminated easily. They therefore, do not provide a good alternative to water scarcity, even though in some cases when properly built, they come in handy and effective sources of water (Kariuki D. K., 2002).

Water samples taken from hand dug water wells have shown significant levels of heavy metal contamination. This is a characteristic of hand dug wells because of their ease in contamination. In the coastal regions of Kenya, for instance, heavy metals contamination has been witnessed in Kwale (Chege, M. W. *et al*, 2013). Even though adverse effects have not been witnessed, it is believed that these heavy metals affect both human and animal life equally. The amount of contaminants including heavy metals in such wells when sampled can be too high, even higher than the maximum allowable limits by the World Health Organization which is about 0.1 mg per litre. (Ibid, 2013).

2.4.7.2 Shallow Wells

Shallow underground water wells are water sources that are dug in a vertical manner which can be carried out through digging, driving or boring in to the ground surface to gain reach of the ground water aquifer which has been recharged due to rainfall. Such water may have contaminants caused by human activities that may be domestic in nature and or industrial (Pritchard, M. *et al*, 2007).

The study conducted in Moduganari, Nigeria to establish the impacts of wastes generated domestically on the quality of ground water tapped from the wells in the area of study. In this research, samples were collected from six wells that were analyzed using examinations of water methods that were physically, chemically and bacteriologically applied. The research results indicated that majority of the water sources utilized by the households and communities in general in this area were to a large extent contaminated with physical, chemical and biological agents. This is probably as a result of human activities that rendered such water sources not fit for human as well as animal consumption. This is can be attributed to the fact that majority of the results obtained were below the recommended values of the World Health Organization's standard (Gwana, A. M. et.al, 2014).

In Kenya, shallow wells have not been included in official government statistics for water consumption by water sources (Rutten, M. M. E. M., 2005). The construction cost of shallow water wells depends on the type of well to be constructed and the depth needed to access water and the density of rock or soil. By late 1990s, Kajiado County in Kenya, for instance, had over 3,000 wells which positively changed the lives of residents through diversification to other sources of income (Ibid, 2005).

In Elgeiyo Marakwet County, analysis were done on the indicators of good quality water specifically during the rainy season of year 2015 and during the following dry season of year 2016. Water samples from 10 randomly selected wells were collected for analysis of their pH, turbidity, total hardness, nitrates, phosphates, fluorides, faecal coliforms, total suspended solids

(TSS) and total dissolved solids (TDS) and their results compared with the standards of the World Health Organization quality guidelines. The outcome of the research indicated that the water pH of the sampled wells was generally low during both the dry (5.35 ± 0.09) and wet (6.14 ± 0.26) seasons, a clear indication that the water was acidic in nature. The findings also indicated that faecal coliforms exceeded the recommended values of the World Health Organization (0/100 ml) for consumption water in both the wet (2.70 ± 1.34/100 ml) and dry (21.56 ± 10.0/100 ml) seasons (Mbaka *et al*, 2017).

In Western Kenya, there is a young Non-Governmental Organization known as “The Bridge Water Project” that drills wells in communities at an affordable cost. Their simple drilling machines were capable of digging up to about 150 to 200 feet. The drilling is to a large extend cost effective and thus commonly applied in this western region. As the process of drilling with machines progresses, casing is simultaneously installed to protect or hinter the drilled hole from collapsing. To reinforce this construction further, a concrete base is installed all-round the small casing (a few feet in diameter) and then left to set up slowly for a day or two (Rutten, M. M. E. M., 2005). After construction and ensuring that the whole system is dry, the water pump is then slowly lowered into the hole fully attached to a hand pump. A careful record of the water flow is then done to determine the amount of water flowing and the safety of water for human and animal consumption since the constructed wells are securely sealed, contamination is basically minimal because the water remains clean and therefore, it can be utilized little or no treatment at all (World Bank, 2009).

Continuous and uninterrupted supply of clean and safe water is highly dependent on the functionality of shallow wells. In sub-Saharan Africa, the non-functionality rates of water wells is as high as thirty five (35%) percent despite significant investment. Sustainability of water supply systems that rely on hand pumps is highly dependent on two variables; the dependability of the spare parts to sustain the demands of drawing water from the wells and the willingness by the communities to sustain the water pumps (Kipkeny, J., 2014).

The capacity of the community to sustain shallow wells is questionable but especially where community water management committees are involved. Members of the community are charged a small fee to access water and most of the time, lack of proper servicing of pumps leads to frequent breakdowns. There are instances where spare parts are not available or are too expensive to get. This has been a great challenge for management of community managed shallow wells. Some wealthy members of the society often have their own water wells, which they privately managed and are passed through to their descendants (Kipkeny, J., 2014) In the researcher's opinion, recommendation of drilled wells for the study area is necessary since the cost of drilling is affordable, and the water harvested would be safe for human and animal consumptions as well as for irrigation.

The photographs below were taken from the study are and the neighbouring county of Makueni to illustrate some of the RWHTs in the said areas and how the harvested water is utilized for farming as well as for domestic consumption. Figures 1 and 2 are photographs of Kivai Primary School in Kaiti Constituency of Makueni County showing roof top rain water harvesting technology. Figure 3 is a water pan (Silanga) in Kolooso village of Matungulu Sub – County as an illustration of surface rain water harvesting technology. Figures 4, 5 and 6 illustrate some of the houses in Kituluni area at different effort levels depending on affordability of the household heads to purchase the RWHT. Figure 7 is a photograph indicating how small scale farmers in Matu ma Mwitu (A village named after the footsteps of a lady).

Figure 1: A section Kivai Primary school, Kaiti Constituency, Makueni County

Source: Researcher

Figure 2 : A building at Kivai Primary school, Kaiti Constituency, Makueni County
Source: Researcher

Figure 3 : A water pan in Kolooso village of Matungulu Sub – County
Source: Researcher

Figure 4: A farmer's house in Kituluni area
Source: Researcher

Figure 5: A farmer’s house in Kituluni area
Source: Researcher

Figure 6: A farmer’s house in Kituluni area
Source: Researcher

Figure 7: Small scale farmers in Matu ma Mwitu practicing surface irrigation
Source: Researcher

2.5 Barriers and Enablers of Utilizing Rain Water Harvesting Technologies among Households

According to Suzenet *et al*., (2002), the main barriers to the utilization of rainwater harvesting technologies include: "lack of information and knowledge; economic and financial constraints; little or total lack of incentives; institutional and regulatory gaps as well as the house-builder attitudes." Developers' attitudes is domiciled on failure to implement or adopt technologies that support water harvesting and recycling in designs of new homes (Goodhew *et al*., 1999).

Sponge (2005), pointed out that it was not an important consideration for private sector house builders to incorporate designs for sustainable homes in their house designs. John Slaughter of the House Builders Federation (HBF) enhances the attitude of developers even though perceived indicated that water conservation features were 'fairly low down the list' of the priorities of the house-builder's (House of Lords 2006). David *et al*., (2010), also identified factors that included the house builders' attitude, financial and economic constraints, lack of legislation to regulate household rainwater harvesting and lack of awareness as some of the barriers for utilization of rainwater harvesting technologies. He concludes by implying that in the United Kingdom, there is still a constrained utilization of rainwater harvesting technologies which leads to the loss of the ability to utilize the systems water demand and consumption at national and as well as the household levels.

In Iran, experts have elicited views that the absence of trained experts for rainwater harvesting is seen as one of the pertinent barriers within city residents in various Iranian cities (Sheikh, V., 2020). There is also a significant level of inadequate perception among households towards water conservation which is critical in the utilization of rainwater technologies in Iran.

Non-Governmental Organizations and other community based as well as faith based groups and networks have for many years been in the forefront in agitating for utilization and use of rain water harvesting (Mati *et.al.* 2006). However, lack of scientifically verifiable information for use by policy makers in designing strategies for water harvesting and mapping areas of potential implementation of rainwater harvesting technologies have hindered the progress.

Sheikh, V., (2020), identified the key enablers for rainwater harvesting technologies as implementing common strategies that center on developing of common guidelines that provide incentives and training, collaboration with other agencies providing the same water harvesting services, mandatory regulations as well as encouraging the public to adopt rain water harvesting technologies. Another option that involves training and extension activities is using online platforms such as social media to prepare and disseminate technical guidelines and to demonstrate use of rainwater harvesting technologies. This can significantly enhance the utilization of RWHTs especially when an incentive component is included either financial or technical (Sheikh, V., 2020).

In Canada, for instance, several researches were carried out to identify barriers to sustainable water management in Canadian urban cities. The Canadian Water and Wastewater Association (CWWA) in a report indicated that there were no regulatory barriers to water re-use but the problems were occasioned by lack of regulations and guidelines on water harvesting and utilization in urban households (Chantelle Leidl *et al*, 2010).

Marsalek, (2002), in their study noted that there was need to have standards for water quality, guidelines for water end users, and standards for technology performance as a measure to address the gap within the regulatory frameworks. The study of Brandes and Ferguson carried out in the year 2004, focused more widely on the "demand-side management and attitudinal barriers, financial barriers, data or information barriers, and administrative barriers. Issues like the myth of abundance, low and subsidized water prices, lack of comprehensive cost-benefit models, an engineering bias that favours centralization, and fragmented administration, are particularly relevant to rainwater harvesting". Another identified barrier was the lack of knowhow among the publics to increase demand for rainwater harvesting which would in turn enhance the idea of progressive policy development. This bottom-up approach would ensure that regulations which stifle progress in rainwater harvesting technologies were removed. The study also recommended the availability of strong leadership to guide in policy development and encourage the existing interested groups to adopt the technologies (Chantelle Leidl *et al.*, 2010).

One of Kenya's biggest challenges in the recent past is the progressing shortage of water and the diminishing rivers **(**GWI, 2013**)**. There is, therefore, need to diversify water harvesting and storage mechanisms to improve or cub the threatened supplies **(**Ibid, 2013**)**. Considering the number of roofed households in the study area, there is a lot of water wastage due to the untapped rain water which leads to soil erosion and water bodies' siltation. The choice of any water harvesting technology or facility is likely to be dependent the household head and can in turn influence negatively or positively, the livelihoods among households.

Water shortages can be as a result of climate change, emanating from changed weather patterns, increased water pollution and the ever increasing water demands and over fetching of water by humans and animals (UNESCO, 2018)**.** A water crisis begins when the available water in any area is lower than the area's requirements. Water scarcity is always caused by: increasing demand for water utilization and completion of the available water resources **(**Ibid, 2018**)**. Every country struggles to reduce scarcity of water. The United Nations (UN) also recognizes the need to mitigate the number of people that lack sustainable access and utilization of clean water and sanitation (UNEP, 2015).

In Kenya, water crisis occurs when there is a situation of failure of the government to supply clean, safe, affordable water for drinking to its population. The country's population relies on water resources, for domestic consumption, agriculture, and fish farming as well as for livestock use (UNESCO, 2018). The destruction of forests mostly through human activities causes severe soil erosion and water pollution hence finding clean water becomes more difficult for the Kenyan population. The current water situation in Kenya causes diseases as well as conflicts among communities over the available water resources (Mogaka, 2009). Consequently, as clean and safe water gets scarce in many parts of Kenya, women and children are likely to walk for long distances daily in search for water needed family use (Ibid, 2009). The search for clean, safe, affordable and accessible drinking water in Kenya is characterized by an increase of large populations moving to large cities like Nairobi, Kisumu, Mombasa and lately Nakuru, leading to the creation of large slum areas with extremely poor living conditions and polluted water (UNESCO, 2018). The interaction of humans and water is now at a critical level in Kenya and the country thus, faces a big shortage of safe, clean affordable and accessible drinking water for livestock, irrigation and domestic use.

In situ rainwater harvesting always focuses at supporting sustainable development in countries south of the Saharan, which mostly faces changes in climatic conditions (Vohland K. and Boubacar B., 2009). It is however, noted that appropriate indicators for rainwater harvesting for long-term sustainability are not documented (Ibid, 2009). In this regard, therefore, the effects for varied indicators of rainwater resource sustainability were considered. These included: in situ rainwater harvesting technologies that enhanced hydrological pointers like infiltration and groundwater recharge; soil nutrients were viewed to be enriched; biomass production increased, with subsequent higher yields (Freeman, 1999). Increased biomass was viewed to have promoted a larger number of plants and animals, even though the original inhabitants might have been displaced by crops thus bring about major changes in the original landscape. Farmers that adopted this kind of rainwater harvesting technologies were realized to have benefitted more from improved food security as well as improved income (Vohland K. and Boubacar B., 2009). Some aspects were, however, partially covered within the scientific literature and thus, more future research was recommended.

In situ rainwater harvesting practices are particularly easy and they rarely provide for much space for technical enhancement. Furthermore, the best practices and traditional methods may be combined in this practice. Assess the potential and influence of RWH technologies with regard to future climate and other global and regional variations poses another major challenge. Related studies to establish the possibilities of RWH have not been concrete, covering, for instance, the potential of up-scaling (Freeman, 1999), and studies on bigger spatial levels have just began evolving in the recent past (Senay and Verdin, 2004).

More critical research is, thus, needed at local and regional levels in order to understand the big picture of the entire problem. The socio-economic and political situations are qualitatively known (Critchley *et al.*, 1992; Oweis *et al*., 1999) but not applied quantitatively to acknowledge and note the individual decisions of farmers. Crop and risk assessment models and approaches that have been developed for RWH technologies (Cohen *et al*., 1995; Young *et al*., 2002) in most cases depend on information from ecological and technical sources. The little information on the effect of RWH technologies on biodiversity conservation indicates that the effects of RWH on landscape functions are not well understood (Young *et al.*, 2002). The study focused on improving agronomic practices but failed to focus on the functional aspects like animal biodiversity (Sukhdev *et al*., 2008). Research focusing on landscape ecology and conservation biology always views human activities as shaping entities, and not disturbing the ecosystem. More research, therefore, is required to put together societal and ecological requirements to reduce trade-offs and avoid the constraints of poverty and land degradation put together.

Another barrier to utilization of rainwater technologies is the process of lock –in which means that there is a status quo that is maintained and this prevents the utilization of alternatives techniques and approaches to rainwater harvesting. Development of Rainwater harvesting technologies, for instance, acknowledges the fact that there is a demand for RWHT. There is need for resources from the parties concerned in the implementation of rainwater harvesting technologies and must work together to address the issues currently faced in utilization of rainwater harvesting technologies (Andavar, V., and Ali, B., 2020).

All the barriers discussed above are related to social regulations that relate to RWHTs and not the technical visibility. This means that there is no challenge or hindrance in feasibility of rainwater harvesting but the hindrance is because of operational, technical and regulatory factors. Cost of installation of RWHTs has been noted to be the largest barrier of all (Quinn, R. *et al*, 2020).

2.5.1 Impact of climate change on rainwater harvesting

The ever increasing demands for water from agriculture, domestic use, climate change and population growth is putting pressure on water. The effects of climate disrruptions directly affect rainfall patterns across the globe (Markandya, A. *et al*, 2015). This has been the concern of experts who have predicted that with increasing effects of global warming and changing rainfall patterns, there is likely to be a reduction in harvested water. It is expected that some regions will experience higher precipitation at the expense of others and there will be extreme weather conditions because of this (Ntale, H. K *et.al*, 2005).

Depending on the economic conditions, different regions in the world are coming up ways to counter the future impacts of climate change and water harvesting is one of the main strategies. This is seen as the alternative especially in rural areas where centralized water systems are non-existent (Onyutha, et.al, 2016).

Haque, M. M., Rahman, A., and Samali, B. (2016) investigated the impact of climate change on rainwater harvesting and concluded that the impact will be severe during the dry season when rainwater savings and reliability will be highly affected. It was concluded that in the rainy season, the effects of climate change can be reduced by improving the roof area and the tank size so that more water can be collected to ensure a continuous supply of water during the dry season. This also calls for a change in the design of rainwater harvesting technologies to cope with the increasing demand for water as a result of the effects of climate change (Doulabian, S. *et al*, 2020).

Longer dry spells also increase demand for water for irrigation and evaporation rate increases. This increases water stressed communities and therefore calls for policies to be designed to facilitate increased investment in rainwater harvesting and treatment. This may involve the local community participation; community based organizations, local government, national government, the private sector and international agencies (Toosi, A. S., Danesh, S., Tousi, E. G., and Doulabian, S., 2020).

2.5.2 Strategies for utilization and promotion of Rainwater Harvesting Technologies

Communities need to be motivated to adopt rainwater-harvesting technologies so as to change household livelihoods and improve their way of life. Many countries have developed strategies for promotion of rainwater harvesting in their rural and urban populations and are reaping huge benefits from this move. With widespread use of rainwater harvesting technologies, there is need for regulatory framework that will guide the utilization and implementation of rainwater harvesting technologies. This will also provide a means of ensuring quality of purchased water harvesting equipment and the dimensions or guidelines for building and or purchasing water storage equipment (UNEP, 2009). In addition, there is also need to have regulations on water treatment to ensure that all water harvested meet the minimum standards for various usage categories. These regulations should include policies that provide for incentives for those adopting the rainwater harvesting technologies. These incentives may include tax exemption, rebates, technical support, and training among others (UN-Habitat, 2005).

Water research is important in ensuring that available resources are adequately exploited and new techniques developed to maximize rainwater harvesting. A dedicated research center provides practical solutions to water harvesting challenges and takes lead in formulation of policies and guidelines for utilization of efficient and cost effective rainwater harvesting technologies. In developed countries, water research centers have been developed purposely for these initiatives (Singano, E. R., 2020).

Developing initiatives to support communities to be self-sufficient by organizing programmes, tailor-made training programmes that includes education on funding and support initiatives that target individuals. In Korea for instance, the Seoul Metropolitan Government came up with a guideline which would allow for joint financial contribution from the local government, the Donor Company, and volunteers in order to facilitate the implementation of RWH efforts (Han, M.Y. and Park, J., 2009). Implementation as well as demonstration projects have been proven to be the most efficient ways of promoting rainwater harvesting technologies. This activity involves developing a complete project and ensuring that during the entire project execution, there is a complete involvement of the community and training conducted hands on by experts. This is often used as a marketing strategy by companies that deal with manufacturing of rainwater harvesting technologies. Since water scarcity problems are site specific, a demonstration project must be situated where all the characteristics of water scarcity are evident and also where all environmental factors support rain water harvesting techniques (Mwamila, T. *et al*., 2016).

The government, both at national and local levels (County Governments for Kenya) play a critical role in promoting the utilization of rainwater harvesting technologies. Apart from developing policies and legislative framework for rainwater harvesting, governments invest in promotion of these technologies through tax incentives, rebates and even funding demonstration projects. It is, therefore, important to develop partnerships with donor funded organizations and government to government initiatives in order to achieve better results (JFS, 2014).

An initiative for individuals to carry out their own supplies was seen as a low cost approach to service delivery and that it was initiated by individual household heads or communities through self-help groups. This method became successful and was large encouraged to promote RWH in Thailand. It also served as a motivational factor to gain external support from the government and non-governmental organizations as well. This program mitigates the over reliance on government initiatives for rainwater harvesting. Under this form of financing model, projects are well managed and operations are smooth due to the close supervision and feeling of ownership from the households or communities (Aliabadi, V. *et al.*, 2020).

Another strategy is the application of the Public-Private partnerships model. This is where all parties involved have a symbiotic relationship that leads to each party benefiting. Both public and private companies can also initiate projects as part of community social responsibility which can in turn, be recognized by the public as well as the community. Such can be an effective way to transfer technological advancements and can also be a better way to address financial constraints in most communities (Huang, Z., *et.al*, 2021).

Domestic rainwater harvesting is one of the strategies to meet the UN vision 2030 agenda for sustainable development and also as a mechanism for building resilience to climate change (Peters, E. J., 2017). Domestic rainwater harvesting projects can be financed through self-financing, government initiatives, microfinance and external development partners (Ibid, 2017). This is a viable option to increasing supply of water and improving quality of life in middle and low income countries. In the Caribbean, governments have put in place efforts to promote domestic rainwater harvesting through creation of awareness, and implementation of small scale projects at the community level that demonstrate the potential of rainwater harvesting (Huang, Z., *et.al*, 2021).

In Kenya, there has not been much financing from government agencies (Oremo, F. *et al*, 2021). Most support provided by the government has been geared towards creation of awareness and technical know-how. Non-Governmental Organizations have been providing financial support for the vulnerable population with financing from development partners. There is therefore a considerable gap to be filled in developing countries and especially in ASAL regions where lack of adequate water is the norm (Ibid, 2021).

2.6 Financing rainwater harvesting technologies

In the Caribbean, initiatives to promote rainwater harvesting technologies including hosting workshops for experts and developing training manuals. However, these initiatives have not had a big impact on improvement of utilization of these technologies. This has been blamed on lack of finance to purchase these systems. Consequently, focus shifted to external funding which has also been noted to be limited (AG Water Solutions., 2012).

People are always ready to undertake self-finance where benefits are demonstrable. However, this is based on percentage income and demand and supply forces. Households have limited budgets to work on and governments and agencies must see the initiatives as supporting through easing of financial burden of households and at the same time promoting adequate water supply. Self-financing has been successful in Africa and Asia through self-help groups and community based organizations which support members in turns, normally called “merry go round”. This initiatives can be adopted to support the vulnerable in the society in order to uplift their standards of living and purchase the water harvesting systems (Lehmann, C. *et al,* 2012). Although communities can be trained to build rain water harvesting systems to reduce costs, poor households still depend on donations from governments and non-governmental organizations to finance these systems (Norman, G. *et al*, 2012). This financing is seen as having an extremely low chance of being recovered. The requirement for financial commitment from poor households is, therefore, unrealistic and new strategies need to be initiated or developed as an option without affecting the uptake of the technology (Ibid, 2012).

Some projects in the Caribbean were financed using the self-finance model, which was seen as the most successful model since the system was built in parts incrementally without putting pressure on the household. This coupled with self-supply of building materials ensured successful implementation of the projects. This initiative developed out of the understanding by the community that there was need to have reliable water supply (CEHI., 2009).

Organized groups in Asia and Africa through the merry-go-round formula have become a major source of funding for water harvesting programmes for poor households. This can be in form of money or facilitating building of rainwater harvesting technologies in kind. Many governments have realized the importance of these programmes and have encouraged registration of these community based groups so that they can get additional loans or government support through social government programme initiatives (Peters, E. J., 2016).

Participation of private organizations through micro-financing has also been a major source of funding for rainwater harvesting technology installations. Even though this mechanism is not popular due to the cost involved, especially on interest rates, some communities have entirely embraced it. Small government programmes to aid poor households that would otherwise not have access to loans has also been effectively used to support these initiatives. In Kenya for example, cash transfers to the elderly and vulnerable populations have assisted in financing rainwater harvesting for the vulnerable households though in small scale (Peters, E. J., 2017).

Even though the commercial banks are seen to play a limited role in financing RWHTs, collaboration among governments, NGOs (both local and international), community based organizations and support groups with a view to promote self-financing eliminates the constraints of financing rainwater harvesting technologies (Nijhof, S. *et al*, 2010).

2.7 The Impact of use of Rain Water Harvesting Technologies on Livelihoods among Households

A person's livelihood refers to their "means of securing the basic necessities of life" (Owusu, 2020). Livelihood is defined as a set of activities essential to everyday life that are conducted over one's life span. Such activities could include securing water, food, fodder, medicine, shelter, and clothing. Livelihoods allow people to secure the basic necessities of life such as food, water, shelter and clothing.

Several studies have shown that benefits of utilization of rainwater harvesting technologies can be huge. Mutekwa, V., and Kusangaya, S. (2006), pointed out that utilization of rainwater harvesting technologies can be categorized into two broad accrued benefits: socio-economic and environmental benefits. In a study on contribution of the use of rainwater technologies in Zimbabwe, results pointed out that farmers that were sampled perceive environmental benefits were not direct benefits of utilization of RWHTs. However, the perceived benefits are enormous especially to the environment. Harvesting of rain water through rainwater harvesting technologies reduces water runoff resulting in reduced soil erosion and hence improving water and soil conservation efforts (Ibid, 2006). It is believed that Rainwater harvesting technologies in Zimbabwe has brought about togetherness and cohesiveness in rural societies through sharing equipment, labour and ideas. Agricultural practices have also improved through diversification of farm produce. Availability of water has led to introduction of new crops for the dry season and also an aspect of intercropping which have become popular and improved farm outputs (Ibid, 2006).

Other benefits accrued from utilization of rainwater harvesting technologies include improved standards of living among adopters of the technology. Furthermore, there is abundant source of water for domestic and agricultural usage which is an indicator of improving household livelihoods. The fact that households have been able to finance RWHTs is another indicator of improving living standards as a result of utilization of these technologies (Ibid, 2018).

In Tamil Nadu, the South Indian State, small scale farming relies on food production through irrigation that is supplied by many small rainwater harvesting storages, basically called tanks. These reservoirs in Tamil Nadu are about eighteen (18%) percent of crop irrigation water in the region (DES, 2011) contributing a big variety of advantages, which include the increased and moderated agricultural production, poverty reduction, improved livelihoods and the provision of ecosystem services. Water availability, therefore, remains a significant item for farmers in relation to the kind of crop to plant and in which season.

Semi-Arid region in Brazil (SAB), on the other hand, has from time to time, been affected by mild to severe droughts, threatening household livelihoods and strongly affecting the living levels of many household farming units (Lindoso *et al*, 2018). In the early 1990s, for example, the Human Coexistence with Semi-Aridity (HCSA) came up as an approach of development. (Ibid, 2018).

That SAB is among the densily populated semi-arid regions on the earth (Armah *et al*., 2018). The SAB's territory entails roughly twelve (12%) percent of the national land cover with several municipalities and with about 23 million people (Armah *et al*., 2018). In these region, it is estimated that about four (4) million small scale farmers who rely on rain for farming are at risk of being affected by climate changes to produce food, fetch water as well as make some income (Ibid, 2018). Since time immemorial, therefore, the region has been affected on most times by mild to severe droughts, endangering household modes of living and extremely suppressing their standards of living, which in turn has led to famine affecting many, migrations as well as loss of assets. (Lindoso *et al*., 2018).

The people living in rural areas of SAB have learnt to cope with situations of water limitations by utilizing the old methods of harvesting rainwater, largely comprising of ground storages that are dug along small flowing streams and rivers, which are then used to collect and reserve storm water in dams (UNEP, 2015). In situations when such dams hold a large amount of water, they face some eminent challenges namely: evaporation, silting leading to less storage space, and fetching distances, since they are in most cases constructed in areas that belong to other people who restrain water reach.

The utilization of water stocks that are found beneath the earth is not easy, using old methods, the building of shallow water wells which are generally dug in the dry beds flowing streams, and water from aquifers is not commonly utilized by farm household since extremely few farmers can afford the expense of accessing deep underground water resources (Bitterman, P. *et al.*, 2016).

It is observed that in the 20th century, for instance, different leaderships came up with ways that would try and solve the water scarcity issues, via putting more funds in water infrastructure and agricultural development that was inclined on the technological models of the green revolution. None of such technologies culminated in sustained evolution in the general context of vulnerability (Lindoso *et al.*, 2018). To counter the top-down model propagated by governments towards small scale farming, a Human Coexistence with Semi-Aridity (HCSA) as a bottom-up model evolved in the early 1990s. This model has been adopted in several governance levels, leading to a Sustainable Development (SD) agenda. Its main technological concept has been to "stock in abundance to cope with scarcity of resources and environmental variability" (Ibid, 2018). HCSA encompasses a big range of tactics to cope with water scarcity in human and agricultural systems, but its technological centre has RWH methods, many of which are advancement of old methods.

Rainwater harvesting can be said to refer to any human intervention to locally collect and store storm water to be utilized for different human and animal activities (Armah *et al*., 2018). Such can be categorized as in-situ methods or ex-situ methods. The former is the types of systems that are capable of retaining storm water in the topsoil while the latter entails systems that utilize a storage component (tank, dam) to divert the storm water from the drain confinement and reserves it for future use. Ex-situ RWH can still be categorized in sub-categories:

a) Domestic RWH (DRWH – is a situation whereby storm water is collected from rooftops and stored in in-built storage facilities for domestic use, and
b) Infield RWH (IRWH) – this is where rainwater is collected, preserved and utilized for domestic and agricultural purposes. The choice of best RWH method depends on the aim of storage (Lindoso *et al*., 2018).

Sustainable water management at all levels and access to safe, clean, affordable and easily accessible drinking sources are pertinent to economic development, growth and productivity of any country (UNEP, 2015). The natural environment to a large extent contributes towards the management, conservation, utilization and regulation of water availability as well as accessibility and water quality and safety while strengthening the available dwindling watersheds (Ibid, 2015). Water shortages affect food availability, incomes and the general livelihoods of non-urban populations. On the other hand, improving water management improves or enhances a region's economy. This renders such regions more resistant to variations in rainfall and thus they are capable of fulfilling the requirements of their households' ever increasing population (Lindoso *et al*., 2018).

Rainwater harvesting as a technology has been known to mitigate extreme poverty because it relaxes the time needed in sourcing for water which is normally a burden to members of the family, especially women and young school-going girls. By ameliorating the time needed to collect water from far, members of the family are able to concentrate on other economic activities and paid labour which is a good source of income for the household. Additionally, water can be used for agricultural purposes and help to improve crop and animal production (Lehmann, C., and Tsukada, R., 2011).

Achieving universal basic education is another benefit of rainwater harvesting. Children no longer have the responsibility of sourcing for water and water harvesting in schools provide enough water for sanitation and drinking. It is estimated that more than fifty (50%) percent of the world's institutions lack water reach mechanisms, and about two-thirds of them lack proper sanitation facilities, circumstances that hamper simple and effective practices such as handwashing with soap (Lourete, A. *et al*, 2009a). In addition, collected rainwater can also be utilized to prepare school meals, wash classrooms, flush toilets and cultivate horticultural gardens. Improved health and nutrition increases children cognitive capacity to absorb what is being taught in class and in turn it also reduces the rates of absence in such schools. Proper sanitation as well as availability of water and construction of better schools helps to achieve the sustainable Development Goals objective of universal basic education (Ibid, 2009a).

Utilization of rainwater harvesting technologies enhance gender equality and empowers women as well the youth. Rainwater harvesting implies that women and youth have amble time of engaging in other economic activities, which also give them the power to make decisions in the household. Additionally, water for anti-natal and post-natal care is available which improves the hygienic conditions for women and their young ones. This also reduces child mortality due to reduced chances of disease prevalence especially among children (Lourete, A. *et al*, 2009b).

It is worth noting that according to UNEP, 2015, slightly above 1.4 billion people globally reside in river catchments where their water utilization and demand exceeds the reservoir's recharge capabilities. Sustainable Development Goal number six outlines relevant targets that linked to achieving water sustainability by the year 2030 as below:

i. **Target 6.1:** globally attaining reach to safe, clean accessible and cheap drinking water.
ii. **Target 6.4:** sustainable water utilization.
iii. **Target 6.5:** implement global integrated water resources management.
iv. **Target 6.a:** ensure expansion and utilization of water harvesting technologies, efficient water use, waste water treatment and recycling as well as reuse technologies;
v. **Target 6.b:** To support and enhance stakeholder and community participation in water management.

In the Kenyan context, it is a normal situation to witness a yard type water connection without pump and also the inclusion of savings accrued from the cost of purchasing water from the street vendors in most households. A large part of the population, mainly those households with low income would realize the extra load of channeling water into their house from the tank as cheaper than purchasing from vendors. For households that were well of, they would manage install water that is fully reticulated (Amos, C. *et al*, 2018). The researcher's consideration would be that all the above-mentioned strategies could be utilized to improve livelihoods in the study area. If the leadership (National and or County Government) in the study area could ensures that the above objectives were observed and implemented, then the study area is likely hoped to achieve water sufficiency by the year 2030.

2.8 Integration of Rain Water Harvesting Technologies in government processes,

Storm water collection is good as water 'savings' for urban areas as well as a source of water for farming, human and animal use in the household, prompting of institutional decision making and social power. In the United States of America, for example, policies have been developed to regulate micro-level harvesting of rainwater. These policies were ideally developed to suit single-family homes, and make provisions for regulatory frameworks for design and installation of rainwater harvesting systems (Meehan, K. M., and Moore, A. W., 2014).

In some states, regulations have been put in place to encourage large scale water collection methods at industrial levels and large scale levels. These systems utilize storm water and rainwater harvesting into construction models which can be can be capable of storing thousands of litres of water. The cost of installing these systems are however prohibitive and widespread use seems impossible unless there was a deliberate attempt to develop regulations and incentives to encourage their use (Bruns, B. R., and Meinzen-Dick, R., 2005). Rebates have been adopted by municipal and city governances in Arizona, California, New Mexico and Texas have picked up and used the rebates in such situations. The city of Santa Monica, California, for instance, presents three categories of rebates, namely: downspouts and gutters, the storage-filtration mechanisms; and the workhorses of storage. Virginia and Arizona, on the other hand, offered state tax credits for individuals and corporations that had managed to install water collection mechanisms (Meehan, K. M., and Moore, A. W., 2014).

Individual households, groups or government institutions with too limited cross border implementation implement most rainwater harvesting activities or incorporation into governmental policy programmes on a national or local government level. To ensure larger scale implementation, it is important to integrate rainwater-harvesting technologies in policies and governmental programmes, formulating sector guidelines and implementation tools and sharing experiences and practices (Ward *et.al,* 2009).

Governmental and non-governmental projects still exhibit the top-down development approach which still ignores the input of the local communities that is extremely important in ensuring sustainability by taking into consideration the needs of the community as well as creating societal ownership. There is also particular focus on developing urban and peri-urban areas and ignoring the rural community, especially areas with difficult access to safe, clean affordable and accessible drinking water. However, this is set to change with more and more governments adopting the right to water declaration, therefore, fostering equity in water access (Kahinda, J. M., and Taigbenu, A. E., 2011).

In Ethiopia, the government initiated rainwater harvesting technologies as part its programme to provide alternative source of water for its population and also soil conservation. These government initiated programmes included rainwater harvesting activities such as creation of ponds, small dams, bunds, and terraces in dry areas in Tigray, Wello and Hararghe regions. There was also involvement of non-governmental organizations in these initiatives through the Integrated Rural Development Projects (IRDPs) and the water sector in most areas of the country.

NGOs participated in interventions such as conservation of rainwater and rainwater harvesting for household and agricultural purposes (Seyoum, M., 2003).

Governments often focus on piped and groundwater to supply water as per of its programmes and often avoid rainwater harvesting technologies leaving it for NGOs and individual households as the implementers (Nyanchaga E. N., 2007). There is a real concern that if rainwater-harvesting technologies are not integrated into government programmes and policies, it will be difficult to mobilize resources for their successful implementation and their utilization will remain scattered. The need for and use of rainwater harvesting technologies will influence the intervention measures (Mumma A., 2007). There is greater success if governments design policies that facilitate rainwater harvesting technologies without stifling their innovation and demand and communities will readily adopt and implement them in order to improve access to clean and safe water for domestic and other uses (Evans, 2002).

In the United Kingdom, the government has established several policies in order to promote use of rainwater harvesting technologies. There has however, been lack of proper implementation mechanism especially where legislation limits action by inadequate support mechanisms (Ward S. *et.al*, (2009).

The Kenya vision 2030 economic development blueprint recognizes the importance of water in the development of economic and social aspects of live. It indicates the need for preservation of water and implementation of new water harvesting methods such as rain water and underground water to ensure that there is water sanitation and access to all citizens in both rural and urban areas (Koehler J., 2016). The strategies put forward by the vision 2030 economic blueprint include introduction of specific strategies to improve water management, storage and harvesting capability, improvement of hydro-meteorological data gathering network, construction of dams and sanitation facilities across the country (Mwenzwa, E. M., and Misati, J. A., 2014). These strategies however do not specify the strategies to improve small scale household water harvesting and conservation.

The constitution of Kenya 2010 placed provision of water services as a function that is devolved to County Governments. The National government is, thus, left with the responsibility of managing international waters and water resources (Owiti A. K., 2007). The Ministry of Water and Irrigation was given the mandate to formulate guidelines and ways for management of water. It is, therefore, the County Governments' duty to implement water sanitation programmes in their areas of jurisdiction (Constitution of Kenya, 2010). The clear delineation of roles between the county and national governments have, however, not significantly improved access to potable and clean water to households. Thirty six (36%) percent of Kenya's population in ASAL areas still have to walk extremely long distances in fetch water for both human and animal use (Republic of Kenya, 2015).

In Matungulu, Machakos County, the Matungulu Water Supply Project was funded by Kenya Italy Department Development Programme at a cost of Ksh. 107 million (Machakos County Integrated Development Plan (MCIDP), 2015). It would serve a population of 28,000 people. The project was currently incomplete and the scope of works included; Drilling and equipping of one borehole, construction of one grade 9 house, laying of a 5 kilometre rising main, construction of 1500 m^3 tank, laying of 15 kilometre gravity main line, fabrication and erection of 250 m^3 and 100 m^3 elevated steel tanks, construction of six water kiosks. After completion the total production capacity would be 720 m^3 per day (Ibid, 2015).

2.9 The Rain Water Harvesting Legal Frameworks

Some form of regulation had been in place for management of water since the beginning of civilization (Bunclark, L. A., and Lankford, B. A., 2011). In India, the advent of colonial rule signaled the transformation of legal frameworks and some of which involved the management of natural resources (Ibid, 2011). The legal transformation included legal frameworks touching on local property rights in land and water and the role of local authorities in management of natural resources. These legislations also, to some extent, affected Rainwater Harvesting. The current national policy on rainwater harvesting in India is based on colonial policies. It, therefore, fails to shift from project oriented approach to water resources. The policy is meant for major national and regional projects and clearly ignores the small scale household rainwater harvesting (Vani, M. S., 2005).

By the year 2000, the Kenyan government tasked the water sector with providing access to clean and reliable water to a population which as at the year 1990, 57% lacked access to clean water. All water resources were managed through centralized government institution which was grossly inefficient due to lack of funding and acute lack of water infrastructure (Owiti A. K'Akumu, 2007). The challenges associated with bad governance in the water sector resulted to the establishment of water Act 2002 to reform the sector. This was influenced by international trends spearheaded by Global Water Partnership (GWP) and strengthened by the Millennium Development Goals (MDGs, 2000), who had put forward a target to minimize by fifty (50%) percent the total population without reach to drinking water by 2015 (United Nations, 2017). In order to achieve its target of providing water to the population, the Government of Kenya adopted the 1999 "National Policy on Water Resources Management and Development"

(NPWRMD), which proposed devolution of the water sector as a means of improving access to water to the rural communities (Nyanchaga E. N., 2007).

The water Act 2002 provided for separation of duties in the water sector resulting in the restructuring of the water sector in compliance with international trends. It led to the establishment of regional Water Service Boards and water service providers to address water related issues and decentralized water management to local autonomous institutions (Mumma A., 2007).

In order to operationalize the functions of County Governments especially in water sector, the Water Act of 2016 was legislated and enacted to specify how the counties will implement water sector structures (Johanna Koehler, 2016). Article 142 (2) of the Water Act 2016, talks of rain water harvesting and household water storage to improve household water availability. Sustainable Development Goal number six also focuses on capacity building in water and sanitation, water harvesting technologies, desalination, water efficiency, recycling as well as water reuse technologies. The basis of all these processes is to ensure water availability to all if not majority of the world population.

Integrated Water Resources Management (IWRM) is the control of surface and subsurface water in quality, quantity and ecology from a multidisciplinary point of view, and aimed on the water requirements of society at large. IWRM needs a base for assessing of all necessary interests and decision-making on utilization of water and water methods in the river basin. Such interests are shown in the base or platform and it needs decision, control and sanctioning powers under governance of government to protect the interest of society at large. A small set of institutional sanctions need to be achieved to allow such IWRM platforms to operate successfully.

A framework with regulations for application has been developed to check on the required capacity-building interventions to arrive at these conditions and to establish such platforms. This framework is based on a development process with and by the stakeholders to come from an identified present water resources management situation to some desired integrated water resources management situation. It is a compromise between the present and an "ideal" IWRM situation, as a result of a negotiation process in which policy makers, water resources and water utility managers and stakeholders are all involved. Integrated Water Resource Management, thus, considers all natural aspects of the water resources, all sectoral interests and stakeholders, the spatial and temporal variation of resources and demands, relevant policy frameworks and all institutional levels. These institutions could be either barriers or enablers in rainwater harvesting technologies and, therefore, impact positively or negatively on peoples' livelihoods (Koehler J., 2016).

The gap that exists in Kenya, therefore, from the year 1999 to date has been the repealing of the Water Act but with little or no implementations (Ibid, 2016). The Water Act 2002, the Constitution of Kenya , 2010 creating the National Government and the County Governments and the Water Act, 2016 have created several bodies and agencies like the Water Services Regulatory Boards (WASREB), Water Resource Management Authority (WARMA), Water Resources Authority (WRA), Basin Water Resources Committee, Water Works Development Agencies, Water Storage Authority, Water Sector Trust Fund as well as Water Tribunals but with little impacts on peoples' livelihoods.

2.10 Theoretical Framework

2.10.1 The Social Dilemma theory

The social dilemma theory focuses on management of all resources or any given resource through decisions, whether the decisions reflect the giving or taking of resources. The theory points out that decision makers face a range of challenges in which personal and common interest conflict - normally called social dilemmas. Even though governments, corporations and other organizations are involved in resource management, individuals also are faced with their own challenges in management of resources (Gifford, R., 2006).

The theory also proposes that factors that are not human related but relevant can still affect the harvesting of any of these resources in their original form before transformation. These factors include the resource scarcity, ease of extraction, the quantity and quality of the resource and even the elusiveness of the resource. Natural resources can decline over time, sometimes caused by human or non-human activities and these influences the way they are utilized and protected for future or current use (Gifford, R., 2006).

The proponent of this model notes that individuals and households utilize available resources along a continuum, which ranges from household, group, or environmental interest to individual-interest. Such individuals thus face social dilemmas on how these interests conflict with each other (Gifford, R., 2008). This model, therefore, explains the influences or impacts that decision making have on the strategies used to make a decision or decisions about some phenomenon. Different outcomes will thus, be available for the decision maker in terms of satisfaction, anger or regret and the environment on the other hand on whether a resource should be depleted or sustained (Ibid, 2008).

The decisions made by a group, a household head, a community or a County Government is thus likely to influence the type of rain water harvesting technology to be used in any given area. Some decisions might be made with some insights of the technology chosen while other decisions might be out of ignorance. The two levels of decisions might in turn influence or determine whether a resource was conserved or depleted, utilized well or misused, recycled or reused and so on and so forth.

This theoretical framework informs this study in the decision making stages of individuals, groups, households, families and governments on what to consider during the selections of any RWHT and what influences such decisions. That there are certain varied factors to be considered before any RWHT is utilized or discarded altogether. This, in turn has an effect on water management and sustainability.

2.11 Conceptual Framework

The study conceptualized that the decision making of household heads, economic factors and social cultural factors influenced the uptake of rain water harvesting technology. These factors were seen to affect or influence livelihoods among households as well as water access and availability. RWHTs were the independent variable while household livelihoods (household assets, household income, agriculture, water access as well as environmental sustainability were the dependent variables.

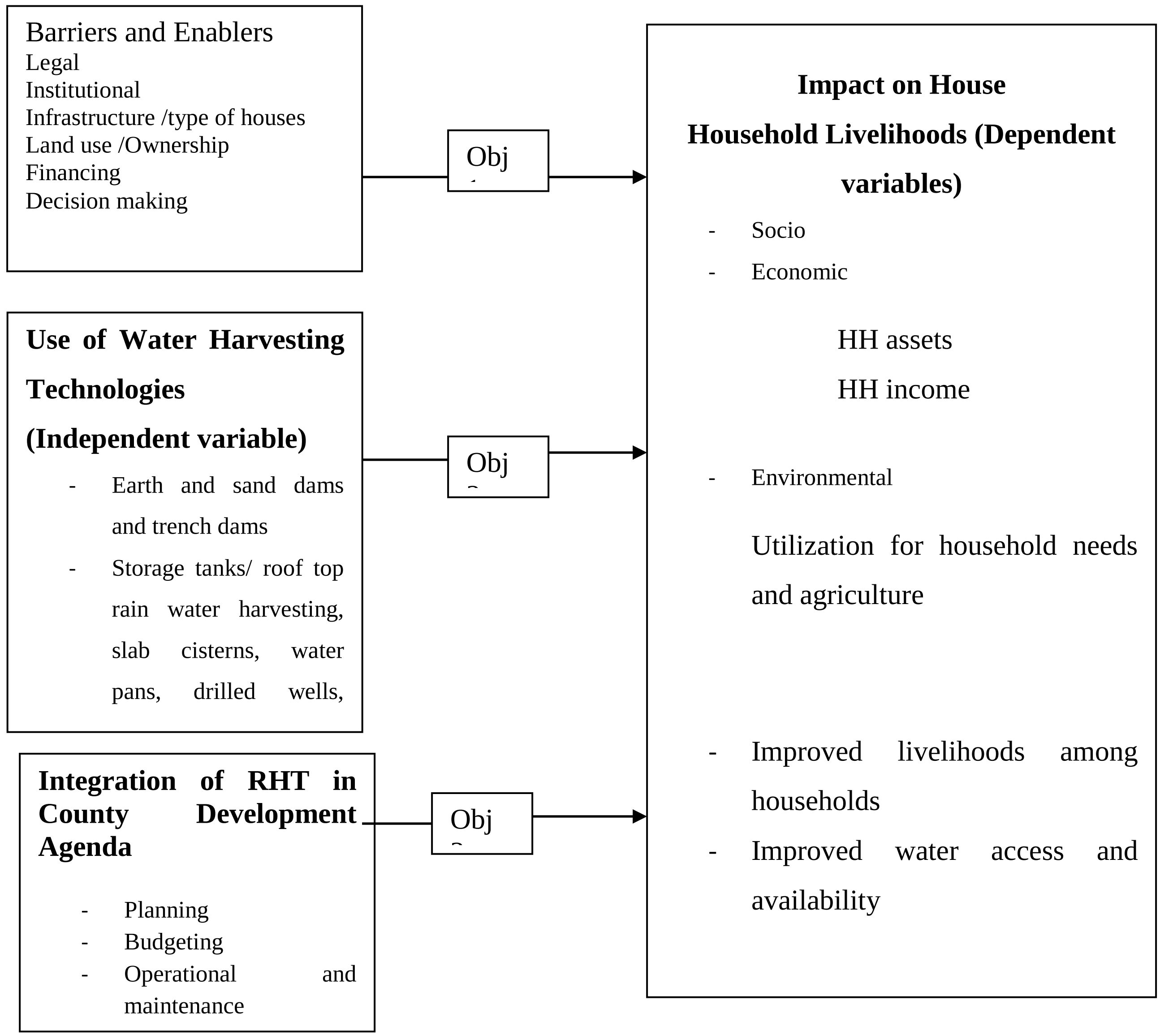


Figure 8: Conceptual Framework

Source: Researcher

2.12 Research Gaps Identified

Several studies on Rain water Harvesting Technologies have been conducted in Pakistan, Afghanistan, Iran and India on how best rain water can be harvested and preserved for future utilization. (Everson *et al.*, 2011), (Mays *et al.*, 2013). Similar studies have also been carried out in Middle East, North Africa, Mexico and Korea on rainwater as an alternative source of water for domestic and livestock utilization (Angelakis, 2016), (Pacey and Cullis, 1986).

The success of Rain water Harvesting Technologies has been recorded in many countries including India, Korea, Canada, Zimbabwe, Japan and Brazil where underground dams and drilled wells for Urban population in India, for instance, have been witnessed and used (Hodson, P. and Jarman, R. 2006), (Nishigaki *et al*., 2004), (Mutekwa, V., and Kusangaya, S., 2006). Studies in Canada have been done to identify the barriers to sustainable water management in Canadian Urban Cities (Chantelle Leidl *et al*, 2010).

In Africa and Kenya in particular, a few studies have been done in Embu and Makueni indicating the ancient water tanks on Makindu River as early as 1907 during the construction of the British East African Railway line (De Vrees, L. 1987). Research on Rain Water Harvesting Technologies, therefore, remains limited in Kenya in particular with limited utilization and implementation strategies to improve water availability to majority of its population.

While the relevance and importance of Rain Water Harvesting Technologies in improving household livelihoods is well known in Kenya both at the National and County levels, little is known to have been done to implement its use as an alternative water sources for farming, animal and human utilization. In Kenya, for instance, it is not well documented how the use of rain water harvesting technologies affect or influence livelihoods among households. It is important to note that thirty six percent (36%) of Kenya’s population in Arid and Semi-Arid Areas still walk for several kilometres to fetch water for both domestic and livestock use. (Republic of Kenya. Ministry of Devolution and Planning, November, 2015).

Focusing on the three specific objectives of the study namely: assessment of the barriers and enablers of utilizing RWHTs among households in Matungulu Sub-County, Kenya; evaluating the livelihood differences of households with or without RWHTs in the study area; and examining the extent to which Machakos County Government integrates RWHTs in its programs, planning and budgeting among its households, each objective will be handled below as a chapter of this research.

CHAPTER THREE: BARRIERS AND ENABLERS OF UTILIZATION OF RAIN WATER HARVESTING TECHNOLOGIES AT COUNTY LEVELS, CASE OF MATUNGULU SUB-COUNTY, MACHAKOS COUNTY KENYA

3.0 Abstract

The demand for water use has grown globally outpacing population growth, and increasingly, many regions are currently reaching levels which water services are unsustainable, especially in arid and semi-arid regions. Lack of enough water for domestic and agricultural use has had negative impacts on households in ASAL areas. There has been however introduction of rainwater harvesting technologies that seeks to alleviate the effects of water scarcity in these areas. Utilization of these technologies however, depends on factors that hinder or encourage households to adopt them. It should be noted that too few studies have been carried out on the enablers and barriers of adopting rainwater harvesting technologies in Kenya. There was, therefore, need to investigate the enablers and barriers of successful utilization of rainwater harvesting technologies and their effect on families in ASAL areas.

Focus group discussions, interviews with key informants (Appendix V), and questionnaires (Appendix II) were utilized to fetch required information. Descriptive statistics were used in data analysis using the Statistical Package for Social Sciences (SPSS version 22 software). This involved calculation of arithmetic mean, standard deviation, percentages, frequencies and Analysis of Variance (ANOVA). Results showed that overall, a composite mean of 4.04 and a standard deviation of 0.699 of the interviewed population agreed that County Government incentives significantly enhanced water collection technologies. This was also supported by a positively strong and significant correlation between the integration of RWHT in the county development agenda and the impact on household livelihoods. A further regression analysis showed that the Integration of RHT had a positive and significant effect on household livelihoods ($\beta= 0.755$, $t=22.351$, $p=0.000<0.05$). Results of this study showed that rainwater technologies are financed mostly by household heads and that County Government initiatives have not been adequately felt. The study findings indicate that the major barriers to adopting rainwater technologies are costs and a lack of expertise on the utilization of RWHT.

To make sure that there is sustainability of rainwater collection methods, the study guides that there needs to be development of clear monitoring systems on water collection in the County. Additionally, there is need to strengthen funding and sensitization on the best RWHT to enhance water harvesting.

Keywords: Governance mechanisms, Rainwater harvesting technologies, Water quality and quantity, Water resource, Water technologies

3.1 Introduction

Throughout generations, people have been living in water scarce areas where collection of rainwater from roof tops and rainwater runoff from the hills were major sources of domestic water. This water collection technique, though simple, enabled early farmers to practice agriculture in the Middle East, North Africa and even Mexico (Pacey and Cullis, 1986).

Competing demands for water from agriculture, domestic use, climate change and population growth is putting pressure on water resources. The effects of climate change directly affects the rainfall patterns across the globe (Markandya, A. *et al,* 2015). This has been the concern of experts who have predicted that with increasing effects of global warming and changing rainfall patterns, there is likely to be a reduced harvested water. This will result in some regions getting more rain at the expense of others leading to extreme weather conditions. (Ntale, H. K *et.al*, 2005).

The international Resource Panel (IRP), 2016, indicated that under current trends, global water requirements will exceed supply by forty (40%) percent by the year 2030. This is reflected by the recognition by the United Nations that there is need to reduce the number of people that lack sustainable access and utilization of clean water and sanitation (UNEP, 2015).

The global effects of climate change as well as increasing non availability of water, coupled with increases in population, changes in demography as well as urbanization puts greater challenges on water supply systems (WHO, 2019). Other alternatives of drinking water sources, irrigation as well as other domestic uses will, therefore, continue to emerge, with a progressive dependence on groundwater resources, rainwater harvesting and recycling of wastewater (Sapkota, M. *et al*, 2018).

Several studies have been carried out on barriers and enablers of rainwater harvesting technologies, however, too little has been documented on the Kenyan case. According to Suzenet *et al*., (2002) key barriers to utilization of rainwater harvesting technologies are: “lack of information and knowledge; economic and financial constraints; absence of incentives; institutional and regulatory gaps; house-builder attitudes.” Developers’ attitudes is domiciled on failure to implement or adopt technologies that support water harvesting and recycling during the designing of new homes (Goodhew *et al*., 1999).

David *et al*, (2010), identified house builders' attitude, financial and economic constraints, lack of legislation to regulate household rainwater harvesting and lack of awareness as some of the barriers for utilization of rainwater harvesting technologies. He concludes by noting that in the United Kingdom, there is still little utilization of rainwater harvesting technologies leading to lose of the ability to use the systems water demand and consumption both at the national and household level.

In Iran, experts have elicited views that the absence of specialized structures for rainwater harvesting is viewed as one of the most critical barriers in many city residents in various Iranian cities. There is also a significant level of inadequate perception among residents towards water conservation which plays a significant part in utilization of rainwater harvesting technologies in Iran (Sheikh, V., 2020).

In Canada, several studies were conducted to identify barriers to sustainable water management in Canadian urban cities. The Canadian Water and Wastewater Association (CWWA) in a report indicated that there were no regulatory barriers to water recycling even though the issues were occasioned by lack of regulations and guidelines on water harvesting and utilization in urban households (Chantelle Leidl *et al*, 2010).

Marsalek *et al*., (2002) in their study noted that there was need to have water quality levels, end-use regulations, and technology performance standards as a measure to address the regulatory gap. The study of Brandes and Ferguson in the year 2004 focused more broadly on "demand-side management and attitudinal barriers, financial barriers, data/information barriers, and administrative barriers. Issues such as the myth of abundance, low and subsidized water prices, lack of comprehensive cost-benefit models, an engineering bias that favours centralization, and fragmented administration, are particularly relevant to RWH".

For many years, Non-Governmental Organizations and other community based as well as faith based groups and networks have been in the forefront in agitating for utilization and use of rain water harvesting. However, lack of scientifically verifiable information for use by policy makers in designing strategies for water harvesting and mapping areas of potential implementation of rainwater harvesting technologies have hindered the progress (Mati *et al*, 2006).

Sheikh, V., (2020) identified the key enablers for rainwater harvesting technologies as implementing usual regulations that pin on developing of common policies, strategies and regulations that provide cash incentives, sensitization and extension services, working with other agencies providing the same water harvesting services, mandatory regulations as well as encouraging the public to adopt rain water harvesting technologies.

Another option that involves training and extension activities is using online platforms such as social media to prepare and disseminate technical guidelines and to demonstrate use of rainwater harvesting technologies. This can significantly improve the utilization of RWHTs especially if an incentive component is included either financial or technical (Ibid, 2020).

The main objective of the study was to provide an understanding of the barriers and enablers of utilizing rainwater-harvesting technologies in the study area and to interrogate the extent to which Machakos County Government integrates water-harvesting technologies in its programs, planning, and budgeting among households in Matungulu Sub-County in Kenya. This study would, therefore, provide critical data on the household utilization of rainwater harvesting technologies that can be used to develop key strategic plans on how to promote the use of RWHT through cost-effective community initiatives to complement the County Government efforts.

3.2 Materials and methods

3.2.1 The study area

The research was carried out in Matungulu Sub-County, Machakos County. Machakos County borders Nairobi, Kiambu, Embu, Kitui, Makueni, Kajiado, Murang'a and Kirinyaga (MCIDP, 2015). It comprises of eight (8) constituencies also referred to as Sub- Counties including Machakos Town, Masinga, Kangundo, Yatta, Mavoko, Matungulu, Kathiani, and Mwala Sub-Counties (MCIDP), 2015) (Figure 9).

1.2690^{0} S, 37.3218^{0} E
Figure 8: Map of Matungulu sub-county

Source: Independent Electrical and Boundaries Commission (IEBC)

The local climate of Matungulu Sub-County is semi-arid with a few hilly terrains (MCIDP, 2015). The annual rainfall of the Sub-County is unevenly distributed and unreliable averaging between 500 mm and 1300 mm. The short rains are experienced in October and December and long rains come from March to May. July is the month with the lowest temperatures while October and March are the warmest months with temperatures varying between 18˚C and 29˚C throughout the year. The total population of Matungulu Sub-County is 199,211 people, with 64,257 Households. It covered an area of 577.5 square kilometers with a population density is 215 persons per square kilometer dominated by the Akamba people (MCIDP, 2015). Matungulu Sub – County was picked for study because there was dire need for water in the area and the demand for it outpaced supply.

3.2.2 Sampling procedure

The research used correlational research design. It used probability sampling method to identify the sample population. This is a method that entailed simple random sampling technique. It helped to produce results that are representative of the whole population. This sampling method was adopted because it gave all elements in the study population an equal chance of being picked in the sample. To select households from all villages in the sub – county for interview, simple random sampling technique was employed using the prepared list acquired after assigning random numbers to the households. A random sample of 384 households was thereafter selected using a table of random numbers to form the sample size.

3.2.3 Data analysis

Mixed methods (qualitative as well as quantitative data analysis) were used to analyze data. Descriptive statistics were utilized through the use of the Statistical Package for Social Sciences

(SPSS version 22 software). This involved calculation of arithmetic mean, standard deviation, percentages, frequencies and Analysis of Variance. The results were then presented in tables, graphs and figures

Primary as well as secondary data was applied. A structured questionnaire (Appendix II) was used to fetch primary data which included respondents' biodata, RWT adopted, Barriers and enablers and policy issues on rainwater harvesting. Focus group discussions with community based organizations, self - help groups and community welfare groups were carried out. Interviews with key informants including area chiefs, members of County Assemblies, religious leaders, chairpersons of self-help groups (Kolooso self-help group, Jiinue self-help group) and village elders were also done. Researcher observations were also noted and recorded.

Secondary data were attained from statistical reports, government documents such as the Machakos County Integrated Development Plan, 2015, Population and Housing Census Reports, Ministry of Agriculture Annual Reports and Food and Agricultural Organization (FAO) reports. These data was used to complement the primary data and to confirm the study findings.

A total of 384 households were considered in the study out of a total of 64,257 households residing in the area under study. The sample was calculated at 95% confidence level, using Fischer's formulae, where (n) referred to the size of the sample (where the population being targeted was more than 10,000), (Z) was the standard normal deviation at the desired confidence level (Z level is 1.96 at 95% significance level), (p) is equal to 50 per cent, (q) is 1 – p while (d) is statistical significance level (0.05).

Equation 1: Fischer's Formula

$$n = \frac{Z^2 Pq}{d^2}$$

n = 384 Households

The analyzed data were then presented in tables and figures.

The study hypothesis was tested using linear regression model stated below:

Equation 2: Linear Regression Model

$y = a + \beta_1 + X_1 + e$

Whereby:

y = Impact on House Household Livelihoods

a = Constant

β_1 = Beta coefficient

X_1= Compute score Barriers and Enablers

X_2= Compute score Water Harvesting Technologies

X_3= Compute score Integration of RHT in County Development Agenda

e = error term

3.3 Results

Documentary data shows that heavy rains are experienced in the study area during the months of March, April, and May as well as in October, November and December. These are the most appropriate times for effective rainwater harvesting to enhance water availability during the dry seasons (Figure 10).

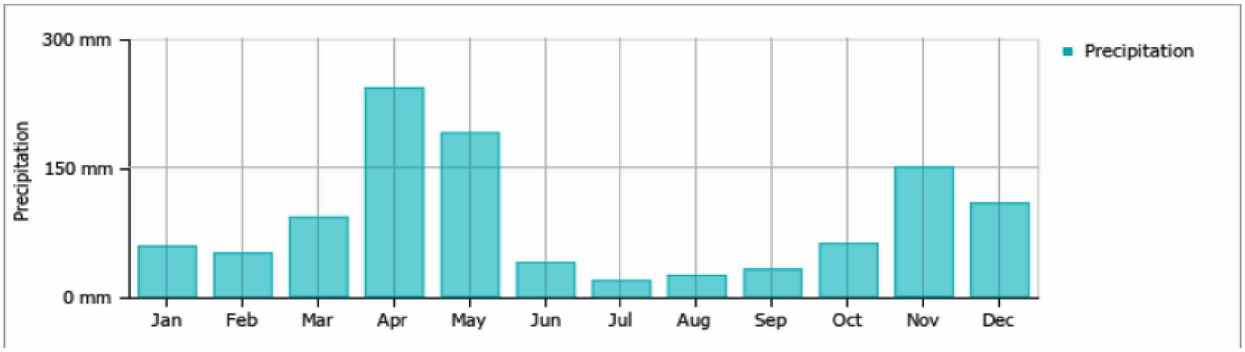


Figure 9: Average monthly rainfall precipitation in Machakos County.

Source: Satellite data on precipitation for Matungulu Sub- County.

From the study, results indicated that a large number of respondents were male representing 61% of the total respondents. This is an indication that there is a bias towards the male gender in matters relating to rainwater harvesting. However, results showed that through the age groups, there was a balanced representation of respondents.

At 75%, farmers represented majority of the respondents to the study followed by self-employed, employed and business people at 11%, 8% and 2% respectively. Considering that farmers were the majority of the respondents, it gives the study a good stand basing on the relevance of the respondents towards achieving the objectives of the study.

The study revealed that majority of households engaged in rainwater harvesting, representing 98% of the respondents however, this practice was done in small quantities that cannot sustain long-term use of the harvested water. This data is presented in table 1below:

Table 1: Utilization of rainwater harvesting technologies

Household RWT	Frequency	Percent
Yes	371	98
No	8	2
Total	**379**	**100**

Source: Researcher

3.3.1 Financing Rainwater harvesting systems

The respondents were asked on whom was the main source of capital in purchasing or constructing the rain water harvesting method and the results were given as below in table 2.

The study findings indicate that the head of household was the main source of capital in the purchase of rain water harvesting method representing 88% of the respondents while 6% of the respondents said it was the community. On the other hand, respondents with 4% said it was carried out by the self-help group while only 1% each of the respondents agreed it was done by the county government and both self and spouse. This was a clear indication that majority of household heads were the main source of capital towards purchasing the rainwater harvesting method.

Table 2: Main Source of Capital

Main Source	Frequency	Percent
Head of Household	327	88
Community	21	6
Self-help Group	17	4
County Government	5	1
Both Self and Spouse	1	1
Total	**371**	**100**

Source: Researcher

3.3.2 Barriers to Utilization of Rain Water Harvesting Technologies

The opinion results were measured using a 5-point Likert-scale ranging from (1) = Strongly Disagree (SD), (2) = Disagree (D), (3) = Undecided (U), (4) = Agree (A) and (5) = Strongly Agree (SA) as shown in Figure 11.

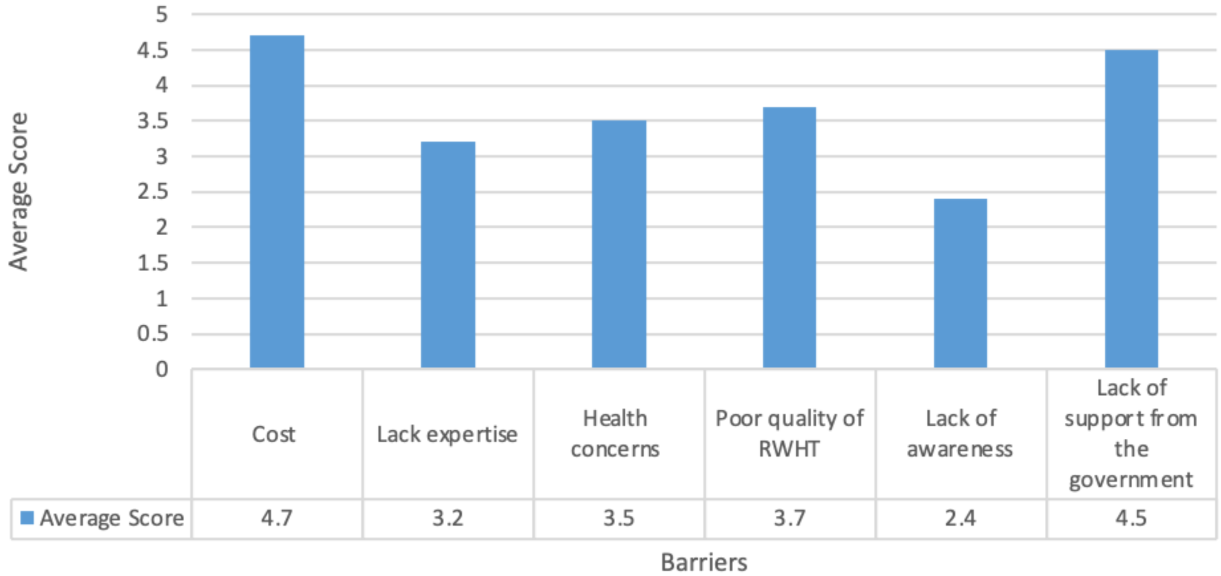


Figure 10: Barriers to utilization of rain water technologies

Source: Researcher

3.3.3 Cost of rainwater harvesting technologies

The research outcomes indicated that many of the respondents at a composite mean of 4.7 on Likert scale believe that cost is the major prohibiting factor hindering utilization of rainwater harvesting technologies. This include cost of purchase, cost of installation and cost of maintenance. They agree that cost vary depending on the technology adopted, which include boreholes, water tanks, wells and dams.

Further, a composite mean of 4.3 believed that the high cost of rainwater harvesting technologies was because of heavy taxation and lack of support from the government. The county government especially has not put in place policies to provide adequate financial incentives to support rainwater-harvesting technologies.

Additionally, the study revealed that the household head was responsible for purchase of rainwater harvesting technologies at 87% of the respondents. Other sources of capital included self-help groups, community and spouse at 4%, 3% and 2% respectively.

3.3.4 Lack of enough expertise

A composite mean of 3.2 of the respondents believe that lack of expertise to adopt and implement these technologies is one of the major barriers. The respondent imply that while some technologies can be easily installed, others need experts to design and build these systems. 75% of respondents indicate that most of the time, local masons and plumbers, who are not adequately trained are used in designing and building rainwater harvesting technologies, leading to poor designs and increased risk to residents.

3.3.5 Health concerns on use of rainwater

Study also indicate that there was skepticism among respondent on the health risks associated with use of rainwater. A composite mean of 3.5 on the Likert scale indicated that rainwater was not good for domestic use because of industrial pollution and other factors which degrade its use. Water in dams, majorly from rainwater run-off was also noted by respondents as not good for domestic use. This limit in use of rainwater has therefore become a barrier as it was noted that water treatment was not practiced at household level.

3.3.6 Poor quality of rainwater harvesting systems

The respondents noted that some of the rainwater harvesting technologies purchased only lasted for a short time before they were replaced or need repairs. A composite mean of 3.7 of respondents believed that this was because of the poor design by locally used technicians and also from effects of extreme weather conditions that accelerate their deterioration. However, 24% of respondents believed that technologies were of good quality but the way in which it was installed was the problem, leading to reduced lifespan.

3.3.7 Lack of awareness on Rainwater Harvesting technologies

Respondents were requested to indicate the level of awareness of the available rain water harvesting technologies and how they were installed and used. A composite mean of 2.4 of the respondents were able to list at least one rainwater harvesting technology. This indicated that there was a good level of awareness on rainwater harvesting technologies. However, 78% of the respondents were not aware on how to effectively install and manage these technologies.

3.3.8 Lack of support from the government

A composite mean of 4.5 of the respondents indicated agreement that County Government does not provide adequate support for rainwater harvesting technologies. The questionnaire further propped the respondents to indicate the level of agreement on certain aspects of support from the county government on utilization of rainwater harvesting technologies. Data was measured in a Likert scale and results indicated that the county government did not do enough to provide support in relation to utilization of rainwater harvesting technologies. These aspects included provision of training, financial support, incentives, developing clear policies on use of rainwater, water treatment and developing projects for sustainable water harvesting.

3.4 Enablers of rainwater harvesting technologies

Respondents were requested to indicate their level of agreement to specific statements on the enablers of utilization and use of rainwater harvesting technologies. The results were measured using a 5-point Likert-scale ranging from (1) = Strongly Disagree (SD), (2) = Disagree (D), (3) = Undecided (U), (4) = Agree (A) and (5) = Strongly Agree (SA) as shown in Figure 12.

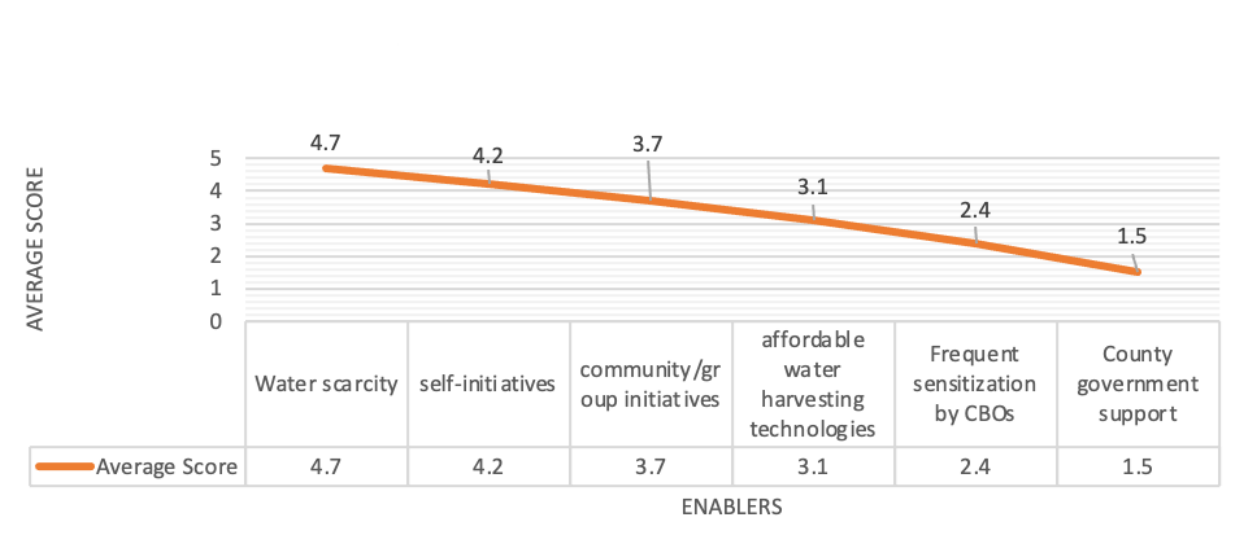


Figure 11: Enablers to utilization of rainwater harvesting technologies

Source: Researcher

Results indicate that water scarcity was a major contributing factor for utilization of rainwater harvesting technologies with composite mean of 4.7. This was followed by self-initiatives, community/group initiatives, affordable water harvesting technologies, frequent campaigns by community based organizations and support from county government at composite means of 4.2, 3.7 3.1, 2.4 and 1.5 respectively.

3.5 Regression Analysis for Barriers and Enablers and Impact on Household Livelihoods

The aim of the research was to assess the barriers and enablers of utilizing rainwater harvesting technologies among households in Matungulu Sub-County, Kenya. Simple linear regression model was used to test the hypothesis in order to meet the requirements of the objective as follows.

3.6 Test of Hypothesis

H_0: Barriers and enablers do not significantly influence the effects of rainwater harvesting technologies among households.

H_1: Barriers and enablers significantly influence the effects of rain water harvesting technologies among households in Matungulu Sub-County, Kenya.

The null hypothesis was tested using the simple linear regression model as stated below.

$Y_1 = a_1 + \beta_1 X_1 + e_1$ Where:

y = Impact on House Household Livelihoods

a_1 = Constant

β_1 = Beta coefficient

X_1= Barriers and Enablers

e_1 = error term

The outcomes were as presented as follows in table 3

Table 3: Model Summary for Barriers and Enablers and Impact on Household Livelihoods

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	0.036[a]	0.001	-0.001	0.566

a. Predictors: (Constant), Barriers and Enablers

Source: Researcher.

The results showed that the model explanatory power between barriers and enablers and the impact on household livelihoods determined by the 'R Square'. This established that only 0.1% of the changes in the impact on household livelihoods can be explained by barriers and enablers. This was not significant.

The ANOVA results above showed an F Value of 0.490 reflecting a significance level of .484[a] meaning the test statistic was not significant at that level. This showed that barriers and enablers did not have a statistical significant impact on household livelihoods at 95% confidence level (Table 4).

Table 4: Analysis of Variance of Barriers and Enablers and Impact on Household Livelihoods

ANOVA[b]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
	Regression	0.157	1	0.157	0.490	0.484[a]
1	Residual	121.089	377	0.321		
	Total	121.246	378			

a. Predictors: (Constant), Barriers and Enablers

b. Dependent Variable: Impact on Household Livelihoods

Source: Researcher

3.7 Discussion

The research established that there existed a huge unutilized potential for rainwater harvesting in Matungulu Sub - County of Machakos County. This agrees with the Global Water Institute, (2013) that indicated that Kenya's greatest challenge in recent times was the increasing water limitations and dying rivers of Athi and Mwitasyano, hence there was need to diversify water harvesting and storage mechanisms that improved the threatened supplies. In addition, there was a lot of water wastage due to the untapped rainwater that led to erosion of the top fertile soils and water bodies' siltation. This is supported by the Average rainfall monthly data presented in the monthly rainfall precipitation data (Figure 10).

The United Nations (UN) recognizes the need to reduce the number of people that lack sustainable access and utilization of clean water and sanitation (UNEP, 2015). In Kenya, a water crisis occurs when there is a situation of inability by the government to supply clean, safe drinking water to its population (UNESCO, 2018). The study identified key barriers to utilization of RWT as; Cost, lack of expertise, health concerns, poor quality RWHT, lack of awareness and lack of support from the government.

The study identified the cost of purchasing rainwater technologies, cost of installation, maintenance and lack of financial support as a major barrier to utilization of rainwater harvesting technologies. This agrees with case studies done by Kim *et al*., (2016), who found out that the cost of a rainwater harvesting system is expensive for most households. It also supports the findings of Suzenet *et al*., (2002) that key barriers to utilization of rainwater harvesting technologies are: "lack of information and knowledge; economic and financial constraints."

Health concerns arising from use of untreated rain water was identified as a major barrier in this study. This confirms the findings by WHO/UNICEF that in developing countries in Africa, Asia and Latin America, satiation services are still un-established or poorly funded. This is evidences by the prevalence of hygiene related diseases in these regions (WHO/UNICEF, 2017). These findings are also reinforced by Smets (2009) noted in his study that access to clean and safe drinking water in industrialized countries is cheaper compared to developing countries. On average, households in industrialized countries utilize about 1.1% of their finances to pay for their water bills. Low income earning households generally use an average 2.6% of their income. Smets further notes that enhancing the reach to affordable water needs a clear focus to the affordability index and taking measures to reduce it such as differentiated pricing, targeted aid programmes, cross-subsidy systems. Many developing countries have implemented such measures.

Lack of expertise to design and build rainwater harvesting systems was noted as another barrier. This supports studies which have found out that lack of knowhow among the publics to increase demand for rainwater harvesting which will in turn promote the idea of progressive policy development. This bottom-up approach will ensure that regulations that stifle progress in rainwater harvesting technologies are removed. The study also recommended the availability of strong leadership to guide in policy development and encourage the existing interested groups to adopt the technologies (Chantelle Leidl *et al,* 2010). The study identified poor quality rainwater harvesting technologies as one of the barriers. This is supported by the study by Marsalek *et al*., (2002) who noted that there was need to have water quality levels, end-use regulations, and technology performance standards as a measure to address the regulatory gap.

Awareness of the availability of RWHT is important in utilization for wider use. The study confirms the findings of Matthew and William (2010), who noted that increased interest in rainwater harvesting was exemplified when a rain water harvesting website hosted by the authors received over two thousand (2000) unique visitors (farmers, pastoralists, water consumers, conservationists, environmentalists, administrators, water reticulators as well as ventors) over three (3) days when a local news channel broadcasts information on rainwater harvesting technologies. The majority of respondents indicated that they had received information on Rain Water Technologies from the radio, indicating that for these technologies to be widely integrated into society, County Governments needed to design their campaigns to utilize the broadcast media. Self-help groups and village barazas also played a key role in community awareness.

The study confirms the findings by Kim *et al*., (2016), that rainwater harvesting is not a high priority for beneficiary developing countries or of high priority in water management policies.

This explains the reason for the poor utilization of these technologies in Kenya. However, findings call for new thinking regarding RWHTs as suggested by Lockwood and Smits, (2011) who propose a self-supply initiative initiated by individual families or groups. The findings of the study also seem to confirm that the main source of funding of water harvesting technologies is the household heads as per the findings of Kim *et al*., (2016), that it is expensive to construct rainwater systems and donor agencies and countries concentrate on financing centralized water supply system. The findings confirm that the government plays a minimal role in financing small-scale water harvesting technologies.

The study findings indicate that motivation to adopt rainwater harvesting technologies centers around water scarcity, affordability, and the need for reliable water supply for domestic and livestock. Support from County Government only accounts for 11% of the motivation factors. This strengthens the findings of Omolara Lade, and David Oloke (2015), that the greater attractions of a RWH system are accessibility, low cost, and easy maintenance at the household level. RWH improves water supply by limiting the temporal and spatial variability of rainfall and provides water for basic human needs and other small-scale productive activities. RWH and storage have proved to be affordable and sustainable. . This indicates that more needs to be done by the County Government for its efforts to be felt.

The County Government of Machakos recognizes the need for adequate access to water and has embarked on a comprehensive water program which has the following components: water resource mapping, drilling, equipping and reticulation of boreholes, weir and dam construction, rehabilitation of existing water projects, rainwater harvesting and strengthening of governance structures for water service providers and community water projects (CIDP, 2018). Among the objectives of the County Integrated Development Plan, 2018 is to establish pro-poor subsidy programs in poor resource settings (free water) and to strengthen governance in water service providers (WSPs) for sustainable provision of water services for domestic, industrial, and agricultural purposes to ensure the conservation of environment. The findings of this study highlighted the cost of RWT as one of the barriers to adopting rainwater technologies, therefore, necessitating subsidy programs for Rain Water Harvesting technologies.

3.8 Conclusion

The outcomes of the research show that rainwater collection methods are supported and financed mainly by the household heads while county government initiatives have not strongly impacted the society. There is a strong pointer from the research that the major barrier to adopting rainwater technologies centers on costs and lack of know-how on how to adopt the technologies. Even though the county government through its integrated development Plan has spelled out plans for the water sector, the lack of adequate budgets has hindered its implementation. This study provides critical data on the household utilization of rainwater technologies that can be used to develop key strategic plans on how to promote the use of RWHT through cost-effective community initiatives to complement the county government efforts. However, further studies need to be done to ascertain the quality and the effects of the use of rainwater for domestic purposes to void the prevalence of diseases in the communities.

Rainwater harvesting technologies give hope to curbing water shortages in arid regions of Machakos County. However, the utilization of the rainwater harvesting technologies depends on the dynamics of governance mechanisms, which the county uses to ensure that policies and incentives trickle down to the residents. Notably, Machakos County Government programs, planning, and budgeting do not significantly influence the effects of rainwater harvesting technologies among households. Further, there is a need for the County Government of Machakos to have a framework that would ensure that the rainwater harvested upholds good quality and is safe for human consumption through a mechanism of testing the quality of such water. To make sure that sustainability of the rainwater harvesting technologies is achieved, the County Government of Machakos requires a clear monitoring system on the total amount of water collected in the county in terms of liters or gallons and its adequacy in serving the local communities.

In addition, Machakos County Government can strengthen its funding, training, awareness creation, and sensitization of its residents on the best technologies of rainwater harvesting to enhance water availability and sustainability.

CHAPTER FOUR: TOWARD IMPROVING HOUSEHOLD LIVELIHOODS USING RAIN WATER HARVESTING TECHNOLOGIES IN MATUNGULU SUB-COUNTY, MACHAKOS, KENYA

4.0 Abstract

Better utilization of rainfall through rainwater harvesting can greatly increase agricultural productivity, improve food security and alleviate poverty. Water is the main limiting resource for crop production in arid sub-Saharan Africa. The biggest challenge currently is growing water shortage and dwindling rivers. This has impacted the livelihoods of rural population in arid and semi-arid counties. The introduction of novel rain-water harvesting (RWH) is, however, seeking to mitigate the effects of perennial droughts in arid areas. Successful utilization of such technologies has the potential to alleviate water problems faced by rural households. In Kenya, too little research has been conducted about utilization of water harvesting technologies and their role in curbing water shortages. Therefore, there was a need to interrogate the extent to which utilization of water harvesting technologies has impacted households in Matungulu Sub-County. Focus group discussions, interview with key informants (Appendix V), and structured questionnaires (Appendix II) were used to collect data for the study which were then analyzed using SPSS version 22 software. The findings indicated that overall, a composite mean of 4.04 and a standard deviation of 0.699 of the respondents agreed that incentives from the county government significantly promoted water harvesting technologies. This was confirmed by a positively strong and significant correlation between the integration of RHT in the county development agenda and the impact on household livelihoods. A further regression analysis indicated that Integration of RHT had a positive and significant influence on household livelihoods ($\beta = 0.755$, $t=22.351$, $p=0.000<0.05$). Results of this survey indicate that rainwater

technologies are financed mostly by household heads and county government initiatives have not been adequately felt. There is a strong indication from the study that water harvesting technologies had a statistically significant influence on the impact on household livelihoods. To ensure sustainability of rainwater harvesting technologies, the study recommends that Machakos County Government need to give continuous support, strengthen stakeholder and community participation in water management practices. Additionally, provide the necessary additional incentives to the community.

Keywords: Households; Harvesting; Livelihoods; Rainwater; Technologies

4.1 Introduction

A total of about 1.2 billion people cannot access clean and safe drinking water globally (Global Water Institute (GWI), 2013 Angoua *et al.*, 2018; Armah *et al*., 2018). The demand for water use has grown globally outpacing population growth, and increasingly, many regions are currently nearing unsustainable water services levels, especially in arid regions (Barry *et al.*, 2008; Baldwin *et al*., 2018; Biswas and Tortajada, 2019; Cherunya *et al*., 2015). According to Kerchof, C., 2016, under current trends, global demand for water will exceed supply by 40 per cent by the year 2030.

Many parts of the world are facing high to extreme water stresses with continued climate change effects (Bryan *et al*, 2018; Carrión-Crespo, 2011; Pradhan and Sahoo, 2019). This stress is due to scarcity of underground water, mismanagement of existing water bodies, increase in river water pollution, lack of water recycling, and wastage (Pradhan and Sahoo, 2019). Fresh and easily accessible water accounts for only 0.014% of all water on Earth leaving 97% of water as saline and slightly less than 3% as inaccessible (United Nations Development Programme (UNDP), 2006, Helmreich and Horn, 2009). Globally, in every six people, one or two people are water stressed, implying that they lack sufficient access to water (United Nations, 2015; Armah *et al*., 2018; Cherunya *et al*., 2015). In Africa, water scarcity is a reality with millions of Africans trekking long distances in search of water (Bancy M. *et al.*, 2007; Armah *et al*., 2018; Cosgrove and Loucks, 2015).

Studies have shown that benefits of utilization of rainwater harvesting technologies can be huge. Mutekwa, V., and Kusangaya, S. (2006) pointed out that utilization of rainwater harvesting technologies can be categorized into two broad accrued benefits; socio-economic and environmental benefits. In a study on contribution of the use of rainwater technologies in Zimbabwe, results pointed out that farmers sampled perceive environmental benefits are not direct benefits of utilization of RWHTs. However, the perceived benefits are enormous especially to the environment. Harvesting of rain water through rainwater harvesting technologies reduce water runoff resulting in reduced soil erosion and hence improving water and soil conservation efforts (Mutekwa, V., and Kusangaya, S., 2006).

It is believed that Rainwater harvesting technologies in Zimbabwe has brought about togetherness and cohesiveness in rural societies through sharing equipment, labour and ideas. Agricultural practices have also improved through diversification of farm produce. Availability of water has led to introduction of new crops for the dry season and also an aspect of intercropping which have become popular and improved farm outputs (Mutekwa, V., and Kusangaya, S., 2006).

Other benefits accrued from utilization of rainwater harvesting technologies include improved standards of living among adopters of the technology. Furthermore, there is abundant source of clean water pro both domestic and agricultural use which is one of the indicators of improving livelihoods. The fact that households have been able to finance RWHTs is another indicator of improving living standards as a result of utilization of these technologies (Ibid, 2018).

About 41 percent of Kenya's population still relies on unsecure water sources, which include ponds, springs, water pans, wells, sand dams and rivers (Pradhan and Sahoo, 2019). Such challenges are common in rural areas and urban slums with piped water treated as a preserve of the affluent in society (GWI, 2013). In Kenya's arid and semi-arid lands (ASALs), the total demand for water often exceeds the water available to people and livestock. This problem is compounded by weak support from government and competition for resources amongst water users, which creates the potential for armed conflict (USAID, 2014). Matungulu Sub-County is a semi-arid region in Kenya that is prone to frequent droughts, water shortages and food insecurity (Machakos County Integrated Development Plan (MCIDP), 2015). It is not well documented how rain water harvesting technologies affect or influence livelihoods among households. Some of the rain water harvesting technologies utilized in Matungulu Sub County include: earth dams, water pans and roof top harvesting (MCIDP), 2015).

It has been established reliably from studies that rainwater harvesting technologies (RWHT) leads to a runoff retention of up to 87% and to double the infiltration (Tamagnone P *et al.,* 2020). Adopting RWHT makes it possible to extend the growing season hence enhancing the crop yield. These benefits contribute to the reduction of the climate-related water stress and the prevention of crop failure enhancing food security (Tamagnone P *et al.,* 2020).

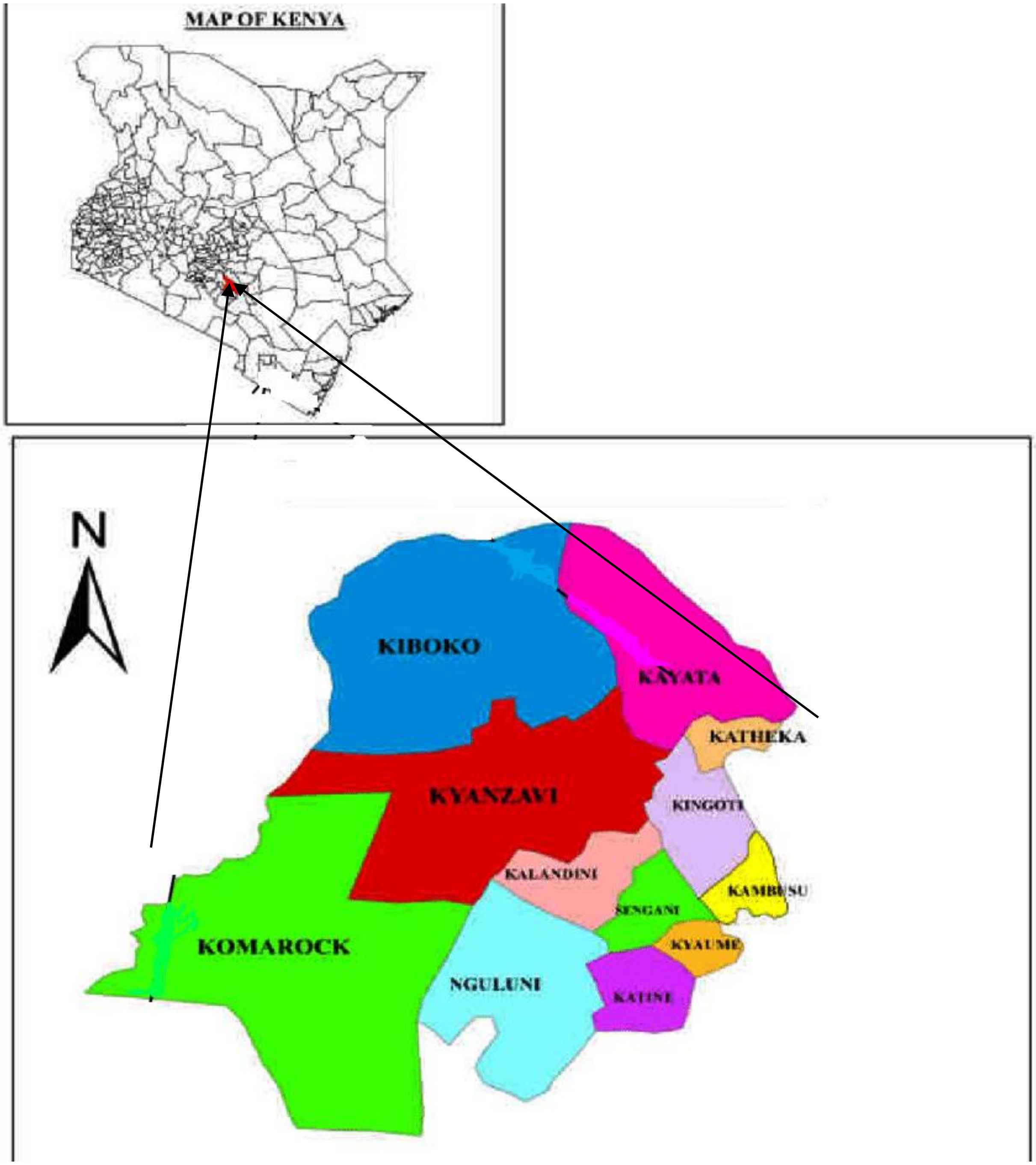
According to Pradhan and Sahoo, (2019), the general objectives of rainwater harvesting are aimed at increasing the volume of water bodies, lessening flood and soil erosion, preventing overuse of underground water and saving money. Rainwater harvesting technologies, on the other hand, include: Roof top rainwater harvesting, rock and surface catchment systems, subsurface dams and sand dams among others (Pradhan and Sahoo, (2019).

The main objective of this study was to provide an understanding of the effects of rain water harvesting technologies on livelihoods in the study area. The specific objectives were to assess the barriers and enablers of utilization of rain water harvesting technologies among households; to assess the livelihood difference of households with water harvesting technologies and those without; to interrogate the extent to which Machakos County Government integrates water harvesting technologies in its programs, planning and budgeting among households in Matungulu Sub-County in Kenya. This study would provide critical data on the household utilization of rain water technologies that can be used to develop key strategic plans on how to promote the use of RWHT through cost effective community initiatives to complement the county government efforts.

4.2 Materials and methods

4.2.1 The study area

The study was conducted in Matungulu Sub-County, Machakos County. It borders Nairobi and Kiambu counties towards the West, Embu towards the North, Kitui towards the East, Makueni towards the South, Kajiado towards the South West, and Murang'a and Kirinyaga towards the North West (MCIDP, 2015). Machakos County comprises of eight (8) constituencies also referred to as Sub- Counties including Machakos Town, Masinga, Kangundo, Yatta, Mavoko, Matungulu, Kathiani, and Mwala Sub-Counties (MCIDP), 2015) (Figure 13).



1.2690^{0} S, 37.3218^{0} E

Figure 12: Map of Matungulu Sub-County
Source: Google Maps

The County has an altitude of 0º 45' to 1º 31' South as well as longitudes 36° 45' to 37° 45' East (MCIDP, 2015). The county's altitude is between 1000 - 1600 meters above sea level.

Subsistence agriculture practices with Maize, sorghum and millet is common (MCIDP, 2015). Matungulu Sub- County comprises of Tala, Matungulu East, Matungulu North, Matungulu West and Kyeleni Wards.

The local climate of Matungulu Sub-County is semi-arid with a few hilly terrains (MCIDP, 2015). The annual rainfall of the Sub-County is unevenly distributed and unreliable averaging between 500 mm and 1300 mm. The short rains are experienced in October and December and long rains come in March to May. July is the coldest month while October and March are the warmest months with temperatures varying between 18˚C and 29˚C throughout the year. The total population of Matungulu Sub-County is 199,211 people, with 64,257 Households. It covered an area of 577.5 square kilometers with a population density is 215 persons per square kilometer dominated by the Akamba people (MCIDP, 2015).

Matungulu is part of Kenya's arid and semi-arid lands (ASALs), where the total demand for water often exceeds the water available to people and livestock. Competition for resources amongst water users creates the potential for armed conflict. Although Kenyans experience periods of severe water scarcity, annual rainfall is actually sufficient to support their livelihoods. The gap arises because a large portion of the water disappears unused through surface runoff, flooding and evaporation. A new approach is needed to unlock the potential of water sources, and use and manage them in a strategic and sustainable way.

4.2.2 Sampling procedure

This was estimated through the use of both primary and secondary data. Primary data collection involved use of a structured questionnaire (Appendix II) to gather relevant information including respondents' bio data, barriers and enablers, RWT adopted, policy issues as well as impact on House Household Livelihoods.

Secondary data collection was based on time series data on food security and rain water harvesting. These data were obtained from statistical abstract reports, government publications such as the Machakos County Integrated Development Plan, 2015, Population and Housing Census Reports, Ministry of Agriculture Annual Reports and Food and Agricultural Organization (FAO) publications. These data was used to complement the primary data and to confirm mechanisms put in place by the county government regarding the use of WHT in the County.

A total of 384 households were considered in the study out of a total of 64,257 households residing in the area under study. The sample was calculated at 95% confidence level, using Fischer's formulae (Equation 1).

$$n = \frac{Z^2 Pq}{d^2}$$

n = 384 Households

Systematic sampling was done using probability sampling technique to select farm households from the study area. This sampling method was chosen since it had an advantage of giving all elements in any given population an equal opportunity of being included in the sample.

4.2.3 Data analysis

Data analysis was done using the Statistical Package for Social Sciences (SPSS version 22 software) mainly through descriptive statistics which included calculation of arithmetic mean, standard deviation, percentages and frequencies. The analyzed data were then presented in tables and figures.

The regression models were used to test relationship between the independent and dependent variables on analysis of effects of rain water harvesting technologies among households in Matungulu Sub-County, Kenya. This was determined using the coefficient of determination. F statistics was applied to test hypothesis based on the study sample of 384 households.

The study hypothesis was tested using linear regression model **(Equation 2).**

Matungulu Sub - County was chosen among other Sub - Counties in Machakos County because it is prone to frequent droughts and unpredictable short rains and RWH technologies were seen to be practiced amongst some households even though on small scale.

4.2.4 Validity and reliability of research instruments

According to Kothari (2004), validity is the most critical criterion indicated the degree to which an instrument measures what it is supposed to measure. Bryman and Bell, 2015 defined validity as the degree to which information collection tools evaluate what they intended to do. Therefore, validity of the research instrument was properly tested through the pilot test, whereby a few respondents who were not included as part of the main study, responded well to the questionnaire. This helped in accepting new suggestions and amendments where necessary to obtain quality results.

Content validity was done by submitting the questionnaire to the relevant supervisors and experts to scrutinize, and rate each item's capacity in the tool providing expert judgment that was relevant and accurate for the research study. Before the actual research study commenced, piloting the tool also allowed the principal investigator to solve questions that needed more clarification. This process helped in validating the accuracy of the questions asked in the questionnaire and also in the achievement of the research objectives of the study.

The test of reliability is an imperative test of sound measurement whereby a measuring instrument is deemed reliable if it provided consistent results (Kothari C. R., 2004). Bryman and Bell (2015) define reliability, as the consistency when applied repeatedly under comparable circumstances that an information collection instrument displays. Pre-testing of the instrument was achieved to aid the research study questionnaire's trustworthiness, reliability or consistency. Centered on the results of the pilot research, Cronbach's Alpha measured the internal consistency of the questionnaire items in assessing the questionnaire's reliability. Cronbach’s test is a measure of a test scale's consistency or reliability and is expressed as a number between 0 and 1 (Cronbach 1951). According to Sekaran and Bougie (2016), any reliability index greater than 0.7 is taken to represent a satisfactory level of instrument reliability, therefore, the reliability threshold for this study was 0.7 and above.

4.3 Results

From the satellite data presented in Figure 14, it is evident that a lot of rainfall is experienced in the months of December, January and February as well as in the months of March, April and May. Such seasons can be targeted for intensive rain water harvesting to enhance water availability in the households.

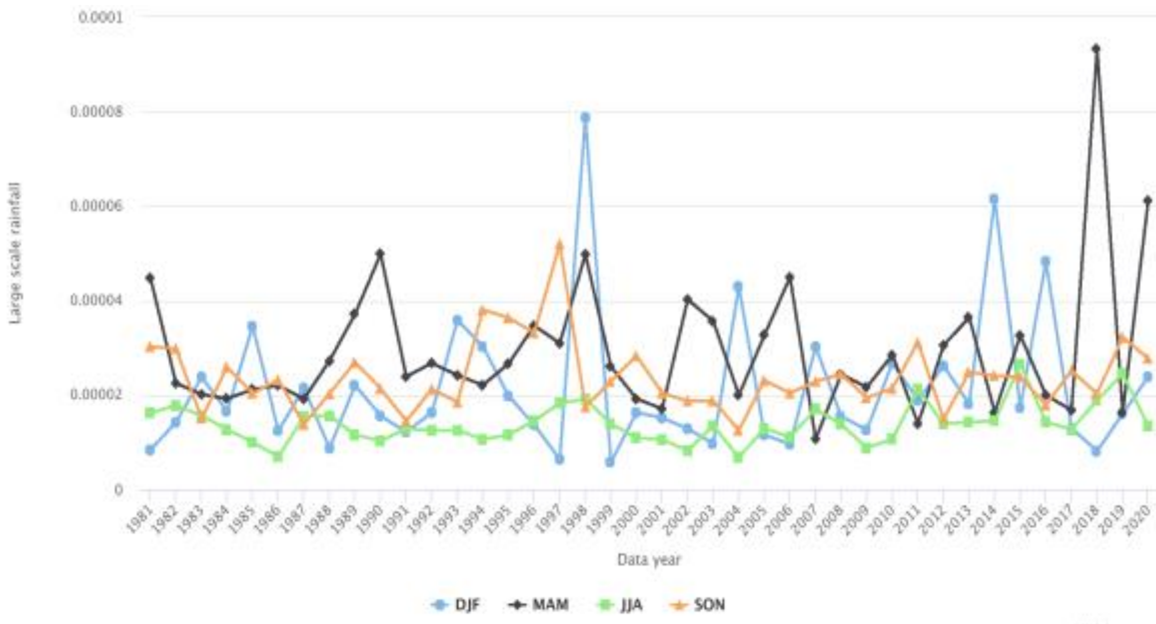


Figure 13: Inter-annual time series

Source: Google Maps

Study results showed that majority of the respondents at 61% were male while female represented 39% of the respondents. This showed that the male gender was higher than the female gender, an indication that the males participated more and appropriately considered in undertaking rain water harvesting technologies than the females. Further, majority of the respondents at 31% were between ages 21 - 30 years and 51 - 60 years each. 21% and 17% of the respondents represented ages 31- 40 years and 41- 50 years respectively. This showed a balanced representation of both the youth and the old participation in rain water harvesting activities.

The study outcomes revealed that majority of the respondents at 75% were farmers, followed by 11% of the respondents who were self-employed. 8%, 4% and 2% of the respondents constituted of employed, other not specified and businesspersons respectively. Being a household survey and relevant to the study topic, achieving 75% of farmers as the majority of the respondents gave a good representation towards making of the study conclusions.

From the study findings indicated in Table 5, majority of the respondents at 98% engaged in household rain water harvesting technologies while only 2% of the respondents did not. The only issue to note is that even if majority of the respondents engaged in rain water harvesting exercise, the technologies used could only allow for too little water collection for domestic use and for a short period of time. Majority of the respondents harvested rain water in small buckets and small drums. Others harvested rain water using shallow wells and water pans that could only last for a few weeks or months. Such methods were not sustainable and hence the women and young girls in most communities kept walking for long distances in search for water.

Table 5: Household utilization of Rain Water harvesting Technologies

Household RWT	Frequency	Percent
Yes	371	98
No	8	2
Total	**379**	**100**

Source: Researcher

4.3.1 Barriers and enablers of utilizing rain water technologies

Analysis of barriers and enablers of utilizing rain water harvesting technologies among Households indicated that majority of the respondents at 98% engaged in household rain water technologies while only 2% of the respondents did not. This contributed significantly to the achievement of the applicable study information.

Household decision making analysis on rain water technologies showed that majority of the respondents as decision makers in the household were the household heads at 87%. This was far followed by the spouse and self-help group at 4% each of the respondents. The community and both self and spouse were at 3% and 2% of the respondents respectively, while the government was only at 1% of the respondents. This was a clear indication that most household decision makers were the head of the households. Majority of the respondents with a mean of 4.51 and a standard deviation of 0.980 agreed that county regulations did not support the technology used while a mean of 3.97 and a standard deviation of 0.479 of the respondents agreed that there was lack of expertise to train and guide individuals on the technologies. Again, respondents with a mean of 3.83 and a standard deviation of 0.682 said that there was lack of funds to utilize the technologies. In addition, respondents with means of 1.94 and 1.75 having standard deviations of 1.314 and 1.354 agreed that there was no enough water from other sources other than rain water and decision by the household head did not facilitate use of technologies respectively. Furthermore, respondents with only a mean of 1.50 and a standard deviation of 1.092 said that beliefs and traditions did not allow household to utilize the technologies.

Overall, a composite mean of 2.92 and a standard deviation of 0.503 implied that all the statements relating to the main barriers that hindered the utilization of RWHTs did significantly impact the households' livelihoods.

4.3.2 Financing use of Rainwater harvesting technologies

The study findings revealed that majority of the respondents at 88% said that the head of household was the main source of capital in the purchase of rain water harvesting method while 6% of the respondents said it was the community. On the other hand, respondents with 4% said it was carried out by the self-help group while only 1% each of the respondents agreed it was done by the county government and both self and spouse. This was a clear indication that majority of household heads were the main source of capital towards purchasing the rain water harvesting method.

Considering the level of inclusiveness in the management of rain water harvesting technologies, the study indicated that majority of the respondents at 79% said that they sometimes practiced level of inclusiveness in the management of RWHTs while 10% of the respondents said that they often practiced. 6%, 3% and 2% of the respondents said that they rarely practiced, had never practiced and extensively practiced level of inclusiveness in the management of RWHTs respectively.

The study findings disclosed that majority of the respondents at 93% said that water scarcity and unavailability motivated them to harvest rain water. 90% and 88% of the respondents agreed to the fact that there was water inaccessibility and because of just self-drive and self-initiative. 86% each of the respondents attributed their motivation to group and community initiatives and to avoid wastage while 85% of the respondents said that it was for domestic, livestock and irrigation purposes. On the other hand, 23%, 11% and 5% of the respondents attributed their motivation to reasonably affordable water harvesting technologies, support from the county government and to frequent campaigns from development organizations on water harvesting respectively. Only an insignificant number of respondents at 0.3% said that there were no funds to put up the system.

The results on the respondents' support for water harvesting programmes showed that majority of the respondents at 85% said that the head of the household was the one who supported the water harvesting programmes mentioned while 9% of the respondents said it was the community. 4% of the respondents indicated that the self-help group supported the water harvesting programs mentioned and, only 0.3% and 0.6% of the respondents said it was supported by the county government and both self and spouse respectively. Once again, this showed a clear indication that majority of household heads supported the water harvesting programs mentioned which aided in realizing quality answers for the study focus.

The study findings on the level of awareness of rain water harvesting technologies revealed that majority of the respondents at 82% each agreed that they were aware of shallow wells and sand dams as rain water harvesting technologies while 73% and 31% of the respondents said that they knew of roof catchment tanks and water pans rain water harvesting technologies respectively. Only 23% of the respondents said they were aware of the rock catchments.

Majority of the respondents at 85% above said that they heard from the radio about the rain water harvesting technology while 29% and 12% of the respondents said that they were informed from their self-help group and village barazas respectively. Only 3% and 1% of the respondents said they saw from the television and got information from the county government respectively.

Majority of the respondents at 92% said they harvested rain water while only 2% did not. This information was too pertinent and vital for this study.

Only 29 respondents out of the total sample of 379 were filtered in these responses, whereby majority of the respondents at 59% said they did not harvest rain water because they had/used a well/borehole. This was followed by 34% of the respondents who said they lacked the harvesting technologies. 3% each of the respondents said it was because they did not know how it was done, there were no funds to put up the system and the roads were made of mad respectively.

Impact of rainwater harvesting on livelihoods.

The results revealed that majority of the respondents at 76% said they used rooftop rainwater harvesting method while 47% of the respondents said they used the surface rainwater harvesting method. 7% of the respondents said they used catchments while only 1% each of the respondents used first flush and filter methods respectively.

4.3.3 Social and economic sustainability

The majority of the respondents at 85% indicated that they used the harvested rainwater for drinking while 76% used it for irrigation purposes. Again, 51% and 32% of the respondents used the harvested rainwater for livestock and domestic purposes respectively. Last but not least, 10% of the respondents said they sold the harvested rain water.

Among the factors used for impact assessment, include Community initiatives, easy and timely access to water, and availability of safe and quality water for drinking, sufficient water supply and income from quality harvest and animals sale (Figure 22). Community initiative, Easy and timely access to water and sufficient water supply forms the minimal deviation and hence almost perfect correlation with the livelihood of the community. Therefore amongst the various factors analyzed, the community initiative, easy and timely access to water and sufficiency of water are the main key factors behind the livelihoods sources of the community.

Majority of the respondents at 88% evidently agreed that women and girls saved time for fetching water to other activities. This was followed by 80% of the respondents who said that they now kept new crops and livestock. 12% and 10% of the respondents said that there was increased acreage on crop land and increased number of livestock respectively. Only 3% of the respondents said that there was enhanced relationship/cohesion with the government and community as a benefit.

The study results revealed that majority of the respondents at 80% clearly indicated that they used the harvested rain water for domestic purposes while 14% of the respondents used it for fish farming. In addition, only 4% and 2% of the respondents used the harvested rain water for horticulture and water venting purposes respectively.

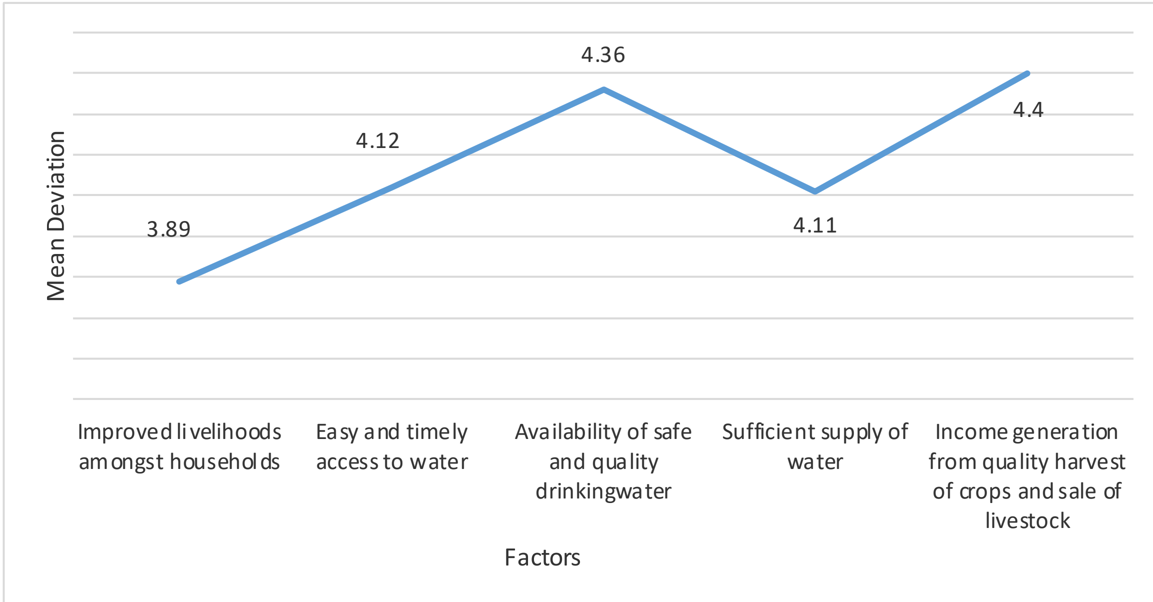


Figure 14: Impact on Household Livelihoods

Source: Researcher

The study results indicated that majority of the respondents at 58% said that their main source of water for domestic and other purposes was rainwater while 38% said they used borehole water. Also, 4% of the respondents said they used tap water and only 0.3% used bottled water. Rain water harvesting technologies affect household water availability, affordability and stability. This is because majority of the respondents with a mean of 4.34 and a standard deviation of 1.037 agreed that rain water harvesting technologies affected their household water affordability while a mean of 3.88 and a standard deviation of 0.760 of the respondents agreed that rain water harvesting technologies affected their household water availability. Furthermore, respondents with an individual mean of 3.82 and a standard deviation of 0.956 said that the rain water harvesting technologies affected their household water stability.

Overall, a composite mean of 4.01 and a standard deviation of 0.918 implied that rain water harvesting technologies significantly affected household water availability, affordability and stability.

4.3.4 Food security and higher income

The study findings in regards to crop production points out that rain water harvesting has led to a major contribution to improving crop production. Supplemental irrigation has provided just enough water to increase rain-fed crops productivity during the dry season or long dry periods between episodes of rain during the rainy season. The social and economic sustainability of rainwater harvesting practices depend largely on the extent of involvement by farmers and the general communities (Vohland, K. and Barry, B., 2009). Farmers applying in situ rainwater harvesting practices were seen to benefit from higher food security and higher income (Ibid, 2009).Water availability is the most important consideration for farmers regarding what, when, and how much to plant in a season (Global Water Institute, 2013).

The net income per households differs with the kind of crop produce. As evidence from figure 16, maize crop is the most produce and sold. It has the highest production and sale with a quantity of less than forty thousand kilograms, followed by beans, watermelon, pigeon peas, onions, tomatoes and cabbages. Generally the net income from quantity of sales below forty thousand kilograms takes a larger percentage which is in the correspondence to level of production.

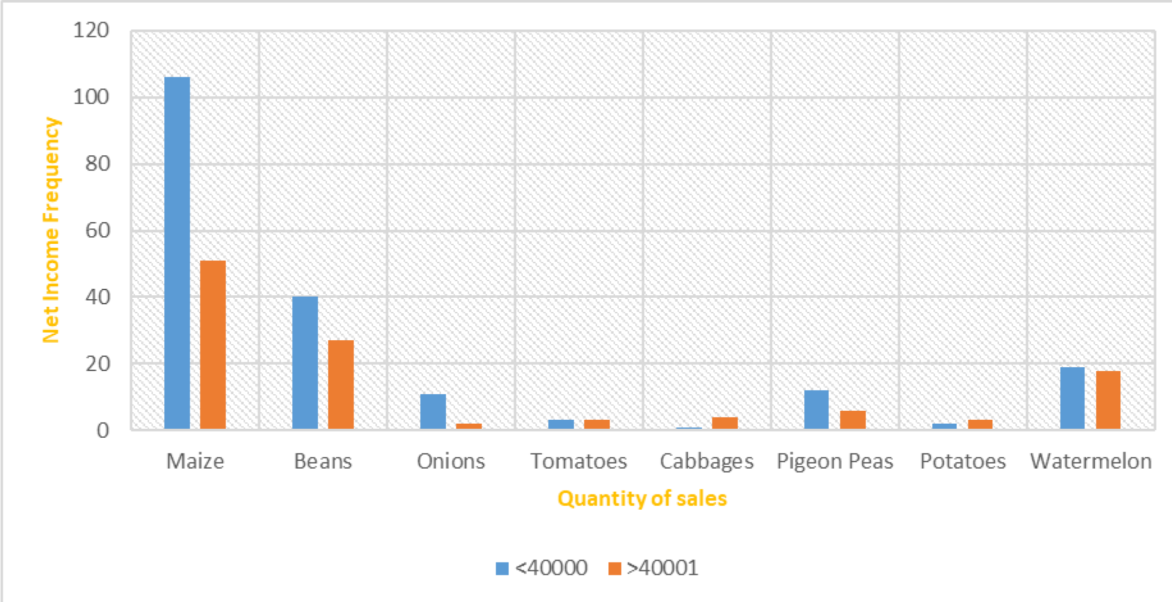


Figure 15: Net income frequency from crops

Source: Researcher

The study results revealed that majority of the respondents with a mean of 4.46 and a standard deviation of 0.861 agreed that low milk production was the main effect of not harvesting rain water. This was followed by poor livestock health effects with a mean of 4.30 and a standard deviation of 0.822 of the respondents. In addition, a mean of 4.20 and a standard deviation of 0.995 of the respondents agreed that it led to no irrigation of crops while a mean of 3.90 and a standard deviation of 0.582 of the respondents agreed to the effect that they went for long distances to fetch water for domestic use hence loss of man hours. Moreover, means of 3.81 and 3.79 with standard deviations of 0.862 and 0.701 of the respondents agreed that it was expensive to buy water and led to poor crop harvests respectively. Last but not least, a mean of 3.65 and a standard deviation of 0.734 of the respondents agreed that not harvesting rain water led to livestock deaths.

The main challenge faced by the majority of the respondents for lack of enough rain water to harvest was livestock stock reduction at 94%. This was followed by 91% each of the respondents who attributed this to some crops not being cultivated and reduction of family income. 90% and 89% of the respondents said that more family income went to fetching of water and it also resulted to women and children walking long distances in search for water respectively. Again, 87% and 85% of the respondents said that it also resulted in reduced crop yields and reduced milk yields respectively. Only 1% of the respondents said it caused drought.

4.3.4.1 The Number of Kilograms per Crop Produced, Priced, Sold and Used At Home

The respondents were asked on the total number of kilograms produced, sale price per kilogram if sold, the kilograms sold in total and the kilograms used at home per crop grown. The results were shown as below in table 6:

Table 6: Crops Production, Sales and Home Consumption

Crops Grown		No. of KGs Produced		Sale Price Per KG		KGs Sold		KGs Used at Home	
		<1000	>1001	<50	>51	<1000	>1001	<200	>201
Maize	**F**	236	71	149	9	117	45	225	62
	%	77	23	94	6	72	28	78	22
Beans	**F**	254	12	4	64	60	12	220	34
	%	95	5	6	94	83	17	87	13
Onions	**F**	34	2	14	1	13	2	32	2
	%	94	6	93	7	87	13	94	6
Tomatoes	**F**	17	3	5	3	5	8	17	2
	%	85	15	63	38	63	37	89	11
Kales	**F**	6	-	-	-	-	-	6	-
	%	100	-	-	-	-	-	100	-
Cabbages	**F**	4	3	5	-	2	3	5	2
	%	57	43	100	-	40	60	71	29
Pigeon Peas	**F**	179	3	1	17	17	3	162	16
	%	98	2	6	94	85	15	91	9
Potatoes	**F**	4	3	1	4	3	2	5	2
	%	57	43	20	80	60	40	71	29
Watermelon	**F**	2	36	2	35	7	30	13	23
	%	5	95	5	95	19	81	36	64

Source: Researcher

The study findings from table 6 above drew the following conclusions:

The number of kilograms produced per crop grown with quantities of <1000 Kgs, revealed that majority of the respondents at 98% indicated pigeon peas while 95% and 94% of the respondents indicated beans and onions with respectively. 85% and 77% of the respondents indicated tomatoes and maize respectively. 57% of the respondents said to have produced cabbages and potatoes each while watermelon had only 5%. Kales produced 100% of the respondents but a frequency of only 6. On the other hand, the number of kilograms produced per crop grown with quantities of >1001 Kgs, showed that majority of the respondents with 95% attributed this to watermelons while 43% each of the respondents indicated cabbages and potatoes. 23% and 15% of the respondents revealed maize and tomatoes respectively while 6% and 5% of the respondents attributed this to onions and beans respectively.

Concerning the sale price of <50Kshs. per kilograms of each crop, the findings results revealed that majority of the respondents at 94% said to have sold maize while 93% and 63% of the respondents indicated onions and tomatoes respectively. 20% of the respondents said potatoes while 6% of the respondents each attributed this to pigeon peas and beans respectively. 5% of the respondents indicated watermelon and 100% of the respondents though with a small frequency of 5 mentioned cabbages. On the other hand, the sale price of >50Kshs. per kilograms of each crop showed that majority of the respondents at 95% mentioned watermelon while 94% each indicated pigeon peas and beans. 80% and 38% of the respondents said to be potatoes and tomatoes respectively. Only 7% and 6% mentioned it to be onions and maize respectively.

Regarding the total number of kilograms sold per crop with quantities of <1000 Kgs, the study results portrayed that majority of the respondents at 87% indicated onions while 85% of the respondents said pigeon peas. 83% and 72% of the respondents stated beans and maize respectively while 63% and 60% said tomatoes and potatoes. 40% and 19% of the respondents attributed this to cabbages and watermelon respectively. On the other hand, the total number of kilograms sold per crop with quantities of >1001 Kgs, revealed that majority of the respondents at 81% said watermelon while 60% of the respondents agreed to cabbages. 40% and 37% of the respondents said it was potatoes and tomatoes respectively. 28%, 17%, 15% and 13% of the respondents attributed this to maize, beans, pigeon peas and onions respectively.

Additionally, on the number on kilograms used at home for consumption with quantities of <200 Kgs, the study revealed that majority of the respondents at 94% mentioned onions while 91% of the respondents said it was pigeon peas. 89% and 87% of the respondents said tomatoes and beans respectively while 78% said it was maize. 71% each of the respondents attributed this to cabbages and potatoes respectively. 36% of the respondents mentioned watermelon while 100% though a small frequency of 6 said kales. On the other hand, the number on kilograms used at home for consumption with quantities of >201 Kgs, indicated that majority of the respondents at 64% mentioned watermelon while 29% of the respondents each said potatoes and cabbages. 22%, 13% and 11% of the respondents attributed this to maize, beans and tomatoes respectively. 9% and 6% of the respondents stated pigeon peas and onions respectively.

4.3.4.2 Total Sales, Cost Incurred and Net Income Per Crop

In addition, the respondents were asked on the total amount of money in Kenya shillings sold, costs incurred (production and transport) and the net income per crop grown. The results were displayed as below in table 7:

Table 7: Crops Sales, Costs and Net Income

Crops Grown		Total Amount of Money Sold in Kenya Shillings		Costs Incurred (Production and Transport) in Kenya Shillings		Net Income in Kenya Shillings	
		<30000	>30001	<10000	>10001	<40000	>40001
Maize	**f**	36	121	139	15	106	51
	%	23	77	90	10	68	32
Beans	**f**	29	37	61	5	40	27
	%	44	56	92	8	60	40
Onions	**f**	10	3	13	-	11	2
	%	77	23	100	-	85	15
Tomatoes	**f**	2	4	6	-	3	3
	%	33	67	100	-	50	50
Cabbages	**f**	1	4	2	2	1	4
	%	20	80	50	50	20	80
Pigeon Peas	**f**	7	11	17	1	12	6
	%	39	61	94	6	67	33
Potatoes	**f**	3	2	2	3	2	3
	%	60	40	40	60	40	60
Watermelon	**f**	9	29	16	21	19	18
	%	24	76	43	57	51	49

Source: Researcher

The study findings from table 7 above drew the following deductions:

The total amount of money sold of <30000 per crop grown, the study findings revealed that majority of the respondents at 77% specified onions while 60% of the respondents indicated potatoes. 44%, 39% and 33% of the respondents indicated beans, pigeon peas and tomatoes respectively. 24%, 23% and 20% of the respondents mentioned watermelon, maize and cabbages respectively. On the other hand, the total amount of money sold of >30001 per crop grown, exhibited that majority of the respondents with 80% attributed this to cabbages while 77% and 76% of the respondents indicated maize and watermelon respectively. 67%, 61% and 56% of the respondents stated tomatoes, pigeon peas and beans respectively while 40% and 23% of the respondents attributed this to potatoes and onions respectively.

Further, the total costs incurred (production and transport) amounting to <10000Kshs. of each crop, the study results revealed that majority of the respondents at 94% said it to be pigeon peas while 90% and 92% of the respondents indicated maize and beans respectively. 50%, 43% and 40% of the respondents said cabbages, watermelon and potatoes respectively. 12(100%) and 6(100%) of the respondents indicated onions and tomatoes respectively. On the other hand, total costs incurred (production and transport) amounting to >10001Kshs. of each crop, showed that majority of the respondents at 3(60%) mentioned potatoes while 21(57%) indicated watermelon. 2(50%) and 15(10%) of the respondents said to be cabbages and maize respectively. 5(8%) and 1(6%) mentioned beans and pigeon peas respectively.

Finally, on the total net income of each crop grown of <40000Kshs, the study findings portrayed that majority of the respondents at 85% indicated onions while 68% of the respondents said maize. 67%, 60%, 51% and 50% of the respondents stated pigeon peas, beans, watermelon and tomatoes respectively. 40% and 20% of the respondents attributed this to potatoes and cabbages respectively. On the other hand, the total net income of each crop grown of >40001Kshs, showed that majority of the respondents at 80% said cabbages while 60% of the respondents agreed to potatoes. 50% and 49% of the respondents said it was tomatoes and watermelon respectively. 40%, 33% and 32% of the respondents attributed this to beans, pigeon peas and maize respectively and 15% mentioned onions.

The overall conclusion from the above study findings in regards to crop production could be rain water harvesting has led to a major contribution to improving crop production. Supplemental irrigation has provided just enough water to increase rain-fed crops productivity during the dry season or long dry periods between episodes of rain during the rainy season. The social and economic sustainability of RWH practices depend largely on the extent of involvement by farmers and the general communities (Botha *et al*., 2004). Farmers applying in situ rainwater harvesting practices were seen to benefit from higher food security and higher income (Ibid, 2009). Water availability is the most important consideration for farmers regarding what, when, and how much to plant in a season (DES, 2011).

The study results showed that majority of the respondents with a mean of 4.40 and a standard deviation of 0.815 agreed that income generation from quality harvest of crops and sale of livestock had a strong impact on household livelihoods (Figure 17). Overall, a composite mean of 4.18 and a standard deviation of 0.566 of the respondents agreed that rainwater harvesting significantly had an impact on household livelihoods.

4.3.4.3 Livestock Reared, Sale and Home Consumption

The respondents were asked on which livestock they reared, number sold, number consumed at home and if sold, what was the price per kilogram or whole. The results were displayed as below in figure 17:

Figure 16: Livestock keeping

Source: Researcher

The study outcomes from figure 17 above drew the following analyses:

On the total number of animals reared with <10, the study revealed that majority of the respondents at 87% indicated goats while 84% of the respondents said sheep. 77% and 68% of the respondents specified poultry and cattle respectively. Only 33% of the respondents mentioned rabbits. On the other hand, the total amount of animals reared with >11, the results exhibited that majority of the respondents with 67% attributed this to rearing rabbits while 32% and 23% of the respondents indicated cattle and poultry respectively. 16% and 13% of the respondents stated sheep and goats respectively. >11 beehives constituted of only 1 respondent resulting to 100%.

In regards to the total number of animals sold constituting of <10, the study showed that majority of the respondents at 92% indicated cattle while 90% of the respondents said sheep. 91% and 45% of the respondents stated goats and poultry respectively. On the other hand, the total amount of animals sold constituting of >11, the results presented that majority of the respondents with 55% attributed this to rearing poultry while 10%, 9 and 8% of the respondents indicated sheep, goats and cattle respectively. 3(100%) sold rabbits while 1(100%) was on beehives.

On the number of animals consumed at home with <10, the study findings revealed that majority of the respondents at 98% consumed goats while 95% of the respondents said sheep. 88%, 81% and 50% mentioned cattle, poultry and rabbits respectively. 2(100%) consumed the bees. On the other hand, the number of animals consumed at home with >11, the findings showed that 14(19%) of the respondents stated poultry while 3(5%) of the respondents said sheep. 1(12%) of the respondents said cattle and 1(2%) of the respondents mentioned goats. 1(50%) of the respondents indicated rabbits.

Further, on the sale price of animal reared per kilogram or whole constituting of <500Kshs, the findings presented that majority of the respondents 61% stated poultry while 1(3%) and 1(2%) of the respondents said goats and sheep respectively. 2(2%) of the respondents indicated cattle. On the other hand, the sale price of animal reared per kilogram or whole constituting of between 500-3000Kshs, the results portrayed that 7(39%) of the respondents indicated poultry and 4(9%) of the respondents mentioned sheep. 3(2%) of the respondents said cattle and 3(100%) indicated rabbits. Again, the sale price of animal reared per kilogram or whole constituting of >3001Kshs, revealed that 32(97%) and 119(96%) of the respondents attributed this to goats and cattle respectively. 41(89%) of the respondents mentioned sheep.

4.3.4.4 Livestock Sales, Costs and Net Income

Likewise, the respondents were asked on the total amount of money in Kenya shillings sold, costs incurred (production and transport) and the net income per animal reared. The results were shown as below in table 8:

Table 8: Livestock Sales, Costs and Net Income

Livestock Reared		Total Amount of Money Sold in Kenya Shillings		Costs Incurred (Production and Transport) in Kenya Shillings		Net Income in Kenya Shillings	
Amounts in Kshs		**7500-100000**	**120000-2000000**	**500-10000**	**20000-500000**	**7000-100000**	**110000-1500000**
Cattle	**f**	56	69	106	17	56	68
	%	45	55	86	14	45	55
Amounts in Kshs		**4000-30000**	**40000-320000**	**1000-5000**	**10000-30000**	**4000-40000**	**45000-300000**
Sheep	**f**	33	14	37	8	37	10
	%	70	30	82	18	79	21
Amounts in Kshs		**500-40000**	**48000-240000**	**200-5000**	**10000-40000**	**1800-40000**	**43000-230000**
Goats	**f**	25	11	26	6	23	10
	%	69	31	81	19	70	30
Amounts in Kshs		**1000-20000**	**24000-96000**	**50-3000**	**5000-50000**	**450-10000**	**11000-85000**
Poultry	**f**	11	7	9	9	9	9
	%	61	39	50	50	50	50
Amounts in Kshs		**20000-40000**		**5000**		**15000-35000**	
Rabbits	**f**	3		3		3	
	%	100		100		100	
Amounts in Kshs		**30000**		**4000**		**26000**	
Bees	**f**	1		1		1	
	%	100		100		100	

Source: Researcher

The study outcomes from table 8 above drew the following interpretations:

The total amount of money sold in Kenya shillings per each livestock reared was as follows; the study revealed that 70% and 69% of the respondents represented sheep and goats respectively were between Kshs.4000-30000 and Kshs.500-40000 respectively. 61% and 45% of the respondents showed poultry and cattle respectively were between Kshs.1000-20000 and Kshs.7500-100000 respectively. Rabbits and bees portrayed 3(100%) for between Kshs.20000-40000 and 1(100%) at Kshs.30000 respectively. On the other hand, respondents between Kshs.120000-2000000 at 55% showed cattle; between Kshs.24000-96000 at 39% displayed poultry; between Kshs.48000-240000 at 31% showed goats and between Kshs.40000-320000 at 30% displayed sheep.

Costs Incurred (Production and Transport) in Kenya Shillings per each livestock reared was as follows: the study presented that cattle and sheep were between Kshs.500-10000 and Kshs.1000-5000 representing 86% and 82% respectively. 81% and 50% of the respondents presented goats and poultry respectively were between Kshs.200-5000 and Kshs.50-3000 respectively. Rabbits and bees portrayed 3(100%) at Kshs.5000 and 1(100%) at Kshs.4000 respectively. On the other hand, 50% and 19% of the respondents showed poultry and goats respectively were between Kshs.5000-50000 and Kshs.10000-40000 respectively. 18% and 14% of the respondents comprised of sheep and cattle that were between Kshs.10000-30000 and Kshs.20000-500000 respectively.

The Net Income in Kenya Shillings per each livestock reared was as follows: the study revealed that 79% and 70% of the respondents portrayed sheep and goats respectively that were between Kshs.4000-40000 and Kshs.1800-40000 respectively. 50% and 45% of the respondents displayed poultry and cattle that were between Kshs.450-10000 and 7000-100000 respectively. Rabbits and bees portrayed 3(100%) at Kshs.15000-35000 and 1(100%) at Kshs.26000 respectively. On the other hand, 55% and 50% of the respondents showed cattle and poultry that were between Kshs.110000-1500000 and Kshs.11000-85000 respectively. 30% and 21% of the respondents indicated goats and sheep that were between Kshs.43000-230000 and Kshs.45000-300000 respectively.

In conclusion from the above study results concerning crop production, there is good productivity from livestock rearing. The benefits of rain water harvesting in the community are evident which promotes the livelihoods of the community. Improving water management improves or enhances national economies, rural agriculture and other food sectors (UNEP, 2015).

4.3.5 Other Activities Performed for Sale Using the Harvested Rain Water

Moreover, the respondents' were asked on which other activities they performed for sale using their harvested rain water. The results were as follows in table 9.

Table 9: Activities Performed Using Harvested Rain Water

Activities	**Frequency**	**Percent**
Fish Farming	50	14
Horticulture	14	4
Domestic Use	285	80
Water Venting	7	2
Total	**356**	**100**

Source: Researcher

The study results revealed that majority of the respondents at 80% clearly indicated that they used the harvested rain water for domestic purposes while 14% of the respondents used it for fish farming. Matungulu Sub – County traditionally, is not a fish farming area. Majority of the interviewed farmers are learning to rear fish with the most common species being mud fish, tilapia and eels. Fish is reared for sale and for domestic use. In addition, only 4% and 2% of the respondents used the harvested rain water for horticulture and water venting purposes respectively

4.4 Statistical analysis

The correlation coefficient is a statistical measure of the strength of the relationship between the relative movements of two variables (Akhilesh G. and Peter W., 2020). Correlation analysis in this study was to show the strength of relationships between the independent and dependent variable. A high correlation meant that two or more variables had a strong relationship with each other, while a weak correlation meant that the variables were hardly related. The correlation matrix displayed revealed that there was a positive weak correlation between barriers and enablers, and impact on household livelihoods which implied that a unit increase in barriers and enablers, increases impact on household livelihoods by 0.036.

The correlation matrix revealed that there was a positive strong and significant correlation between integration of RHT in county development agenda and impact on household livelihoods which implied that a unit increase in integration of RHT in county development agenda increases impact on household livelihoods by 0.755.

Table 10: Analysis of Variance of WHT and Impact on Household Livelihoods

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	0.703[a]	0.495	0.493	0.403

Predictors: (Constant), Water Harvesting Technologies

Source: Researcher

Table 11: Model Summary for WHT and Impact on Household Livelihoods

ANOVA[b]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	59.967	1	59.967	368.926	0.000[a]
	Residual	61.280	377	0.163		
	Total	121.247	378			

a. Predictors: (Constant), Water Harvesting Technologies

b. Dependent Variable: Impact on Household Livelihoods

Source: Researcher

Regression analysis technique was used in this study to find out whether the independent variables influenced the dependent variable. Regressions help uncover areas in operations that can be optimized by highlighting trends and relationships between factors (Dana L., 2020). The standardized regression - beta weights (ß) - was used to assess the independent effect of each variable in the regression equation on the dependent variable. The regression model aided in describing how the mean of the dependent variable changes with the changing condition.

The first objective of the study was to assess the barriers and enablers of utilizing rain water harvesting technologies among households in Matungulu Sub-County, Kenya. Simple linear regression model was used to test the hypothesis in order to meet the requirements of the first objective as follows.

H_0: Livelihood differences of households do not significantly influence the effects of rain water harvesting technologies and those without in Matungulu Sub-County, Kenya.

H_1: Livelihood differences of households significantly influence the effects of rain water harvesting technologies and those without in Matungulu Sub-County, Kenya.

4.5 Model summary for WHT and impact on household livelihoods

The results showed the model explanatory power between water harvesting technologies and the impact on household livelihoods determined by the 'R square'. This established that 49.5% of the changes in the impact on household livelihoods can be explained by water harvesting technologies while the remaining percentage of the impact on household livelihoods at 50.5% can be explained by other factors excluded from the model.

The ANOVA results showed an F Value of 368.926 reflecting a significance level of .000[a] meaning the test statistic is significant at that level. This revealed that water harvesting technologies had a statistical significant impact on household livelihoods at 95% confidence level.

The results indicated that water harvesting technologies had a positive and statistically significant influence on the impact on household livelihoods (β= 0.703, t=19.207, $p=0.000<0.05$). This further implied that a unit change in water harvesting technologies holding other factors constant increases impact on household livelihoods by 0.703 units (Figure 17).

Based on the research findings achieved, we reject the null hypothesis which stated that water harvesting technologies do not significantly influence the effects of rain water harvesting technologies among households. Therefore, using the statistical findings, the regression model can be substituted as: $y = 1.263 + 0.703X_2$.

4.6 Discussion

RWH systems aim to minimize seasonal variation in water availability such as droughts and dry spells (Rockström, J. *et al*., 2003). The social and economic sustainability of RWH practices depend largely on the extent of involvement by farmers and the general communities. This might be the weakest link in the chain of sustainability issues (Botha *et al*., 2004). The more local communities are involved in planning, the higher the possibility that RWH structures will be maintained and benefits are shared (Bangoura, 2002). The study observed that decisions on the use of Rain Water harvesting technologies are influenced by the household heads. Other influencers are self-help groups, community and governments. In this case, the county government had the least influence on decisions to use rain water harvesting technologies.

The study identified key barriers to utilization of RWT as; Lack of funds to utilize the technologies, regulations that does not support the technology use and lack of expertise to train and guide on utilization of rain water technologies. This agrees with case studies done by Kim *et al*., (2016), who found out that the cost of a rainwater harvesting system is economically prohibitive for most individual households. The United Nations (UN) recognizes the need to reduce the number of people that lack sustainable access and utilization of clean water and sanitation (UNEP, 2015). In Kenya, water crisis occurs when there is a situation of inability by the government to supply clean, safe drinking water to its population (UNESCO, 2018).

The study found out that major socio-economic benefits of harvesting rainwater included women and girls saving time for fetching water, increased opportunities for new crops and livestock, increased acreage on crop land and increased number of livestock. This supports the findings by World Health Organization (2019) that improving water storage through improved rainwater harvesting technologies can enable communities to spend less time and the effort of physically collecting it, and thus communities can be productive in other ways. This can also result in greater personal safety by reducing the need to make long or risky journeys to collect water, less expenditure on health and communities can remain economically productive.

This is further depicted in this study with findings suggesting that rain water harvesting technologies affect household water availability, affordability and stability. This is because majority of the respondents with a mean of 4.34 and a standard deviation of 1.037 agreed that rain water harvesting technologies affected their household water affordability while a mean of 3.88 and a standard deviation of 0.760 of the respondents agreed that rain water harvesting technologies affected their household water availability. Overall, a composite mean of 4.01 and a standard deviation of 0.918 implied that rain water harvesting technologies significantly affected household water availability, affordability and stability.

Availability of water for irrigation has also significantly increased the household income. The study findings suggest that rain water harvesting has led to a major contribution to improving crop production. Supplemental irrigation has provided just enough water to increase rain-fed crops productivity during the dry season or long dry periods between episodes of rain during the rainy season. This supports the findings of Rockström, J., Barron, J., and Fox, P. (2003) who found out that under erratic rainfall conditions in the semi-arid zone of sub-Saharan Africa, a major contribution to improving crop production can be anticipated from improved and up-scaled SWC and RWH conservation practices.

The findings suggest that where there is a surplus, households are able to earn income from sale of farm produce. This confirms the findings of UNEP, (2015) which affirms that improving water management practices improves or enhances national economies, rural agriculture and other food sectors. These make them more resilient to variances in rainfall and thus they are able to fulfill the needs of their households' growing population.

Livestock production is also positively affected by availability of water from rainwater harvesting. The study results suggest that household benefit from increased milk production as well as general livestock profitability. This confirms the findings of World Health Organization, 2009 which stated that rainwater harvesting practices improved hydrological indicators such as infiltration and groundwater recharge. Soil nutrients were seen to be enriched. Biomass production increased, with subsequent higher yields. He further states that higher biomass was noted to have supported a higher number of plants and animals. He concluded that farmers applying rainwater harvesting practices were seen to benefit from higher food security and higher income.

In my own opinion, it is now clear that lack of water for domestic, agriculture and livestock use affects households in terms of time consumed searching for it, strain due to lack of water and it affects the economy in general since there will be low productivity, poor yields, reduced or no income at all. The lack of water also affects education mostly of the girl child since she is likely to miss school in search of water for domestic use.

Considering the cost of installation of rain water harvesting technologies which has been cited as the main barrier to adoption of the technologies, I tend to think that this cost issue might just be a mind - set issue of the household heads which in turn affects the adoption. The other main barrier cited was limited government support which I also tend to think that I might be the notion of overdependence on the government by communities and specific households.

The study identified key areas of benefits of rainwater harvesting as reduced distance for sourcing water. From the study's regression analysis, the study indicated that barriers and enablers had a positive but statistically insignificant influence on the impact on household livelihoods ($\beta= 0.036$, $t=0.700$, $p=0.484>0.05$) therefore, we accepted the null hypothesis which stated that barriers and enablers do not significantly influence the effects of rain water harvesting technologies among households. On the other hand, water harvesting technologies had a positive and statistically significant influence on the impact on household livelihoods ($\beta= 0.703$, $t=19.207$, $p=0.000<0.05$) hence, we rejected the null hypothesis which stated that water harvesting technologies do not significantly influence the effects of rain water harvesting technologies among households.

4.7 Conclusion

Water harvesting technologies had a statistically significant influence on the impact on household livelihoods. It was established that a number of rainwater harvesting technologies had been utilized by several households in the study area as a way of supplementing rain-fed agriculture. Moreover, Integration of RHT in County Development Agenda was also considered to have a statistically significant influence on the impact on household livelihoods Majority of the respondents agreed that rain water harvesting significantly impacted household livelihoods.

RWH technologies improves agricultural production and enhances rural households' standard of living, improves household income and reduces environmental degradation. There is therefore, need to create awareness amongst communities, sensitize them and even develop short training sessions to enlighten farmers and rural communities on the utilization of rainwater harvesting technologies.

CHAPTER FIVE: INTEGRATION AND IMPLEMENTATION OF RAINWATER HARVESTING TECHNOLOGIES IN DEVELOPMENT PROGRAMS, PLANNING AND BUDGETING OF MACHAKOS COUNTY, KENYA.

5.0 Abstract

The constitution of Kenya 2010 placed the supply of water and services related to sanitation as a devolved function of County Governments. The clear delineation of roles between the County and National Governments have not significantly improved access to potable and clean water to households. Thirty six (36%) percent of Kenya's population in ASAL areas still have to walk many kilometres in search for water for animal and human utilization (Republic of Kenya, 2015). There has been introduction of new rainwater harvesting technologies that can alleviate the water scarcity, however little progress has been made on improvement of access to clean water in ASAL areas. There is, therefore, need to investigate the initiatives by the County government of Machakos to integrate and implement water harvesting technologies in its development programs, planning and budgeting among households in Matungulu sub-county.

Structured questionnaires (Appendix II) were utilized to fetch primary data which were then analyzed using the Statistical Package for Social Sciences (SPSS version 22). Data was presented using tables, Charts and bar graphs to provide clarity of the findings. Calculation of arithmetic mean, standard deviation, Analysis of variance and regression analysis was done in order to deduce clear understanding of the finding. Documentary evidence was also used to find out the programmes and initiatives put in place by the County Government of Machakos.

The findings suggest that the County government had put in place mechanisms to integrate rainwater harvesting technologies in its development agenda however, the cost remains the biggest impediment to integration of these technologies. A regression analysis showed that the Integration of RHT had a positive and significant effect on household livelihoods (β= 0.755, t=22.351, p=0.000<0.05).

The study recommends that the county government of Machakos develop programs to support integration of rainwater harvesting technologies including providing subsidies, training, engaging development partners to finance rainwater harvesting and providing technical support.

Keywords: Governance mechanisms, Machakos, Matungulu, Rainwater harvesting technologies, Water quality and quantity, Water resource, Water technologies

5.1 Introduction

Storm water collection is valued not merely as water 'savings' for urban areas but also as a way of water production in the household, generating new ways of decision making and social power. In the United States of America, policies have been developed to regulate micro-level harvesting of rainwater. These policies were ideally developed to suit single-household homes, and they make provisions for regulatory frameworks for design and installation of rainwater harvesting systems (Meehan, K. M., and Moore, A. W., 2014).

In some states, regulations have been developed that encourage large scale harvesting methods at industrial levels and large scale developments. These systems generally encompasses storm water and rainwater harvesting into structural designs which can be able to store thousands of litres of water. The cost of installing these systems are however, prohibitive and widespread use seems impossible unless there is a deliberate attempt to develop regulations and incentives to encourage their use (Bruns, B. R., and Meinzen-Dick, R. (2005). Rebates have been used by different administrations in Arizona, California, for instance with different types of rebates being applied from time to time (Meehan, K. M., and Moore, A. W., 2014).

Individual households, groups or government institutions with too limited cross border implementation implement most rainwater harvesting activities or incorporation into governmental policy programmes on a national or local government level. To ensure larger scale implementation, it is important to integrate rainwater-harvesting technologies in policies and governmental programmes, formulating sector guidelines and implementation tools and sharing experiences and practices (Ward *et.al*. 2009).

Governmental and non-governmental projects still exhibit the top-down development approach which still ignore the input of the local community which is important in ensuring sustainability by taking into consideration the needs of the community as well as creating societal ownership. There is also focus on developing urban and peri-urban areas and ignoring the rural community, especially areas with difficult access to water. However, this is set to change with more and more governments adopting the right to water declaration, therefore fostering equity in water access (Kahinda, J. M., and Taigbenu, A. E., 2011).

In Ethiopia, the government initiated rainwater harvesting technologies as part its programme to provide alternative source of water for its citizens and also soil conservation. These government initiated programmes included rainwater activities such as building of ponds, small dams and terraces in most dry areas in Tigray, Wello and Hararghe regions. There was also involvement of non-governmental organizations in these initiatives through the Integrated Rural Development Projects (IRDPs) and the water sector in most regions of the country. NGOs participated in interventions such as conservation of rainwater and rainwater harvesting for household and agricultural purposes (Seyoum, M., 2003).

Governments often focus on piped and groundwater to supply water as per of its programmes and often avoid rainwater harvesting leaving it for NGOs and individual households as the implementers (Nyanchaga E. N., 2007). There is a genuine concern that if rainwater-harvesting technologies are not integrated into government programmes and policies, it will be difficult to mobilize resources for their successful implementation and their utilization will remain scattered. The need for and use of rainwater harvesting technologies will influence the intervention measures (Albert Mumma, 2007). There is greater success if governments design policies that facilitate rainwater-harvesting technologies without stifling their innovation and demand and communities will readily adopt and implement them in order to improve reach to clean and safe water for domestic and other uses (Evans, 2002).

In the United Kingdom, the government has established several policies in order to promote use of rainwater harvesting technologies. There is however there has been lack of proper implementation mechanism especially where legislation limits action by inadequate support mechanisms (Ward S. *et.al.* (2009).

The Kenya vision 2030 economic development blueprint recognizes the importance of water in economic and social development. It highlights the need for conservation of water resources and implementation of new water harvesting methods such as rain water and underground water to ensure water sanitation and access to all citizens in both rural and urban areas (Koehler J., 2016). The strategies put forward by the vision 2030 economic blueprint include introducing specific strategies to improve water management, storage and harvesting capability, improvement of hydro-meteorological data gathering network, construction of dams and sanitation facilities across the country (Mwenzwa, E. M., and Misati, J. A., 2014). These strategies however do not specify the strategies to improve small scale household water harvesting and conservation.

The constitution of Kenya 2010 placed provision of water utilities as a decentralized function of county governments. The National government was left with the responsibility of managing international waters and water resources (Owiti A. K., 2007). The Ministry of Water and Irrigation was given the mandate to formulate regulations for management of water resources. It is therefore the responsibility of County governments to implement water sanitation programmes in their areas of jurisdiction (Constitution of Kenya, 2010).

Some form of regulation had been in place for management of water resources since the establishment of civilization (Bunclark, L. A., and Lankford, B. A., 2011). In India, the advent of colonial rule signaled the transformation of legal frameworks and some of which involved the management of natural resources. The legal transformation included legal frameworks touching on local property rights in land and water and the role of local authorities in management of natural resources. These legislations also to some extent affected Rainwater Harvesting. The current national policy on rainwater harvesting in India is based on colonial policies. If fails to shift from project oriented approach to water resources. The policy is meant for major national and regional projects and clearly ignores the small-scale household rainwater harvesting (Vani, M. S., 2005).

By the year 2000, the Kenyan government tasked the water sector with providing access to clean and reliable water to a population which as at the year 1990, 57% lacked access to clean water. All water resources were managed through centralized government institution, which was grossly inefficient due to lack of funding and acute lack of water infrastructure

(Owiti A. K., 2007). The challenges associated with bad governance in the sector that deals with water led to the formulation of water Act 2002 to reform the sector. This was influenced by international trends spearheaded by Global Water Partnership (GWP) and strengthened by the Millennium Development Goals (2000), who had aimed at minimizing by half the total population that could not reach safe drinking water by 2015 (United Nations, 2017). In order to achieve its target of providing water to the population, the Government of Kenya adopted the 1999 "National Policy on Water Resources Management and Development" (NPWRMD), which proposed decentralization of the water sector as a means of improving access to water to the rural communities (Nyanchaga E. N., 2007).

In order to operationalize the functions of county governments especially in water sector, the Water Act 2016 was legislated and enacted to specify how the counties will implement water sector structures (Johanna Koehler, 2016). Article 142 (2) of the Water ACT 2016, talks of rain water harvesting and household water storage to improve household water availability. Sustainable Development Goal number six also focuses on capacity building in water and sanitation, water harvesting technologies, desalination, water efficiency, recycling as well as reuse technologies. The basis of all these process is to ensure water availability to all if not majority of the world population. The water Act 2002 provided for separation of roles and responsibilities in the water sector resulting in restructuring the water sector in compliance with international trends. It led to the formation of regional Water Service Boards and water service providers to address water related issues and decentralized water management to local autonomous institutions (Mumma A., 2007).

The clear delineation of roles between the county and national governments have not significantly improved access to potable and clean water to households. 36% of Kenya's population in ASAL areas still have to walk for several kilometres in search for water for animal and human utilization (Republic of Kenya, 2015).

In Matungulu, Machakos County, the Matungulu Water Supply Project was funded by Kenya Italy Department Development Programme at a cost of Ksh. 107 million (Machakos County Integrated Development Plan (MCIDP), 2015). It will serve a population of 28,000 people. The project is currently incomplete and the scope of works include; Drilling and equipping of one borehole, construction of one grade 9 house, laying of a 5 kilometre rising main, construction of 1500 m^3 tank, laying of 15 kilometre gravity main line, fabrication and erection of 250 m^3 and 100 m^3 elevated steel tanks, construction of six water kiosks. After completion the total production capacity will be 720 ^{m3} per day (MCIDP, 2015). The main objective of this model is to try and appraise the extent to which Machakos County Government integrates RWHTs in its programs, planning and budgeting among households in Matungulu Sub-County, Kenya.

Considering the social dilemma theory, it focuses on management of all resources or any given resource through decisions, whether the decisions reflect the giving or taking of resources. The theory points out that decision makers face a range of challenges in which personal and common interest conflict - normally called social dilemmas. Even though governments, corporations and other organizations are involved in resource management, individuals also are faced with their own challenges in management of resources (Gifford, R., 2006).

The theory also proposes that factors that are not human related but relevant can still affect the harvesting of any of these resources in their original form before transformation. These factors include the resource scarcity, ease of extraction, the quantity and quality of the resource and even the elusiveness of the resource. Natural resources can decline over time, sometimes caused by human or non-human activities and these influences the way they are utilized and protected for future or current use (Gifford, R., 2006).

The proponent of this model notes that individuals and households utilize available resources along a continuum, which ranges from household, group, or environmental interest to individual-interest. Such individuals thus face social dilemmas on how these interests conflict with each other (Gifford, 2008). This model, therefore, explains the influences or impacts that decision making have on the strategies used to make a decision or decisions about some phenomenon. Different outcomes will thus, be available for the decision maker in terms of satisfaction, anger or regret and the environment on the other hand on whether a resource should be depleted or sustained (Gifford R., 2008).

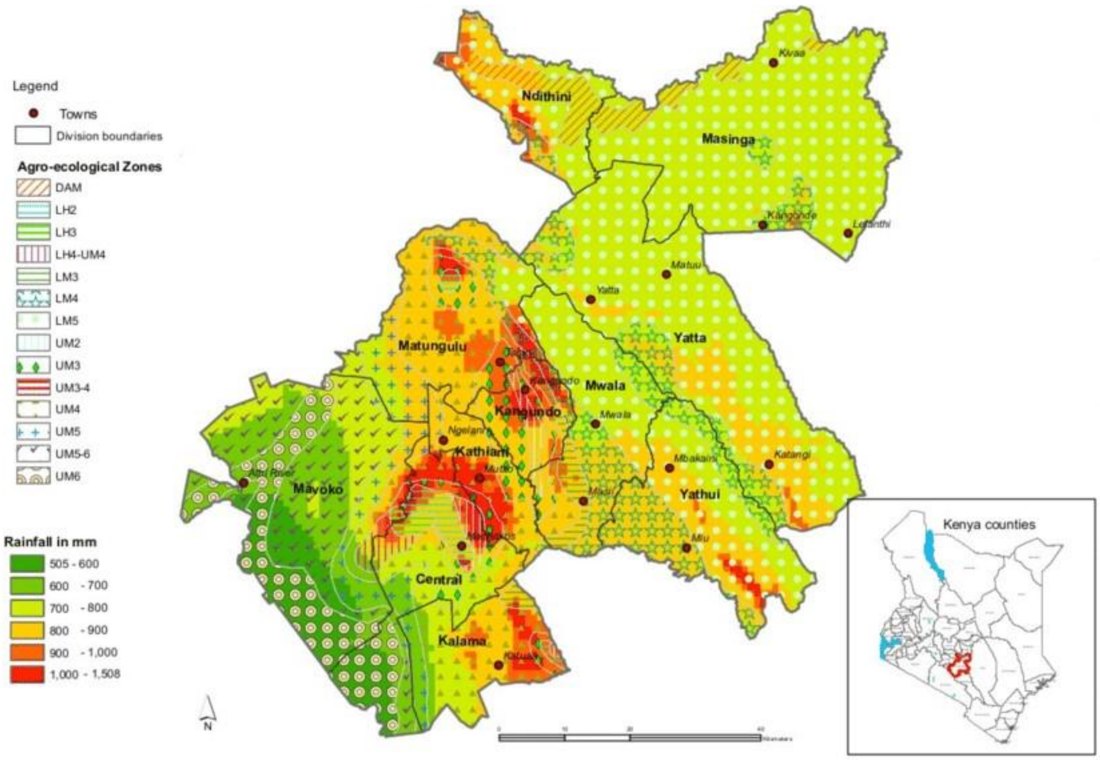
The decisions made by a group, a household head, a community or a County Government is thus likely to influence the type of rain water harvesting technology to be used in any given area. Some decisions might be made with some insights of the technology chosen while other decisions might be out of ignorance. The two levels of decisions might in turn influence or determine whether a resource was conserved or depleted, utilized well or misused, recycled or reused and so on and so forth.

5.2 Materials and methods

5.2.1 The study area

The research was carried out in Matungulu Sub-County, Machakos County. It borders Nairobi, Kiambu, Embu, Kitui, Makueni, Kajiado, Murang'a and Kirinyaga (MCIDP, 2015). Machakos County comprises eight (8) constituencies also referred to as Sub- Counties including Machakos Town, Masinga, Kangundo, Yatta, Mavoko, Matungulu, Kathiani, and Mwala Sub-Counties (MCIDP), 2015).

Matungulu is a semi –arid area with few hilly terrains (MCIDP, 2015). The sub-county has an annual precipitation of between 500 mm and 1300 mm making the rainfall patterns unreliable. The short rains are experienced in October and December and long rains come from March to May with temperatures varying between 18˚C and 29˚C throughout the year. The total population of Matungulu Sub-County is 199,211 people, with 64,257 Households. It covered an area of 577.5 square kilometers with a population density is 215 persons per square kilometer dominated by the Akamba people (MCIDP, 2015).



1.2690^{0} S, 37.3218^{0} E

Figure 17: Machakos County Map
Source: Google Maps

5.2.2 Sampling procedure

To select households from all villages in the sub-county for interview, simple random sampling was employed using the prepared list acquired after assigning random numbers to the households, a random sample of 384 households was selected using table of random numbers. Documentary evidence was also sourced to investigate strategies and programmes placed by the county government in integration of rainwater harvesting technologies.

5.2.3 Data analysis

Descriptive statistics were used in data analysis through the use of the Statistical Package for Social Sciences (SPSS version 22 software). This involved calculation of arithmetic mean, standard deviation, percentages, frequencies, Analysis of Variance and regression analysis.

Primary and secondary data was used. Structured questionnaires were used to collect primary data which included, integration of rainwater harvesting technologies in the community, financing rainwater harvesting technologies, and county government incentives.

Secondary data were obtained from statistical reports, government documents like the Machakos County Integrated Development Plan, 2015, Population and Housing Census documents, Ministry of Agriculture Annual Reports and Food and Agricultural Organization (FAO) publications. These data was used to complement the primary data and to confirm the study findings.

A total of 384 households were considered in the study out of a total of 64,257 households residing in the area under study. The sample was calculated at 95% confidence level, using Fischer's formulae (**Equation 1).**

$$n = \frac{Z^2 Pq}{d^2}$$

n = 384 Households

The analyzed data were then presented in tables and figures.

The study hypothesis was tested using linear regression model **(equation 2)**.

5.3 Results

This section provided result based on the assessment outcomes of the following: RWHTs and how it was integrated in the community, main source of capital to purchase RWHT and the County Government efforts to empower households to purchase the technologies. The objective of research in this chapter was to interrogate the extent to which Machakos County Government integrates water harvesting technologies in its programs, planning and budgeting in Matungulu Sub-County, Kenya.

5.3.1 RWHTs Integrated in the Community

The respondents' were asked on how the rainwater harvesting technologies were integrated in the community and the results were as displayed in Figure 19.

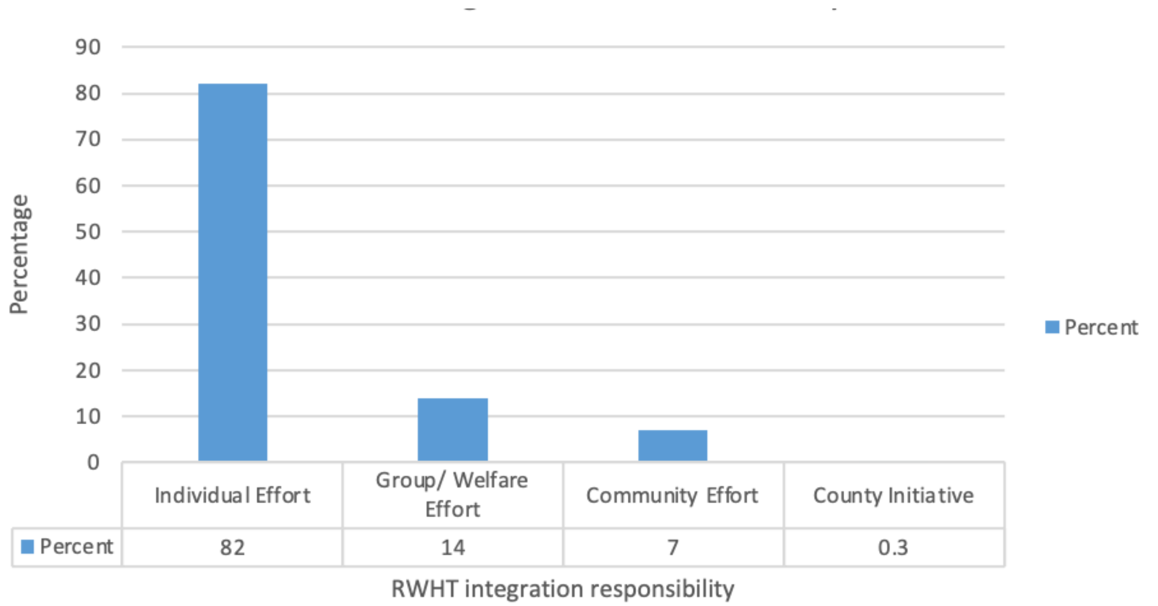


Figure 18: RWHTs Integrated in the Community

Source: Researcher

Majority of the respondents at 82% said that rainwater harvesting technologies integration was an individual effort while 14% of the respondents attributed this to group/welfare effort. 7% and 0.3% of the respondents said it was community effort and the county initiative respectively.

5.3.2 Main Source of Capital to Purchase Rain Water Harvesting Method

The respondents' were asked on what was the main source of income to purchase or construct the rain water harvesting method and the results were shown as below in figure 20.

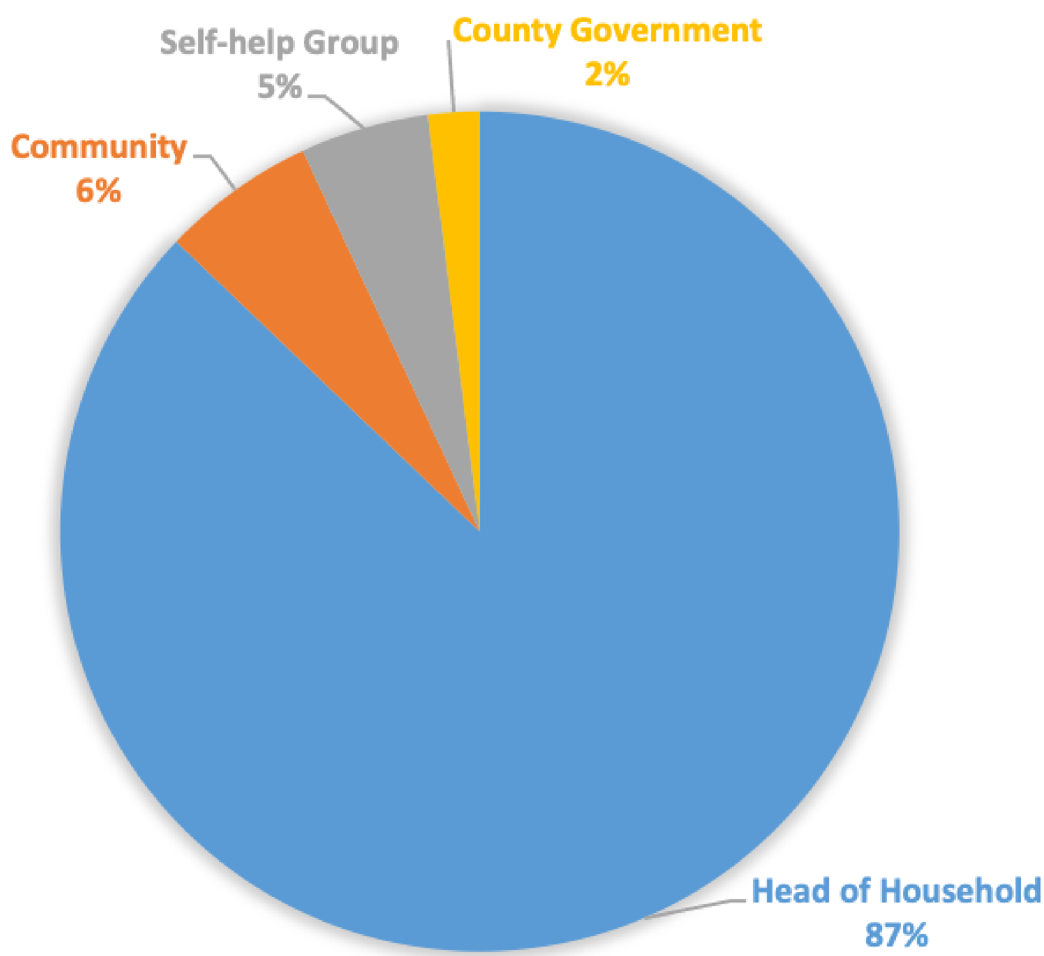


Figure 19: Main Source of Capital to Purchase Rain Water Harvesting Method

Source: Researcher

The study findings above revealed that majority of the respondents at 88% said that the head of household was the main source of income to purchase the rainwater harvesting method while 6% of the respondents said it was the community. Five percent of the respondents said it was done by the self-help group while only 2% of the respondents was done by the county government.

5.3.3 County Government Empowerment on Any Rain Water Technologies

The findings indicate that the County government has initiated programmes to empower residents on the utilization and use of rainwater harvesting technologies. This was confirmed by a positive response rate of 95% of the respondents while only 5% of the respondents did not. This was a great significance of support accorded to the community from the county government.

Table 12: County Government Empowerment

Empowerment	Frequency	Percent
Yes	361	95
No	18	5
Total	379	100

Source: Researcher

5.3.4 County government initiatives for integration of rainwater harvesting technologies

The study identified several initiatives by the county government to promote utilization of rainwater harvesting technologies. These are represented in figure 21 below:

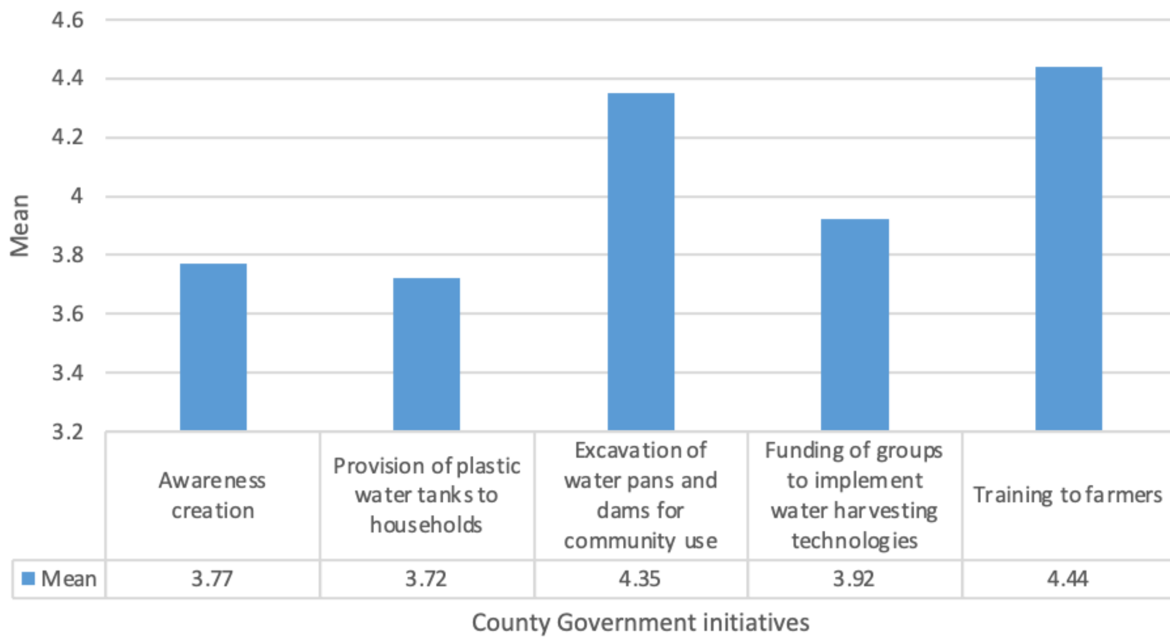


Figure 20: County government initiatives for integration of rainwater harvesting technologies.

Source: Researcher

The study results in figure 21 above indicated that more than half of the respondents with a mean of 4.44 and a standard deviation of 0.916 agreed that the county government of Machakos provided training to farmers as an incentive, which promoted water-harvesting technologies. This was followed by a mean of 4.35 and a standard deviation of 1.037 of the respondents who said excavation of water pans and dams for community use was also given as an incentive. Again, a mean of 3.92 and a standard deviation of 0.670 of the respondents agreed that funding of groups to implement water-harvesting technologies was also given by the county government as an incentive. In addition, means of 3.77 and 3.72 with standard deviations of 0.727 and 0.915 of the respondents agreed awareness creation and provision of plastic water tanks to households were given by the county government respectively.

Overall, a composite mean of 4.04 and a standard deviation of 0.699 of the respondents agreed that the above incentives from the county government of Machakos significantly encouraged water harvesting technologies.

5.3.5 Suggestions for promotion and utilization of rainwater harvesting technologies

The respondents were requested to suggest ways in which County Government would promote utilization of rainwater harvesting technologies. The findings indicate that that majority of the respondents at 96% said that subsidize on water storage tanks by the County Government of Machakos could encourage them harvest water while 94% of the respondents suggested in getting assistance in water treatment. 91% of the respondents said community empowerment through training could be ideal. Furthermore, 88% each of the respondents suggested on subsidize of roofing materials and creation of markets for the farm produces would be a great boost for rainwater harvesting. Lastly, 85% of the respondents suggested on coming up with better ways of storing and conserving, the harvested water could be of great support.

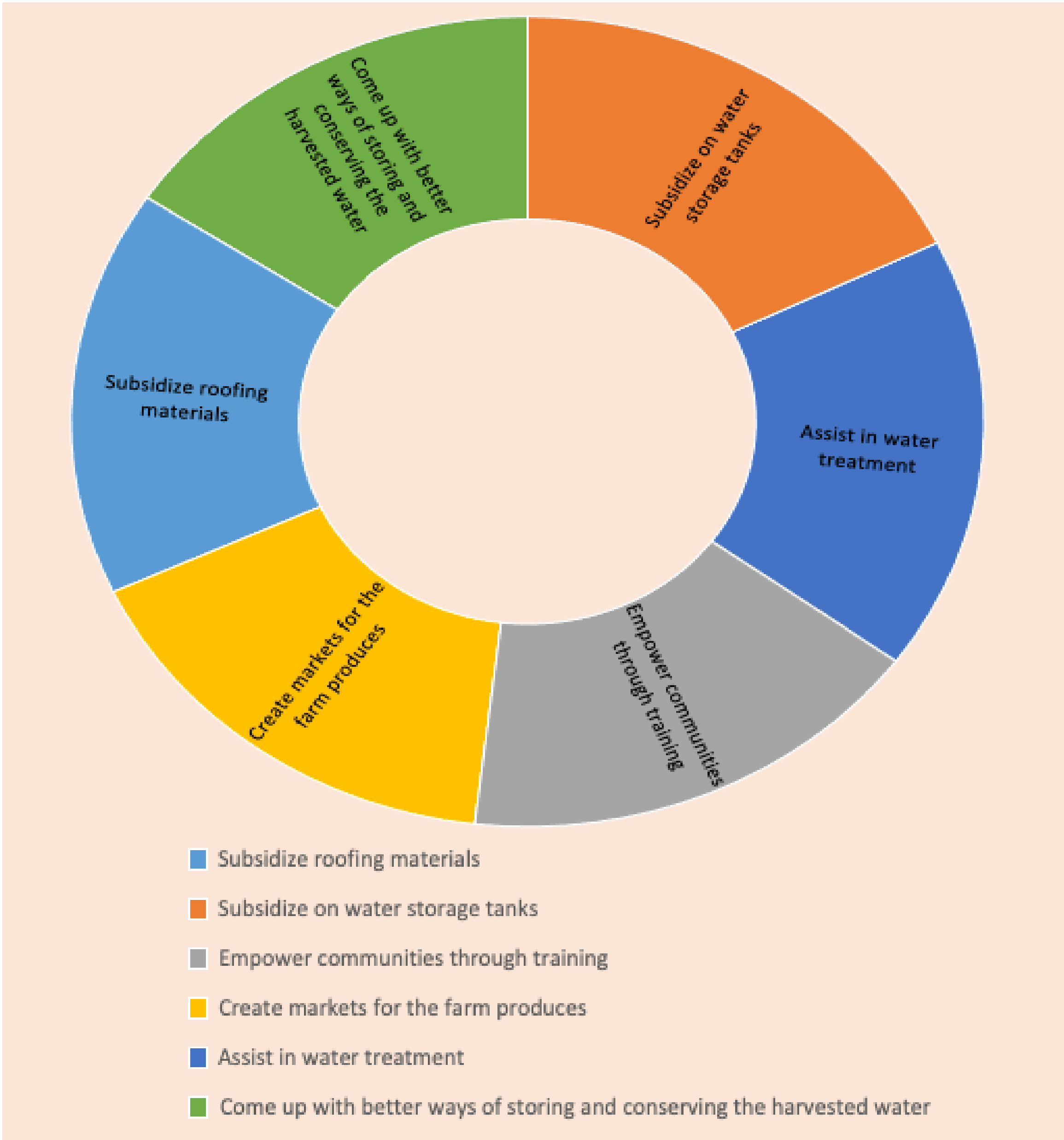


Figure 21: Suggestions for promotion and utilization of rainwater harvesting technologies

Source: Researcher

5.4 Inferential Statistics

The study further carried out inferential statistics using correlation and regression analyses for purposes of hypotheses testing as displayed in the tables below.

5.4.1 Correlation Analysis

The correlation coefficient is a statistical measure of the strength of the relationship between the relative movements of two variables (Akhilesh Ganti and Peter Westfall, 2020). Correlation analysis in this study was to show the strength of relationships between the independent and dependent variable. A high correlation meant that two or more variables had a strong relationship with each other, while a weak correlation meant that the variables were hardly related.

5.4.2 Correlation Analysis for Water Harvesting Technologies and Impact on Household Livelihoods

Pearson Correlation coefficient was used to determine the relationship between water harvesting technologies and impact on household livelihoods as shown in table 13 below.

Table 13: Correlation Analysis for WHT and Impact on Household Livelihood

Variable		Performance
	Pearson Correlation	0.703**
Water Harvesting Technologies	Sig. (2-tailed)	0.000
	N	379

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Researcher

The correlation matrix displayed in table 4.40 above revealed that there was a positive strong and significant correlation between water harvesting technologies and impact on household livelihoods which implied that a unit increase in water harvesting technologies increases impact on household livelihoods by 0.703.

5.4.3 Correlation Analysis for Integration of RHT in County Development Agenda and Impact on Household Livelihoods

Pearson Correlation coefficient was used to determine the relationship between integration of RHT in county development agenda and impact on household livelihoods as displayed in table 14 below:

Table 14: Correlation Analysis for Integration of RHT in CDA and Impact on Household Livelihoods

Variable		Performance
Integration of RHT in County Development Agenda	Pearson Correlation	0.755**
	Sig. (2-tailed)	0.000
	N	379

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Researcher

The correlation matrix displayed in table 12 above revealed that there was a positive strong and significant correlation between integration of RHT in county development agenda and impact on household livelihoods which implied that a unit increase in integration of RHT in county development agenda increases impact on household livelihoods by 0.755.

5.4.4 Regression Analysis

This technique was used in this study to find out whether the independent variables influenced the dependent variable. Regressions help uncover areas in operations that can be optimized by highlighting trends and relationships between factors (Dana Liberty, 2020). The standardized regression - beta weights (ß) - was used to assess the independent effect of each variable in the regression equation on the dependent variable. The regression model aided in describing how the mean of the dependent variable changes with the changing condition.

5.4.5 Regression Analysis for Machakos County Government Programs, Planning and Budgeting and Impact on Household Livelihoods

Simple linear regression model was used to test the hypothesis to achieve the requirements of the objective as follows.

5.4.6 Test of Hypothesis

H_0: Machakos County Government programs, planning and budgeting do not significantly influence the effects of rainwater harvesting technologies among households in Matungulu Sub-County, Kenya.

H_1: Machakos County Government programs, planning and budgeting significantly influences the effects of rainwater harvesting technologies among households in Matungulu Sub-County, Kenya.

The null hypothesis was tested using the simple linear regression model (Equation 2).

Table 15: Model Summary for Integration of RHT in County Development Agenda and Impact on Household Livelihoods

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.755[a]	0.570	0.569	0.372

a. Predictors: (Constant), Integration of RHT in County Development Agenda

Source: Researcher

The results in table 15 above showed the model explanatory power between Integration of RHT in County Development Agenda and the impact on household livelihoods determined by the 'R square'. This established that 57.0% of the changes in the impact on household livelihoods can be explained by Integration of RHT in County Development Agenda while the remaining percentage of the impact on household livelihoods at 42.3% can be explained by other factors excluded from the model.

Table 16: Analysis of Variance of Integration of RHT in County Development Agenda and Impact on Household Livelihoods

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	69.101	1	69.101	499.577	0.000[a]
	Residual	52.146	377	0.138		
	Total	121.247	378			

a. Predictors: (Constant), Integration of RHT in County Development Agenda

b. Dependent Variable: Impact on Household Livelihoods

Source: Researcher

The ANOVA results above showed an F Value of 499.577 reflecting a significance level of .000[a] meaning the test statistic is significant at that level. This revealed that Integration of RHT in County Development Agenda had a statistical significant impact on household livelihoods at 95% confidence level.

Table 17: Model Coefficients of Integration of RHT in County Development Agenda and Impact on Household Livelihoods

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.706	0.112		15.221	0.000
	Integration of RHT in County Development Agenda	0.611	0.027	0.755	22.351	0.000

a. Dependent Variable: Impact on Household Livelihoods

Source: Researcher

The results indicated that Integration of RHT in County Development Agenda had a positive and statistically significant influence on the impact on household livelihoods (β= 0.755, t=22.351, p=0.000<0.05). This further implied that a unit change in Integration of RHT in

County Development Agenda holding other factors constant increases impact on household livelihoods by 0.755 units.

Based on the research findings achieved, the null hypothesis which stated that Machakos County Government programs, planning and budgeting do not significantly influence the effects of rain water harvesting technologies among households was rejected. Therefore, using the statistical findings, the regression model can be substituted as: $y = 1.706 + 0.755X_3$

5.5 Discussion

The study findings indicated that majority of the respondents with a mean of 4.44 and a standard deviation of 0.916 agreed that the county government of Machakos provided training to farmers as an incentive which encouraged water harvesting technologies while a mean of 4.35 and a standard deviation of 1.037 of the respondents said that excavation of water pans and dams for community use was also provided as an incentive. On the other hand, a mean of 3.92 and a standard deviation of 0.670 of the respondents agreed that funding of groups to implement water harvesting technologies was likewise given by the county government as an incentive. In addition, means of 3.77 and 3.72 with standard deviations of 0.727 and 0.915 of the respondents agreed that awareness creation and provision of plastic water tanks to households were given by the county government respectively. These study results support the findings of Katie M. Meehan and Anna W. Moore (2014) who found out that in the United States of America, rebates have been adopted by administrative governments in Arizona, California, New Mexico and Texas as earlier discussed.

Overall, a composite mean of 4.04 and a standard deviation of 0.699 of the respondents agreed that the above incentives from the county government of Machakos significantly encouraged or promoted water harvesting technologies. This was confirmed by a positive strong and significant correlation between integration of RHT in county development agenda and impact on household livelihoods. A further regression analysis indicated that Integration of RHT in County Development Agenda had a positive and statistically significant influence on the impact on household livelihoods ($\beta = 0.755$, $t=22.351$, $p=0.000<0.05$), hence, the rejection of the null hypothesis which stated that Machakos County Government programs, planning and budgeting do not significantly influence the effects of rain water harvesting technologies among households.

According to the Machakos County Integrated Development Plan (2015), there is an ongoing Matungulu Water Supply Project funded by Kenya Italy Department Development Programme at a cost of Ksh. 107 million which will serve a population of 28,000 people. The project scope of works includes: drilling and equipping of one borehole, construction of one grade 9 house, laying of a 5 kilometre rising main, construction of 1500 m^3 tank, laying of 15 kilometre gravity main line, fabrication and erection of 250 m^3 and 100 m^3 elevated steel tanks, construction of six water kiosks. Once completed, the total production capacity will be 720 m^3 per day (MCIDP, 2015).

In addition, there are legal frameworks on Article 142 (2) of the Water ACT 2016, which talks about rain water harvesting and household water storage to improve household water availability. SDG 6 also focuses on capacity building in water and sanitation, water harvesting technologies, desalination, water efficiency, recycling as well as reuse technologies.

The County Government of Machakos recognizes the need for adequate access to water and has embarked on a comprehensive water program which has the following components:

water resource mapping, drilling, equipping and reticulation of boreholes, weir and dam construction, rehabilitation of existing water projects, rainwater harvesting and strengthening of governance structures for water service providers and community water projects (CIDP, 2018). Among the objectives of the County Integrated Development Plan, 2018 is to establish pro-poor subsidy programs in poor resource settings (free water) and to strengthen governance in water service providers (WSPs) for sustainable provision of water services for domestic, industrial, and agricultural purposes to ensure the conservation of environment. The findings of this study highlighted the cost of RWT as one of the barriers to adopting rainwater technologies, therefore, necessitating subsidy programs for Rain Water Harvesting technologies.

5.6 Conclusion and recommendations

There is a deliberate initiative by the county government of Machakos to integrate rain water harvesting initiatives in its programmes. However, more needs to be done to provide adequate measures to promote utilization of these technologies. There is need to develop regulatory framework and include incentives as part of policy. The County Government also must ensure that guidelines for water treatment and use are developed to guard against increase in waterborne diseases that may further hinder the utilization of rainwater in the county.

There is also an urgent need to include rainwater-harvesting programmes in the county government budgets. Apart from this, there is a huge potential in involvement of donors and non-governmental organizations in initiatives that promote rainwater-harvesting technologies. The study noted that county government does not participate in initiatives that promote use of rainwater harvesting technologies at the household level. There is therefore an urgent need to bridge this gap by involving development partners and community based organizations to assist the vulnerable, who cannot afford these technologies to access financial support to set up these technologies.

CHAPTER SIX: SUMMARY OF FINDINGS, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

This chapter provides the summary of findings, discussion, conclusions and recommendations, whereas also made suggestions for further research. The study findings were summarized in line with the main purpose of the study which was to carry out an analysis of the effects of rain water harvesting technologies on livelihoods among households in Matungulu Sub-County, Machakos, Kenya.

6.1 Questionnaires Response Rate

The target response rate was 384 questionnaires, out of which 379 questionnaires were correctly filled and returned achieving a 99% return rate. According to C.R. Kothari (2007), a response rate of more than 70% is appropriate for data analysis which is considered in helping reduce sample biasness. Proficient and experienced research assistants contributed positively to the attainment of this response rate. The findings were depicted as below in table 18.

Table 18: Response Rate

Return Rate	Frequency	Percent
Returned Questionnaires	379	99
Unreturned Questionnaires	5	1
Total	**384**	**100**

Source: Researcher

6.2 Respondents Biodata

Bio-data of the respondents is a too vital consideration in social research, since it informs the nature of responses achieved. For example, age and gender of the respondents helps in understanding the views and dynamics about the respondents. Equally, the level of education of the respondents are too critical as it determines how they express their opinions about a research problem and it determines the nature of responses achieved from a particular study. These altogether, defines the quality of responses from a particular study.

In this regard, the study sought the bio-data for the household heads, specifically the gender, age, highest level of education completed and the main occupation of the household head as shown in the relevant tables below.

6.2.1 Gender

The study sought the respondents' gender as indicated below in table 19.

Table 19: Gender

Gender	Frequency	Percent
Male	231	61
Female	148	39
Total	**379**	**100**

Source: Researcher

From the study findings in table 19 above, majority of the respondents at 61% were male while female represented 39% of the respondents. This showed that the percentage for the male gender was higher than the female gender, an indication that the males participated more and appropriately considered in undertaking rain water harvesting technologies than the females.

6.2.2 Age Group

The respondents' age group was collected and presented as below in table 20.

Table 20: Age Group

Age	Frequency	Percent
21-30 years	118	31
31-40 years	80	21
41-50 years	65	17
51-60 years	116	31
Total	**379**	**100**

Source: Researcher

The study results above indicated that majority of the respondents at 31% were between ages 21 - 30 years and 51 - 60 years each. 21% and 17% of the respondents represented ages 31 - 40 years and 41 - 50 years respectively. This showed a balanced representation of both the youth and the old participation in rain water harvesting activities.

6.2.3 Highest Level of Education

The study sought information concerning the respondents' highest level of education as depicted in table 21 below.

Table 21: Level of Education

Level of Education	Frequency	Percent
Primary	35	9
Secondary	296	78
Tertiary	19	5
Never been to school	21	6
Others	8	2
Total	**379**	**100**

Source: Researcher

The study results above showed majority of the respondents at 78% had obtained a secondary education level, followed by 9% of the respondents with a primary education level. 6% of the respondents had never been to school, 5% of the respondents had achieved a tertiary level and the least at only 2% of the respondents constituted of others not specified. The representations depicted some good literacy levels of the respondents that helped in achieving quality responses. And again, at least majority of the respondents had attained some basic education and could easily understand the study in perspective and respond with ease, and also able to understand and conceptualize rain water harvesting technologies practices.

6.3.4 Main Occupation of the Household Head

Finally on bio-data of the respondents, the study solicited information concerning the main occupation of the household head as depicted in table 22 below:

Table 22: Main Occupation of the Household Head

Occupation	Frequency	Percent
Farmer	284	75
Business-person	6	2
Employed	32	8
Self-Employed	43	11
Other	14	4
Total	**379**	**100**

Source: Researcher

The study outcomes above revealed that majority of the respondents at 75% were farmers, followed by 11% of the respondents who were self-employed. 8%, 4% and 2% of the respondents constituted of employed, other not specified and businesspersons respectively. Being a household survey and relevant to the study topic, achieving 75% of farmers as the majority of the respondents gave a good representation towards making of the study conclusions. This was important because it represented the interested sector of the population most affected by the study.

6.4 Reliability Statistics

According to Sekaran and Bougie (2016), any reliability index greater than 0.7 represented an acceptable level of instrument reliability. Therefore, the reliability threshold for this study was 0.7 and hence considered to be reliable as shown in table 23 below.

Table 23: Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.714	.694	4

Source: Researcher

6.5 Summary of findings

The study conducted a household survey of 379 target response in among households in Machakos County in Kenya. Data collection was done through the use of structured questionnaires (Appendix II), then analysed using SPSS statistical package version 22. Data presentation was in tables, frequencies, percentages, means and standard deviation for the purpose of interpretation.

Bio-data for the household heads comprised of the gender where most of the interviewees at 61% were male while female represented 39%; the age group displayed most of the interviewees at 31% each were between ages 21 - 30 years and 51 - 60 years whereas, 21% and 17% of the respondents represented ages 31 - 40 years and 41 - 50 years respectively. On the highest level of education, the results showed a most of the respondents at 78% had obtained a secondary education level, followed by 9% of the respondents with a primary education level. 6% of the respondents never had been to school, 5% of the respondents achieved a tertiary level and the least at 2% of the respondents constituted of others. In addition, as ones occupation, most of the interviewees at 75% were farmers, followed by

11% of the respondents who were self-employed. 8%, 4% and 2% of the respondents constituted of employed, other not specified and businessperson respectively.

From the study's correlation results, it was revealed that there was a positive and strong correlation between water harvesting technologies, integration of RHT in county development agenda and impact on household livelihoods. However, there was a positive but weak correlation between barriers and enablers, and impact on household livelihoods.

From the study's regression analysis, the study indicated that barriers and enablers had a positive but statistically insignificant influence on the impact on household livelihoods (β= 0.036, t=0.700, p=0.484>0.05) therefore, we accepted the null hypothesis which stated that barriers and enablers do not significantly influence the effects of rain water harvesting technologies among households. On the other hand, water harvesting technologies had a positive and statistically significant influence on the impact on household livelihoods (β= 0.703, t=19.207, p=0.000<0.05) hence, we rejected the null hypothesis which stated that water harvesting technologies do not significantly influence the effects of rain water harvesting technologies among households. In addition, Integration of RHT in County Development Agenda had a positive and statistically significant influence on the impact on household livelihoods (β= 0.755, t=22.351, p=0.000<0.05) hence, we rejected the null hypothesis which stated that Machakos County Government programs, planning and budgeting do not significantly influence the effects of rain water harvesting technologies among households.

6.6 Discussion of the Findings

This section focused on detailed discussion of the major findings in relation to the main purpose of the study was to come up with comprehensive conclusion. This was discussed as per each study objective as indicated below.

6.6.1 Barriers and Enablers and Impact on Household Livelihoods

The first objective of the study was to assess the barriers and enablers of utilizing rain water harvesting technologies among households in Matungulu Sub-County, Kenya.

The study findings portrayed that majority of the respondents with a mean of 4.51 and a standard deviation of 0.980 agreed that, as one of the main barriers to utilizing RWHTs, county regulations did not support the technology used which significantly impacted households' livelihoods while a mean of 3.97 and a standard deviation of 0.479 of the respondents said that lack of expertise to train and guide individuals on the technologies considerably also impacted the household livelihoods. Furthermore, respondents with a mean of 3.83 and a standard deviation of 0.682 said that lack of funds to utilize the technologies equally was a hindrance to rain water harvesting technologies utilization. In addition, respondents with means of 1.94 and 1.75 having standard deviations of 1.314 and 1.354 agreed that insufficient water from other sources other than rain water and decision by the household head did not facilitate use of technologies respectively. Furthermore, respondents with only a mean of 1.50 and a standard deviation of 1.092 said that beliefs and traditions did not allow household to utilize the technologies.

Overall, a composite mean of 2.92 and a standard deviation of 0.503 implied that the main barriers stated in this study insignificantly hindered the utilization of RWHTs among the households. These findings were confirmed by the regression analysis that barriers and enablers had a positive but statistically insignificant influence on the impact on household livelihoods ($\beta = 0.036$, $t=0.700$, $p=0.484>0.05$), therefore, it led to the acceptance of the null hypothesis which stated that barriers and enablers do not significantly influence the effects of rain water harvesting technologies among households. Again the correlation analysis had indicated a positive but weak correlation between barriers and enablers, and impact on household livelihoods.

However, the GWI (2013) had stated that, Kenya's biggest challenges currently was the growing water shortage and dwindling rivers, hence there was need to diversify water harvesting and storage mechanisms that improved the threatened supplies. In addition, there was a lot of water wastage due to the untapped rain water that led to soil erosion and water bodies' siltation. Furthermore, the GWI (2013) continued to state that the choice of water harvesting technology or facility was likely to be dependent on the household head which in turn influenced livelihoods among households. In addition, Thornton *et al*., (2002) acknowledged that the assessment of the likely effects of RWH practices in relation to future climate and other global and regional changes continued to be a challenge.

The study found out that there is a huge untapped potential for rainwater harvesting in Kenya. This agrees with the Global Water Institute, (2013) which stated that Kenya's most eminent challenge in recent times was the increasing water scarcity and dying rivers, hence there was the need to diversify water harvesting and storage mechanisms that improved the threatened supplies. In addition, there was a lot of water wastage due to the untapped rainwater that led to soil erosion and siltation of water bodies. This is supported by the Average rainfall monthly data presented in the Inter-Annual time series.

The study observed that decisions on the use of Rain Water harvesting technologies are influenced by the household head. Other influencers are self-help groups, communities, and governments. This agrees with the findings of Botha *et al*., (2004) that the social and economic sustainability of RWH practices mostly relies on the extent at which most households and the communities. The study also agrees with Bangoura, (2002) who noted that the more rural households are involved in planning, then RWH structures are likely to be maintained and benefits shared. In this case, the county government had the least influence on decisions to use rainwater harvesting technologies. This affirms the findings by Botha *et al*., (2004) that dependence on farmers and communities on the social and economic sustainability of RWH can be the weakest link. There is therefore a need for more involvement of policymakers to ensure the success of RWHT.

The United Nations (UN) recognizes the need to reduce the number of people that lack sustainable access and utilization of clean water and sanitation (UNEP, 2015). In Kenya, a water crisis occurs when there is a situation of inability by the government to supply clean, safe drinking water to its population (UNESCO, 2018). The study identified key barriers to utilization of RWT as; Lack of funds to utilize the technologies, regulations that do not support the technology use, and lack of expertise to train and guide on utilization of rainwater technologies. This agrees with case studies done by Kim *et al*., (2016), who found out that the cost of a rainwater harvesting system is economically prohibitive for most individual households.

The study confirms the findings by Kim *et al*., (2016), that rainwater harvesting is not a high priority in water management policies. This explains the reason for the poor utilization of these technologies in Kenya. However, findings call for new thinking regarding RWHTs as suggested by Lockwood and Smits, (2011) who propose a self-supply initiative initiated by individual families or groups. The findings of the study also seem to confirm that the main source of funding of water harvesting technologies is the household heads as per the findings of Kim *et al*., (2016), that it is expensive to construct rainwater systems and donor agencies and countries concentrate on financing centralized water supply system. The findings confirm that the government plays a minimal role in financing small-scale water harvesting technologies.

The study findings indicate that motivation to adopt rainwater harvesting technologies centres around water scarcity, affordability, and the need for reliable water supply for domestic and livestock. Support from County Government only accounts for 11% of the motivation factors. This strengthens the findings of Omolara Lade, and David Oloke (2015), that the major appealing factors of an RWH system are accessibility, less costly, and easy to maintain at the household level. RWH improves water supply by reducing the temporal and spatial variability of rainfall and providing water for basic human and animal needs. Storm water collection and storage have proved to be affordable and sustainable. This indicates that more needs to be done by the County Government for its efforts to be felt.

Awareness of the availability of RWHT is important in utilization for wider use. The study confirms the findings of Matthew and William (2010), who noted that increased interest in RWH was exemplified when a rainwater harvesting website hosted by the authors received over 2000 unique visitors over 3 days when a local news channel broadcasts information on rainwater harvesting systems. The majority of respondents indicate that they received information on Rain Water Technologies from the radio, indicating that for these technologies to be widely integrated into society, County Governments must design their campaigns to utilize the broadcast media. Self-help groups and village barazas also play a key role in community awareness.

The County Government of Machakos recognizes the need for adequate access to water and has embarked on a comprehensive water program which has the following components: water resource mapping, drilling, equipping and reticulation of boreholes, weir and dam construction, rehabilitation of existing water projects, rainwater harvesting and strengthening of governance structures for water service providers and community water projects (CIDP, 2018). Among the objectives of the County Integrated Development Plan, 2018 is to establish pro-poor subsidy programs in poor resource settings (free water) and to strengthen governance in water service providers (WSPs) for sustainable provision of water services for domestic, industrial, and agricultural purposes to ensure the conservation of environment. The findings of this study highlighted the cost of RWT as one of the barriers to adopting rainwater technologies, therefore, necessitating subsidy programs for Rain Water Harvesting technologies.

6.6.2 Water Harvesting Technologies and Impact on Household Livelihoods

The second objective of the study was to assess the livelihood difference of households with water harvesting technologies and those without in Matungulu Sub-County, Kenya.

The study results revealed that majority of the respondents with individual mean of 4.46 and a standard deviation of 0.861 agreed that low milk production was one of the main effects of not harvesting rain water while mean of 4.30 and a standard deviation of 0.822 of the respondents agreed that this led to poor livestock health. In addition, a mean of 4.20 and a standard deviation of 0.995 of the respondents agreed that this caused no irrigation of crops while a mean of 3.90 and a standard deviation of 0.582 of the respondents agreed that they went for long distances to fetch water for domestic use hence loss of man hours. On the other hand, means of 3.81 and 3.79 with standard deviations of 0.862 and 0.701 of the respondents agreed that it was expensive to buy water and also led to poor crop harvests respectively. Finally, a mean of 3.65 and a standard deviation of 0.734 of the respondents agreed that not harvesting rain water caused livestock deaths.

Overall, this implied that rain water harvesting had a significant impact on household livelihoods with a composite mean and standard deviation of 4.02 and 0.794 respectively. These results were further confirmed by the regression analysis that water harvesting technologies had a positive and statistically significant influence on the impact on household livelihoods ($\beta= 0.703$, $t=19.207$, $p=0.000<0.05$), hence, the rejection of the null hypothesis which stated that water harvesting technologies do not significantly influence the effects of rain water harvesting technologies among households.

RWH is defined as any human interventions for locally collecting and storing rainfall for different human activities (Lindoso *et al.*, 2018). In this regard, these study findings are in consistent with Mogaka (2009), who stated that, as clean and safe water gets scarce in many parts of Kenya, women and children will likely walk for long distances daily in search for water needed family use. UNESCO (2018), indicated that search for clean water in Kenya is characterized by an increase of large populations moving to large cities like Nairobi, leading to the creation of large slum areas with too poor living conditions and polluted water. It further detailed that the interaction of humans and water is now at a critical level in Kenya and the country thus faces a big shortage safe and clean drinking water as well as water for livestock, irrigation and domestic use. Water availability is the most critical consideration for farmers regarding what to plant and when (DES, 2011).

RWH methods focus to minimize seasonal variation in water availability such as droughts and dry spells (Rockstro M. *et al*., 2002). The social and economic sustainability of RWH practices mostly relies on the extent of household participation and the communities at large (Botha *et al*., 2004). The more the rural households are involved in planning, the higher the probability that RWH structures will be maintained and benefits shared (Bangoura, 2002). The study observed that decisions on the use of Rain Water harvesting technologies are influenced by the household head. Other influencers are self-help groups, community and governments. In this case, the county government had the least influence on decisions to use rain water harvesting technologies.

The study identified key barriers to utilization of RWT as; Lack of funds to utilize the technologies, regulations that do not support the technology use and lack of expertise to train and guide on utilization of rainwater technologies. This agrees with case studies done by Kim *et al*., (2016), who found out that the cost of a rainwater harvesting system is too expensive for most households. The United Nations (UN) recognizes the need to reduce the number of people that lack sustainable access and utilization of clean water and sanitation (UNEP, 2015). In Kenya, water crisis occurs when there is a situation of inability by the government to supply clean, safe drinking water to its population (UNESCO, 2018).

The study found out that major socio-economic benefits of harvesting rainwater included women and girls saved time for fetching water, increased opportunities for new crops and livestock, increased acreage on cropland, increased number of livestock respectively. This supports the findings by World Health Organization (2019) that improving water storage through improved rainwater harvesting technologies can enable communities to take little time and the effort of physically collecting it, and thus communities can be productive in other ways. This can also lead to bigger personal safety by minimizing the requirement to make long or risky journeys to fetch water, less expenditure on health, communities can remain economically productive. This is further depicted in this study with findings suggesting that rain water harvesting technologies affect household water availability, affordability and stability. This is because majority of the respondents with a mean of 4.34 and a standard deviation of 1.037 agreed that rain water harvesting technologies affected their household water affordability while a mean of 3.88 and a standard deviation of 0.760 of the respondents agreed that rain water harvesting technologies affected their household water availability. Overall, a composite mean of 4.01 and a standard deviation of 0.918 implied that rain water harvesting technologies significantly affected household water availability, affordability and stability.

Availability of water for irrigation has also significantly increased the household income. The study findings suggest that rain water harvesting has led to a major contribution to improving crop production. Supplemental irrigation has provided too little amount of water to enhance crop production through irrigation during the dry seasons. This supports the findings of Rockstro M. *et al*., (2002) who found out that under unpredictable rainfall situations in the semi-arid African regions of south of the Saharan, a major contribution to enhancing crop production can be expected from enhanced and up-scaled SWC and RWH conservation methods.

The findings also suggest that where there is a surplus, households are able to earn income from sale of farm produce. This confirms the findings UNEP, (2015) that improving water management improves or enhances national and rural economies. These make them more resilient to variances in rainfall and thus they are capable of fulfilling the requirements of their households' increasing numbers.

Livestock production is also positively affected by availability of water from rainwater harvesting. The study results suggest that household benefit from increased milk production as well as general livestock profitability. This confirms the findings of Ibid (2009) that rainwater harvesting methods enhance hydrological indicators like infiltration and recharge of ground water bodies. Soil nutrients were viewed to improve. Biomass production doubled, with subsequent improved production. He further states that higher biomass was noted to have supported many plants and animals. He concluded that farmers applying rainwater harvesting practices were seen to benefit from improved food security and increased income.

The study identified key areas of benefits of rainwater harvesting as reduced distance for sourcing water From the study's regression analysis, the study indicated that barriers and enablers had a positive but statistically insignificant influence on the impact on household livelihoods ($\beta = 0.036$, $t=0.700$, $p=0.484>0.05$) therefore, we accepted the null hypothesis which stated that barriers and enablers do not significantly influence the effects of rain water harvesting technologies among households. On the other hand, water harvesting technologies had a positive and statistically significant influence on the impact on household livelihoods ($\beta = 0.703$, $t=19.207$, $p=0.000<0.05$) hence, we rejected the null hypothesis which stated that water harvesting technologies do not significantly influence the effects of rain water harvesting technologies among households.

6.6.3 Machakos County Government Programs, Planning and Budgeting and Impact on Household Livelihoods

The third objective of the study was to assess interrogate the extent to which Machakos County Government integrates water harvesting technologies in its programs, planning and budgeting in Matungulu Sub-County, Kenya.

The study findings indicated that majority of the respondents with a mean of 4.44 and a standard deviation of 0.916 agreed that the county government of Machakos provided training to farmers as an incentive which encouraged water harvesting technologies while a mean of 4.35 and a standard deviation of 1.037 of the respondents said that excavation of water pans and dams for community use was also provided as an incentive. On the other hand, a mean of 3.92 and a standard deviation of 0.670 of the respondents agreed that funding of groups to implement water harvesting technologies was likewise given by the county government as an incentive. In addition, means of 3.77 and 3.72 with standard deviations of 0.727 and 0.915 of the respondents agreed that awareness creation and provision of plastic water tanks to households were given by the county government respectively. These study results support the findings of Katie M. Meehan and Anna W. Moore (2014) who found out that in the United States of America, rebates have been adopted by administrative governments in Arizona, California, New Mexico and Texas.

Overall, a composite mean of 4.04 and a standard deviation of 0.699 of the respondents accepted that the mentioned incentives from the county government of Machakos significantly encouraged water harvesting technologies. This was confirmed by a positive strong and significant correlation between integration of RHT in county development agenda and impact on household livelihoods. A further regression analysis indicated that Integration of RHT in County Development Agenda had a positive and statistically significant influence on the impact on household livelihoods (β= 0.755, t=22.351, p=0.000<0.05), hence, the rejection of the null hypothesis which stated that Machakos County Government programs, planning and budgeting do not significantly influence the effects of rain water harvesting technologies among households.

According to the Machakos County Integrated Development Plan (2015), there is an ongoing Matungulu Water Supply Project funded by Kenya Italy Department Development Programme at a cost of Ksh. 107 million which will serve a population of 28,000 people. The project scope of works includes: drilling and equipping of one borehole, construction of one grade 9 house, laying of a 5 kilometre rising main, construction of 1500 m^3 tank, laying of 15 kilometre gravity main line, fabrication and erection of 250 m^3 and 100 m^3 elevated steel tanks, construction of six water kiosks. Once completed, the total production capacity will be 720 m^3 per day (MCIDP, 2015).

In addition, there are legal frameworks on Article 142 (2) of the Water ACT 2016, which talks about rain water harvesting and household water storage to improve household water availability. SDG 6 also focuses on capacity building in water and sanitation, water harvesting technologies, desalination, water efficiency, recycling as well as reuse technologies.

6.6.4 Impact on Household Livelihoods

The dependent variable was on the impact on house household livelihoods. The study results showed that majority of the respondents with a mean of 4.40 and a standard deviation of 0.815 agreed that income generation from quality harvest of crops and sale of livestock had a significant impact on household livelihoods. Again, a mean of 4.36 and a standard deviation of 0.780 of the respondents said that availability of safe and quality water for drinking majorly impacted household livelihoods significantly. Furthermore, means of 4.12 and 4.11 with standard deviations of 0.811 and 0.843 of the respondents attributed this to easy and timely access to water by the community and that there was sufficient supply of water in the area respectively. A mean of 3.89 with a standard deviation 0.673 of the respondents agreed that rain water harvesting improved livelihoods amongst households. Overall, a composite mean of 4.18 and a standard deviation of 0.566 of the respondents agreed that rain water harvesting significantly had an impact on household livelihoods.

The findings of this study supports the report by UNEP (2015) which reported that water shortages affected food security, incomes and the general livelihoods of rural populations. In contrast, improving water management improved or enhanced national economies, rural agriculture and other food sectors. These made them more resilient to variances in rainfall and thus the ability to fulfill the needs of households' growing population. It is clear that utilization of rain water harvesting technologies in the study area has led to improved quality of life through increased food production, increased sale of livestock products and the improvement in the general welfare of the community.

Results also support the findings of Lehmann, C., and Tsukada, R. (2011), which indicated that utilization of rainwater harvesting technologies was a means of creating gender equality and empowerment of the female gender. Respondents clearly indicated that water-harvesting technologies saved them time for searching water through walking long distances. This was beneficial because communities would utilize the available time to do other economic activities that would be enable them generate more income to the households.

6.7 Conclusions

The use of water harvesting technologies had a statistically significant influence on the impact on household livelihoods. Mostly the household heads finance rainwater technologies and county government initiatives have not been adequately felt. The major barriers to adopting rainwater technologies centre on costs and lack of know-how on how to utilize the technologies. Even though the county government through its integrated development Plan has spelled out plans for the water sector, the lack of adequate budgets has hindered its implementation at household level.

There are opportunities for improving utilization of rainwater harvesting technologies in ASAL regions and authorities can mobilize the communities to self-finance these initiatives. However, the utilization of the rainwater harvesting technologies depends on the dynamics of governance mechanisms which the county uses to ensure that policies and incentives trickle down to the residents.

General wellbeing of the households are significantly improved through availability of water. This includes improvement of sanitation that enhance the health standards of the households. This ensures that members of the household are able to engage in other economic activities that improves their income as well as children are able to have equal access to education.

There is a deliberate initiative by the county government of Machakos to integrate rain water harvesting initiatives in its programmes. The study noted that county government does not participate in initiatives that promote use of rainwater harvesting technologies at the household level. There is therefore an urgent need to bridge this gap by involving development partners and community based organizations to assist the vulnerable, who cannot afford these technologies to access financial support to set up these technologies.

6.8 Recommendations

Based on the research conclusions, the recommendations below were made:

i. There needs to be proper financing, promoting and capacity building on rainwater harvesting technologies at rural households to realize targets of access to safe and affordable water among rural households.

ii. The Machakos County Government should to give continuous financial as well as technical support, strengthen stakeholder and community participation in rain water management practices besides, and provide the necessary incentives to the community.

iii. Since the current capacities, number and distribution of water pans, boreholes and water wells and not fully known and established, the government in partnership with private sector and community should plan to drill more wells and boreholes and encourage households to harvest rain water for human and animal consumptions as well as for irrigation.

iv. The government and non-governmental organizations should implement the existing policies, legislations and plans on rain water harvesting to enhance rain water availability and rural livelihoods among households.

6.9 Suggestions for Further Research

The focus of this study was on the analysis of the effects of Rain Water Harvesting Technologies on household livelihoods. There are other numerous factors that impact on the effects of rain water harvesting technologies on livelihoods among households. Further research needs to be carried out to better understand rain water harvesting practices as a whole and also establish the role of stakeholders in water sustainability. Future studies also need to be carried out to determine the effects of cultural as well as ecological determinants on rain water harvesting management and its sustainability.

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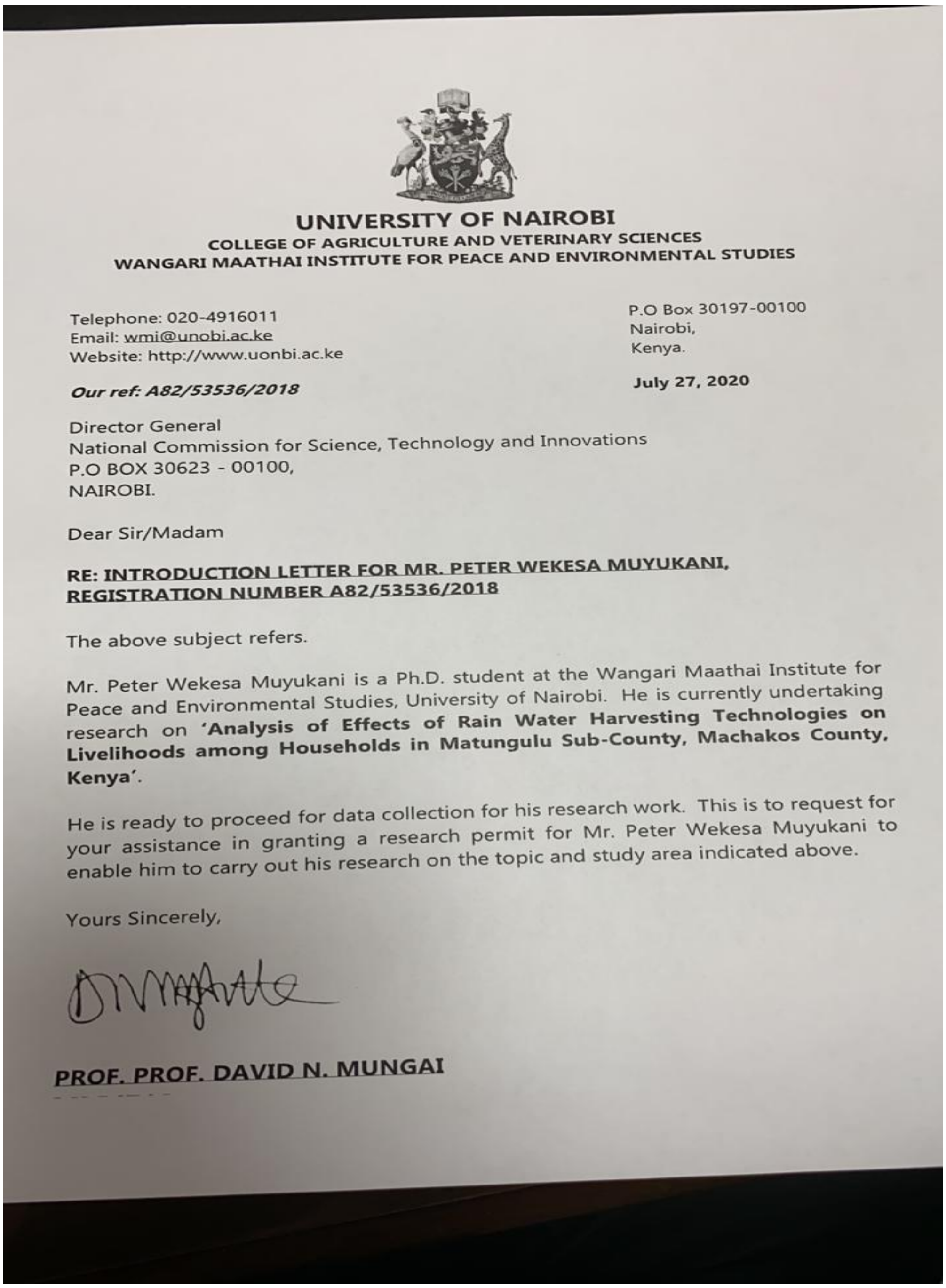
APPENDICES

Appendix I: Letter of Introduction



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P.O Box 30197-00100
Nairobi,
Kenya.

Our ref: A82/53536/2018

July 27, 2020

Director General
National Commission for Science, Technology and Innovations
P.O BOX 30623 - 00100,
NAIROBI.

Dear Sir/Madam

RE: INTRODUCTION LETTER FOR MR. PETER WEKESA MUYUKANI, REGISTRATION NUMBER A82/53536/2018

The above subject refers.

Mr. Peter Wekesa Muyukani is a Ph.D. student at the Wangari Maathai Institute for Peace and Environmental Studies, University of Nairobi. He is currently undertaking research on **'Analysis of Effects of Rain Water Harvesting Technologies on Livelihoods among Households in Matungulu Sub-County, Machakos County, Kenya'**.

He is ready to proceed for data collection for his research work. This is to request for your assistance in granting a research permit for Mr. Peter Wekesa Muyukani to enable him to carry out his research on the topic and study area indicated above.

Yours Sincerely,

PROF. PROF. DAVID N. MUNGAI

Appendix II: Household Questionnaire

<u>Introduction</u>

My name is Peter Wekesa, a PhD student at Wangari Mathai Institute, University of Nairobi. I am conducting research on **"Analysis of Effects of Rain Water Harvesting Technologies on Livelihoods among Households in Matungulu, Machakos County, Kenya."**

All the information provided will be confidential and will not be used for any other purpose but academic.

<u>SECTION A: BIO-DATA FOR HOUSEHOLD HEADS</u>

Please tick the appropriate box.

1.Gender: Female [ ] Male [ ]

2.What is your age in years? [ ]

3.Highest level of education completed? Primary [ ] Secondary [ ] Tertiary [ ] Never been to school [ ] Others [ ]

4.What is your main occupation as the household head: Farmer [ ] Businessperson [ ] Employed [ ] Self Employed [ ] Other? ________________________

<u>SECTION B: TO ASSESS THE BARRIERS AND ENABLERS OF UTILIZING RAIN WATER HARVESTING TECHNOLOGIES AMONG HOUSEHOLDS IN THESTUDY AREA</u>

5.Does your household have rain water harvesting technologies?

Yes [ ] No [ ]

6. Who makes decisions on rain water harvesting technologies in your household?

i. Household Head [ ]

ii. Spouse ☐

iii. Self-help group ☐

iv. Community ☐

v. Government ☐

vi. Any Other (Please Specify) ____________________

7.What are the main barriers that hinder you from utilizing rain water harvesting technologies? Indicate your opinion on the level of agreement in a Likert scale of 1-5 below. [Please circle: (1) = Strongly Disagree, (2) =Disagree, (3) =Undecided, (4) =Agree, (5) = Strongly Agree]

	Reason for Barriers	**Circle Appropriately**
1	Lack of funds to utilize the technologies	1 2 3 4 5
2	County regulations do not support the technology use	1 2 3 4 5
3	Lack of expertise to train and guide you on the technologies	1 2 3 4 5
4	There is not enough water from other sources other than rain water	1 2 3 4 5
5	Decision by the Household head do not facilitate us of technologies	1 2 3 4 5
6	Beliefs and traditions do not allow household to utilize the technologies	1 2 3 4 5

8. Who is the **MAIN SOURCE** of capital to purchase or construct your rain water harvesting method? **(Circle Single Answer)**

a) Head of household

b) Community

c) Self-help group

d) County Government

e) Other, Specify_____________

9. What is the level of inclusiveness in the management of rain water harvesting technologies among households in Matungulu Sub-County? [1 = Never Practiced, (2) = Rarely Practiced, (3) = Sometimes Practiced, (4) Often Practiced (5) = Extensively Practiced]

Indicate Appropriately (Single Answer) [1 2 3 4 5]

10. What motivates you **MOST** to harvest rain water? **Tick Appropriately**

1	Support from the County Government	
2	Self-drive and self-initiative	
3	Water scarcity, unavailability	
4	Water inaccessibility	
5	Group and Community initiatives	
6	To avoid wastage	
7	For domestic, livestock and irrigation purposes	
8	Reasonably affordable water harvesting technologies	
9	Frequent campaigns from development organizations on water harvesting	
10	Other (Please Specify)	

11. Who supports the water harvesting programs that you mentioned?

(Circle Single Answer)

a) Head of Household

b) Community

c) Self-help group

d) County Government

e) Other, Specify______________

12. Which of the following rain water harvesting technologies are you aware of?

(Multiple Answers)

	Rain Water Harvesting Technology	**Tick**
1	Sand Dams	
2	Roof Catchment Tanks	
3	Water Pans	
4	Rock Catchments	
5	Shallow Wells	
6	Other (Specify)	

13. How did you become aware of the above methods? (Circle Appropriately)

a) Radio

b) Self-help group

c) Village Barazas

d) Television (TV)

e) Print/Billboard Advertisement

f) County Government

<u>SECTION C: TO ANALYZE THE IMPACTS OF RAIN WATER HARVESTING TECHNOLOGIES ON LIVELIHOODS OF HOUSEHOLDS IN THE STUDY AREA</u>

14. Do you harvest rain water? Yes [ ] No [ ]

15. If **no**, why don't you harvest water?...

16. If **yes**, which method(s) do you use to harvest rain water?

a) Surface rainwater harvesting [ ]

b) Rooftop rainwater harvesting [ ]

c) Catchments [ ]

d) First Flush [ ]

e) Filter [ ]

f) Other, Specify________________________________

17. How do you utilize your harvested rain water?

a) For Sale [ ]

b) For Drinking [ ]

c) For Livestock [ ]

d) For Cleaning [ ]

e) For Irrigation [ ]

f) Other (Specify)________________________________

18. What are the benefits of rain water harvesting experienced by your household?

a) Women and girls save time for fetching water to other activities

b) Enhanced relationship/cohesion with the government and community

c) Increased acreage on crop land

d) Increased number of livestock

e) New crops and livestock now kept

19. Which crops do you produce for domestic use and/or for sale using your harvested rain water? (**Tick Appropriately)**

		C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
	Crop Grown	**Number of KGs produced**	**If sold, sale price per KG**	**KGs sold**	**KGs used at home**	**Total amount of money sold (C2*C3)**	**Costs incurred (production and transport)**	**Net income (C5-C6)**
1	Maize							
2	Beans							
3	Onions							
4	Tomatoes							
5	Kales							
6	Cabbages							
7	Bananas							
8	Pigeon peas							
9	Sorghum/ Millet							
10	Pepper							
11	Potatoes							
12	Watermelon							

20. Which livestock do you produce for sale using your harvested rain water?

Tick Appropriately

		L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**
	Livestock Reared	**Number reared**	**Number sold**	**Number consumed at home**	**If sold, sale price per KG or whole**	**Total amount of money (L2*L4)**	**Costs incurred (production and transport)**	**Net income (L5-L6)**
1	Cattle							
2	Sheep							
3	Goats							
4	Poultry							
5	Rabbits							
6	Bees							

21. Which other activities do you perform for sale using your harvested rain water?**(Circle)**

a) Fish Farming

b) Horticulture

c) Domestic Use

d) Water Venting

e) Other, specify________________________

22. Which is your main source of water for domestic and other purposes?

a) Rainwater ☐

b) Borehole Water ☐

c) Tap Water ☐

d) Bottled Water ☐

23. To what extent do rain water harvesting technologies affect your household water availability, affordability, stability? (1= It has no effect, (2) = It rarely has an effect, (3) = It sometimes has an effect, (4) = It often has a big effect, (5) = It always has a big effect) **Circle Appropriately.**

Availability	**Affordability**	**Stability**
[1 2 3 4 5]	[1 2 3 4 5]	[1 2 3 4 5]

24. What are the effects of not harvesting rain water? Indicate your opinion on the level of agreement in a Likert scale of 1-5.

[Please circle: (1) = Strongly Disagree, (2) =Disagree, (3) =Undecided, (4) =Agree, (5) = Strongly Agree]

	Effects	**Circle Appropriately**
1	Poor crop harvests	1 2 3 4 5
2	Low milk production	1 2 3 4 5
3	Long distances to fetch water for domestic use hence loss of man hours	1 2 3 4 5
4	No irrigation of crops	1 2 3 4 5
5	Livestock deaths	1 2 3 4 5

6	Poor livestock health	1 2 3 4 5
7	It is expensive to buy water	1 2 3 4 5

25. What challenges do you face when there is not enough rain water to harvest? **Tick Appropriately**

1	Women and children walk long distances in search for water	
2	You reduce stock of your livestock	
3	Some crops are not cultivated	
4	More family income goes to fetching of water	
5	Reduced family income	
6	Reduced crop yields	
7	Reduced milk yields	
8	Others (Specify)	

SECTION D: TO INTERROGATE THE EXTENT TO WHICH THE COUNTY GOVERNMENT INTEGRATES WATER HARVESTING TECHNOLOGIES IN ITS PROGRAMS, PLANNING AND BUDGETING

26. Who decides on the choice of rain water harvesting method to be utilized? **(Circle Single Answer)**

a) Head of Household

b) Community

c) Group

d) County Government

e) Other, specify________________________

27. How is rain water harvesting technologies integrated in the community?

a) Individual Effort ☐

b) Group/ Welfare Effort ☐

c) Community Effort ☐

d) County Initiative ☐

28. What is the **MAIN SOURCE** of income to purchase or construct your rain water harvesting method?**(Circle) (Single Answer)**

a) Head of household ☐

b) Community ☐

c) Group ☐

d) County Government ☐

e) Other, specify________________________

29. Does the County Government of Machakos empower you in any way on water harvesting technologies? Yes ☐ No ☐

30. Which kind of incentives does the County Government of Machakos give to encourage water harvesting technologies? Indicate your opinion on the level of agreement in a Likert scale of 1-5.

[Please circle: (1) = Strongly Disagree, (2) =Disagree, (3) =Undecided, (4) =Agree, (5) = Strongly Agree]

	Incentives by County Government	**Circle Appropriately**

1	Awareness creation	1 2 3 4 5
2	Provision of plastic water tanks to households	1 2 3 4 5
3	Excavation of water pans and dams for community use	1 2 3 4 5
4	Funding of groups to implement water harvesting technologies	1 2 3 4 5
5	Training to farmers	1 2 3 4 5

31. What do you think the County Government of Machakos can put in place to encourage rain water harvesting?

1	Subsidize roofing materials	
2	Subsidize on water storage tanks	
3	Empower communities through training	
4	Create markets for the farm produces	
5	Assist in water treatment	
6	Come up with better ways of storing and conserving the harvested water	

SECTION E: IMPACT ON HOUSE HOUSEHOLD LIVELIHOODS

32. Statements on impact on household livelihoods. Indicate your opinion on the level of agreement in a Likert scale of 1-5.

[Please circle: (1) = Strongly Disagree, (2) =Disagree, (3) =Undecided, (4) =Agree, (5) = Strongly Agree]

	Impact on Household Livelihoods	**Circle Appropriately**
1	Improved livelihoods amongst households	1 2 3 4 5
2	Easy and timely access to water by the community	1 2 3 4 5
3	Availability of safe and quality water for drinking	1 2 3 4 5
4	There's sufficient supply of water in the area	1 2 3 4 5
5	Income generation from quality harvest of crops and sale of livestock	1 2 3 4 5

Thank you for your time

Appendix III: Research License from NACOSTI

[redacted]

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **155655**

Date of Issue: **16/August/2020**

RESEARCH LICENSE

This is to Certify that Mr.. peter Muyukani wekesa of University of Nairobi, has been licensed to conduct research in Machakos on the topic: ANALYSIS OF EFFECTS OF RAIN WATER HARVESTING TECHNOLOGIES ON LIVELIHOODS AMONG HOUSEHOLDS IN MATUNGULU SUB-COUNTY, MACHAKOS, KENYA for the period ending : 16/August/2021.

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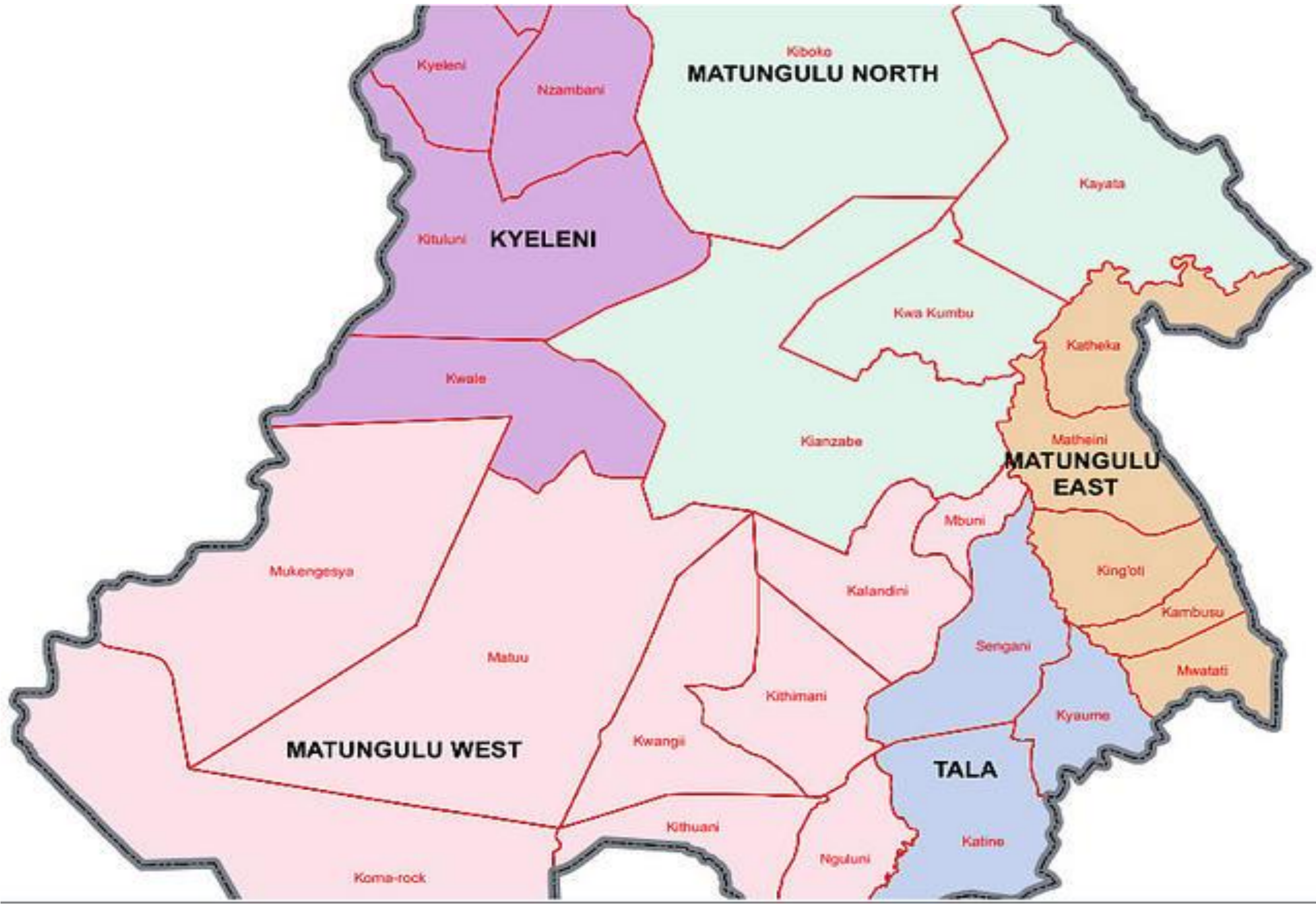
Appendix IV: Machakos County Map



1.2690^{0} S, 37.3218^{0} E

Machakos County (MCIDP, 2015)

Source: IEBC

Appendix V: Interview Guide for Key Informants

Date of interview______________________

Place of interview_____________________

Respondent's name____________________

Respondent's occupation________________

Respondent's age______________________(years)

Respondent's education level________________________

1) What is your perception towards the uptake of rainwater harvesting technologies?

   a) Adequate (b) Not adequate (c) threateningly inadequate

2) What is your view on the extent of the practice of Rainwater Harvesting Technologies in Matungulu Sub - County?

3) Are there workshops or field days to educate households or farmers about Rainwater Harvesting Technologies? If yes, how often do they take place?

4) How have households responded to the use of Rainwater Harvesting Technologies in this area?

   a) Strongly (b) Less strongly (c) Very weak

5) What has been the impact of Rainwater Harvesting Technologies on household livelihoods in the study area?

6) What activities are the government currently engaged in to ensure increased or promotion of Rainwater Harvesting Technologies?

7) What do you think should be done to encourage the use of Rainwater Harvesting Technologies in the area?

Thank you very much for your time.

Appendix VI: Work Plan

YEAR	2018				2019												2020								
ACTIVITY	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**
Course work																									
Proposal Development																									
Proposal presentation																									
Data collection																									
Data analysis, thesis write up																									
Peer presentation																									
Presentation of results and final																									
Publications																									
Graduation																									

Appendix VII: Budget

S/NO.	ITEM	UNITS	UNIT COST (KSHS)	TOTAL (KSHS)
1	Village Guide	30 days x 1	2,500	75,000
2	Research Assistant	30 days x 2	2,000	120,000
3	Researcher's Allowance	30 days	6,500	195,000
4	Communication and Internet	30 days	1,500	45,000
5	Transport to Matungulu and back	30 days	4,000	120,000
6	Local transport (Motorbikes)	30 days	500	15,000
7	Field supervision	3 days	5,000	15,000
8	Focus group discussions	5 days x 10	1,000	50,000
9	Cartridge	3 cartridges	10,000	30,000
10	Printing papers	10 realms	500	5,000
11	Publications	2 papers	15,000	30,000
	TOTAL			**700,000**