RAINWATER HARVESTING: AS AN ADAPTATION STRATEGY FOR ENHANCED WATER SOURCE IN MACHAKOS TOWN.

BY

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DECLARATION

This research project is my original work and has not been presented for any academic award in any other university.

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DEDICATION

I wish to dedicate this work to my late Dad Mzee John Nzengya Kilyungi who gave his best to show me the value of education; my loving husband Rev. Shadrack Kyalo Kasinga for his unwavering support and my great sons Nathan, Mumo and John who have already began the academic journey.

ABSTRACT

The study was conducted out in Machakos town the capital of Machakos County. The overall objective of the study was to find out whether rooftop rainwater harvesting is an adaptive strategy to enhance water supply in Machakos town. Machakos town has been facing water shortage for decades which is a setback for its development .The piped water is no longer reliable and therefore majority of the residents have turned into borehole water supply. The study reviewed the existing policy, legal and institutional framework for water supply and demand management. It also assessed the current water supply and condition in Machakos town. From the target population of 11583 households, sample size of 207 household heads was arrived. The study was based on stratified sampling procedure where some households were selected at intervals and only those available formed the sample data. The sample data were subjected to exploratory analyses to show distribution tendencies required for description of the survey data. Differences in means between two samples were specified using students t- test statistic, the independence between household samples were specified using chi-square test and strength of associations were measured using Pearson's Correlation static, all at α 0.05. The data was obtained from both primary and secondary sources. The findings of the study would be an eye-opener to all the stakeholders interested in finding a long-term solution to the perennial water shortage affecting Machakos town. The study found out that water inadequacy in Machakos town was a challenge due to fast population growth. Most of the residents rely on boreholes as their main source of water for all uses. Piped water is rationed to those who get the service with some taps having totally been dry for years. Those who practice roof top rainwater harvesting do not store enough to carry them through the dry spell. It was noted that in Machakos town, rooftop rainwater can be harvested and utilized for both domestic and other uses. Many modern homes in Machakos town have no roof top rainwater harvesting system. In such cases, rainwater from the roofs is wasted. The results of the study may be used by stakeholders to formulate policies that would ensure development of rainwater harvesting as a key source of urban water supply for urban areas in Arid and Semi-Arid areas, particularly Machakos town; whose existing water supply is below the demand as urban population increases every year. Thus, the study recommends that; all stakeholders in the water sector in Machakos town have to come together to marshal ideas and resources in order to enhance roof top rain water harvesting; failure to which Machakos will continue to face water shortage. This also has a ripple effect in slowing down economic/industrial growth of this strategic town. As the population continues to increase with the attendant increased demand for more, the already bad situation occasioned by the impacts of climate change can only get worse. The said concerted efforts will enhance the existing water supply to Machakos town, which currently depends on water from boreholes, as the main source. The study also recommends construction of road site water harvesting to enhance supply for water for non-domestic uses. This is vital because Machakos town has many tarmac roads, streets and paved surfaces, which collect large amount of water and drain it to rivers and streams onwards to the Indian Ocean. This large amount of water that is lost perennially could be harvested, treated by following standard treatment procedures and finally supplied for irrigation and other water –depended activities in Machakos town.

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ACRONYMS AND ABBREVIATIONS

ASL	Above sea level
ASAL	Arid and Semi-Arid Lands
CBD	Central Business District
CESR	Committee on Economics, Social and Cultural Rights
GIS	Geographic Information System
GOK	Government of Kenya
ITCZ	Inter Tropical Convergence Zone
KNBS	Kenya National Bureau of Statistics
LCD	Less Developed Countries
MDGs	Millennium Development Goals
NACOSTI	
NGOs	Non-governmental Organizations
NWCPC	National Water Conservation and Pipeline Corporation
OECD	Organization for Economic Cooperation and Development
RTRWH	Roof-top Rainwater Harvesting
RWH	Rainwater harvesting
SPSS	Statistical Package for the Social Sciences
TV	Television
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
WARMA	Water Resource Management Authority
WHO	World Health Organization
WSSP	Water Sector Strategic Plan

DEFINITION OF TERMS

Central Business District- the commercial and business centre of a city.

Geographic Information System- a system created in a manner that allows it to gain, stock, and influence, analyse, manage, and reflect spatial or geographic data.

Inter Tropical Convergence Zone- a low-pressure belt that orbits the Earth Generally close to the equator where the Northern and Southern Hemispheres trade winds converge.

Kenya National Bureau of Statistics- a department that operates under Kenya's Ministry of Planning whose main role is to collect and compile regular cross-sectoral data for the government.

Mega city- a significantly large city that is composed of a population of more than ten million people.

Meteorological drought- this is used in reference to the minimization of rainfall for a particular period, below an established statistical amount of the long-term average for the specified time period. It is a simple absence or deficit of rainfall from the normal.

Millennium Development Goals- eight objectives that are composed of quantifiable targets and clear targets for improving the lives of the world's poorest people.

Per capita Water use- Water use per person/individual

Potable water- water that is safe to consume or to use for food preparation without creating a risk of health problems.

Rainwater harvesting-This is a method used for gathering, storage and using rainwater for the sake of land irrigation and additional uses.

Rooftop Rain Water Harvesting-This is the system through which rainwater is harvested from the roof harvesting and stored in storage reservoirs.

Runoff- the draining away of water (or substances carried in it) from the surface of a part of land, a structure or construction.

Salinity level- the saltiness or amount of salt dissolved in a body of water.

Statistical Package for the Social Sciences (SPSS) - a software package used in statistical examination of data.

Storm water runoff- the excess drained into creeks, bays and other water sources after a rainstorm.

UN-Habitat- United Nations agency for human settlements and maintainable urban development.

Vision 2030- is the country's growth programme from 2008 to 2030.

Water rationing- the controlled distribution of water due to its scarcity.

Water Stressed Countries- countries where the request for water surpasses the available quantity during a particular phase and when poor quality confines its use.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Water has lately been the most serious limiting factor to development world over, assuming a strategic importance almost at par with oil. Accessibility to water is considered as a fundamental human need and an important indicator for human progress. It supports the fulfilment of additional human rights and is a condition for achieving wider human improvement targets. As such, restricted access to water slows down economic growth, fosters deep inequalities in terms of wealth and sex and is one of the central barriers to enhanced progress in the world. As at 2015-2016 the population was 7.3 billion and was developing at a rate of about **1.13%** per year. The average populace increase now is projected at 80 million per year. The globe is reliant on less than 1% of the total amount of fresh water to sustain more than 7 billion people. It is projected that half of the global populace lives in cities. Consequently, the number is expected to rise to 60% within the next two decades. Urban growth is growing significantly in developing countries where the cities are constantly gaining an average of 5 million inhabitants monthly. The increasing growth of urban populations results in unanticipated challenges with water and hygiene occurring as the major and painful ones when deficient. Countries are racing to find new water sources to satiate the thirst of urban populations and industry (Chamock, 1985).

Consequently, the water is also dispersed unevenly in the globe. About 54 per cent of the world, or 3.9 billion people, dwell in urban areas and the number will grow between 60 and 92 per cent by the close of the century. A 1.5°C rise in the average global temperature again will expose 357 million urban dwellers to extreme droughts while the figure for a 2°C rise will be 696 million, research shows.   Not only are our cities headed to a dry future, but the scarcity will multiply because people are moving to urban areas at alarming rates. As a result, the urban water demand will rise by 80 per cent by 2050.   A 2015 study, published in the Global Environmental Change, says expanding dry lands and increasing urbanisation could make nearly 0.5 million square km of urban areas drought-prone by 2030. This is nearly 300 per cent increase from the 0.17 million square km of urban area identified as drought-prone in 2000**.**Most worryingly, “climate change will alter the timing and distribution of water,”(*Sushmita Sengupta*, 2018***)***

Kenya is experiencing a rapidly growing population that is also shifting from rural to urban. In the last census of 2009, an estimated 39% of the Kenyan population was urban based. The unequal distribution of human settlements and water resources has led to continued problems in relation to the availability of fresh water and accessibility. This is influenced by the fact that the entire amounts of fresh water across the globe have always persisted roughly the same.

There is declined Levels of Water Per Capita in Kenya. The annual fresh water supply at 647 m3 per person per year is one of the bottommost in the world and which was anticipated that towards the end of 2010, the rate of renewable freshwater supply would have declined to just over 500 m3 per capita annually, and by 2020, to 235 m3. Consequently, the levels are significantly lower `below the international standards of 1000 m3 per capita, and far below Kenya’s neighbours, Uganda and Tanzania, that have yearly per capita renewable water provisions of 2,940 m3 and 2,696 m3 per capita, correspondingly.(National water policy 2010).

In the developing countries, water crisis is more evident in the fast-expanding cities . Cities have seen explosive growth in recent decades as a result of migration from rural areas or natural increase in the towns .Most of these towns are already failing to provide basic services – including water and sanitation – to new residents, who typically occupy informal slums and shanty towns beyond the reach of municipal services. Population growth, then, is a driving force behind the breakneck pace of urbanization and compounds the challenges of providing safe water to city dwellers. Population growth, then, is a driving force behind the breakneck pace of urbanization and compounds the challenges of providing safe water to city dwellers. (Water and Population: Laurie Mazur, , 2012).

Some of the major challenges that are linked to water are affecting the people’s expenditure. They present themselves in the form of water related catastrophes such as droughts and floods and the lack of access to safe water and hygiene. These issues have colossal results on human health and prosperity, wellbeing, the surroundings, economic development and growth. In spite of the fact that water supply and sanitation scope expanded somewhere in the range of 1990 and 2008, the development of the globes urban populaces risks those outcomes. We are expecting more trouble later on due to climate change, which is the main cause of change in rainfall patterns. Most of the world water issues happen because of uneven distribution of rainfall in terms of time and space, which have been exacerbated by climate change. A few nations experience the ill effects of water deficiencies while others have excessive water on their land.

Rainwater management is required to solve the complications that are linked with water now and in the future. Rainwater has grown to become a major issue in various international assemblies comprising World Water Forum and UNEP gatherings. There are wide ranges of rainwater harvesting practices that are evident across the globe. The traditional and modern practices are utilized in arid, wet or monsoonal climates. In this case, populations have the option of adjusting to traditional knowledge or new technology.

Rainwater harvesting has positioned itself as one of the most favourable substitutes for supplying freshwater in a time when people are experiencing an increase in water scarcity and growing demand. The United Nations Committee of Economics states that Social and Cultural Right, "The human right to water give everyone the right to sufficient, safe, reasonable and physically available and low-priced water for domestic and individual" (Committee on Economics, Social and Cultural Rights (CESR) 2002 – "The Right to Water.") Yet for 1.1 billion people, adequate, safe, satisfactory and inexpensive water for life is a hope for yet to come years and not a reality as at now.

Throughout the world, the essential water problem is how best to reconcile the increasing use of fixed supply with the needs and constraints of human socially, in a way that will maintain a stable environment (Biswas, 1978). Kenya faces a significant problem with its current population of approximately 49 million and a projected population of 51 million by 2020 in regards to the management of its limited water assets (GOK, 2006). The scale of the disputes and challenges and harshness of the water crisis that presently face Kenya cuts across most segments of the economy, making water services delivery a high importance demanding urgent responsiveness.

Currently water demand outgrows water supplies in all key sectors in the country. For instance, while the country has an irrigation potential of 539,000 ha (based on surface water availability), there is potential to raise this to at least 10.5 million ha through enhanced development of additional water storage. One way of achieving this target is harvesting rainwater.

Kenya gains a renewal supply of less than 650m^3 for every individual per year which makes it one of the scarce regions in the globe. Additionally, the yearly rainfall is highly variable.

Consequently, it is estimated that the renewable freshwater in Kenya will be 235m^3 per capita. The minimal levels of water supply services and the reducing rate of water resources on a national level is being experienced at all the levels in Kenya. The World Bank estimates that 54% of the population or 23.6 million individuals will be living in urban Kenya by 2030.

The increasing population puts pressure on water resources through land, agriculture, and energy use among other factors. The influx of individuals moving to large cities such as Nairobi, has also caused huge problem of supplying clean water especially to fast growing slums. (Kenya Water Crisis, 2017). The present scuffle that Kenya faces is facing is to supply clean water throughout the entire population in urban areas. This is due to increase in community settlements and over use of the water due to increased demand.

Water deficiency is a well-known problem in Machakos County. It is evident that only 30% of the county's populace receives clean water. The problem is more in urban areas within the county. In Machakos town Maruba dam which is the leading source of water was expanded with the view of increasing water supply but did not solve the problem. The establishment of County Governments has created hope among the residents that there will be water supply to estates as a priority. However, the County Government does not seem sentient of the needs of local people as many residents so far do not have the water supplied to them but are relying on private boreholes.

1.2 Statement of the Problem

The greatest challenge the world faces today in the quest for sustainable human settlements is the rapid increase in urban population. Cities and towns accommodate majority of the globes population. The metropolitan population of the globe has increased significantly from about 200 million, which represented 15% of the population in 1900 to 2.9 billion, which represented 50% of the globes population in 2000. It is also evident that the sum of cities with a population that exceeds 1 million rose from 17 in 1900 to 388 in 2000 (McGranahan et al., 2005).

As indicated in a recent article (World Mega cities: Densities), the number of mega cities increased from 29 to 34 (mega cities are metropolitan regions with residents who exceed 10 million). Urban populations are increasing three times faster than overall populations and increased population globally means reduced per capita access to natural resources especially water. Informal service providers are subjected to the task of providing water to the poor in urban regions. It is also evident that the ground water cradles are increasingly protected and contaminated and are not categorised as safe for use (national water policy -2010). The increased settlement of people in cities leads to the need to foster urban schemes that contribute to the well-being of humans and minimising ecology service burdens.

As more people continue to live in urban settlements, the habitats have served as a change of ecosystem. In this case, it is crucial to foster the urban settlements that continue to contribute to the well-being of human beings and minimising ecosystem service burdens. Accordingly, rainwater collection is a profitable supplementary hotspot for household water prompting developing enthusiasm for the utilization of rainwater catchment frameworks in the urban zones. In its widest sense, rainwater reaping is an invention used for the purpose of harvesting and keeping rainwater for use from housetops, pavement surfaces or shake catchments using forthright strategies, for example, containers and pots and furthermore built procedures. There are different sorts of rainwater gathering incorporate utilization of underground tank and where the water is directed out when being used. It is protected and has an amazingly low rate of dissipation. A sort of lake is generally mud-bottomed, but might be fixed with concrete at times. Surface keep running off is directed into them to shape ponds.This is another kind of substantial scale adaptation of rainwater collecting. The most widely recognized utilization of a rain-encouraged maintenance lake is watering livestock. However, the water can likewise be drawn out to water gardens, crops, or different plants. Lake collection is just suitable in zones with a lot of precipitation and soil that is wealthy in dirt, since sandy soils splash up water too rapidly to consider much overflow. Other forms of rainwater harvesting include planting pits, micro-basins, retention basins, gully plug, bunds, field trenches, conjunctive use, sand dams, controlled drainage or fog drip.

Rooftop rainwater harvesting (RTRWH) is the most widely recognized strategy for household use. It includes rainwater gathered on the rooftops and passed on with drains to a capacity supply, where it gives water at the purpose of utilization. Rainwater collecting has the ability to enhance water fonts when they turn out to be rare or are of low quality like blackish groundwater or contaminated surface water in the stormy period.

Considering that Kenya is a water scarce country, with over eighty percent of the total landmass covered by ASALS whose mean annual rainfall is less than 200mm and that 37% of sub-Saharan African and by extensions Kenya, water in cities in the new millennium will definitely be a very critical resource in developing issues and nation building. Where the government is unable to provide adequate and reliable water supply to its citizens to meet their needs, there is a great need to provide an alternative which allows people to be self-sufficient as prerequisite for better livelihoods and this is rainwater harvesting.

Machakos town experiences water shortage, which is a challenge to the residents. In a survey carried out, among those interviewed, 21% indicated that their central water source was boreholes. 30% stated that they purchased from water merchants and 15% indicated that they acquired their water from river, 22% most of who are based in the town stated that they had piped water connection.

1.3 Research Questions

i. Is population growth the primary cause of water shortage in Machakos town?
ii. What adaptation strategies have been used by households to overcome water shortage in the town?
iii. Is rooftop rainwater harvesting a measure to enhance water supply in Machakos town?
iv. What are the common methods of water harvesting in Machakos town?

1.4 Objectives

i. To find out whether population increase is the main cause of water shortage in Machakos town
ii. To detect the adaptation strategies used by the households to overcome water shortage in Machakos town
iii. To find out whether rooftop rainwater harvesting is a measure to enhance water supply in Machakos town.
iv. To find out the Common methods of water harvesting in Machakos town.

1.5 Hypotheses

1. H0: There is no significant relationship between water harvesting and adequacy of water supply in Machakos town.

2. H0: There is no significant relationship between population growth and water shortage in Machakos town.

1.6 Significance and Justification of the Study

A study done by Inside Informality, WB report No.36347-KE (2006), shows that 80% of the unfortunate people in Kenya lack access to affordable and safe consumption water. The study also shows that protecting the water sources has failed to provide a solution of the contaminated ground water sources and utilization of the inappropriate sources of water by the informal providers is discouraged. It is evident that people queue for water for many hours, which is not tested or controlled, and the price of the water is 5 to 20 times higher than payments charged by official suppliers to desperate consumers. There are underserved that host 50% of the urban population and are developing significantly faster as compared to other areas in the region. It is expected that the number of the undeserved will grow significantly making it necessary to increase the access to safe water. Additionally, the informal providers occur in the form of cartels that profit from the existing monopoly power by altering competition and establishing artificial shortages in the regions.

Kenya recently launched an ambitious socio-economic development agenda; the Kenya Vision 2030, which envisages attainment of middle-income status by the year 2030 (National water harvesting and storage -2010). The Vision forecasts the expansion of tourism, agricultural, industrial, business and financial sectors and heavy investments in economic, social and political infrastructure. Concurrently, Kenya subscribes to the Millennium Development Goals (MDGs) that require nations to halve the amount of their populations without admission to safe drinking water by 2015.

To respond to these framework Plans, the Ministry of Water and Irrigation developed a Water Sector Strategic Plan (WSSP) of 2010, which outlines the development of responsive pathways. By this (WSSP) the people of Kenya are poised to improve attitudes towards human interactions with the natural environment; more so, on the conservation of water catchment areas, especially the, water towers. These actions should lead to reduced poverty levels, enhanced food security, reduced unemployment, good health and creation of wealth, all necessary for realization of the Vision 2030. The latter envisages that by 2020 the demand for water to power the economy shall rise well over an estimated 16,500 mm3 per day, which require some strategies to meet the demand. Kenya's natural water assets furthermore fail to provide equal transportation of water to the varying areas of the nation. The nation's water towers do not attain a fair distribution in the nation with climate change taking a noteworthy toll on the water accessible. This leaves a large portion of the inhabitants with very little supply of water. Fast development has likewise determined poor urban inhabitants to the ghettos, where there is no water or hygiene, and congestion fuels the effectively hazardous health circumstances.

Rainwater harvesting can be a solution for times when the steady water supply has been affected. It is of great use during times of drought. Rainwater is the clean source of easily available drinkable water and if practised in urban residential areas, it can meet almost 50% of the city’s water needs (Water in crisis-spotlight Kenya). Additionally, households and commercial buildings can lead to the preservation of water bills. The harvesting rainwater is not limited to the maximum utilization of a freely accessible resource but also about reducing the influence of urban growth on our natural ambiances. In fact, failure to harvest rain results not only in the evident loss of a treasurable resource but also heavy soil erosion.

Rainwater harvesting has the ability to play a direct and indirect role in the attainment of many of the MDGs, mostly domestic requirements of safe drinking water. A more all-inclusive view of individuals wellbeing is taken by era ecology valuation (M.A 2005) in which human wellbeing is not only a consequence of good well-being and satisfactory basic delivery of food, housing and other measurable needs but also linked to sovereignty of choice and achievement, safety and the need for good societal dealings.(M.A (2005) . To meet this demand requires the development of elaborate water storage systems such as the Grand Falls Multipurpose reservoir with storage of 5.4Bm^3; the two multi-purpose dams on Nyando and Nzoia River with a joint storage of 2.4Bm^3; and the 22 medium-sized multi-purpose dams with a total volume of 2Bm^3.

Water is used by man directly for his own extensive economic and social development, hence quite a highly valuable and mobile resource. Shortage of water has conditioned the progress of civilization and development. With continued climate change and depletion of ground water, research should be done to conciliate available water resources and water demands as regards both quality and quantity at present and in the future. Rainwater harvesting is a reliable source that can enhance water supply for a majority of the households. This topic attempted to critically review the water access in the area of study which is a water scarce region as currently water demand outstrips water supplies.

The urban water problem is becoming chronic as a result of rapid population growth in Machakos town, which poses a major problem resulting to greater demand for water. Water supply schemes in Machakos deliver services to roughly 86% of the total population (WHO/ UNICEF 2010). However, the service is not continuous. This has resulted to severe water rationing. Most of the institutions in Machakos town obtain their water from boreholes that they have drilled. Most of these organizations have little attention in the services of public water department as their organizations though linked to the public source does not have flowing water in their taps most of the time. A number of them had demanded for disconnection from the County government to guard against being charged for services that were not being offered. If appropriate measures are not taken to address water supply and demand issues then the town stands the risk of not realising its full potential in terms of economic and social development. Sustainable and efficient use of water would enhance the achievement of the millennium development goals (MDG) especially goal number 1(to eradicate extreme poverty and hunger) and goal number 7 (to ensure environmental sustainability) and consequently reduce stress on water resources. The findings of this study will therefore be useful to government officials both at the National and county level especially in the ministry of environment & water and ministry of trade & industrialisation by informing policy decisions such as prioritising water management to meet the increasing demands of the town. Despite contributing to studies on water as reference, the results of this study will assist the government and policy makers to plan better and manage water matters especially on RWH.

There is need for a review on what has been done and what remains to be done to correct the water problems. Simple contrivances that discourse the vital issues have to be utilized to provide the residents with water. Rainwater harvesting is a significant alternative that is worth analysing for Machakos, the headquarters of the county. Rainwater catchment systems present themselves as a manageable solution that is adaptable in many parts of the country. A majority of houses are equipped with storage tanks to harvest rainwater although they don't store enough water to serve in between the rain seasons. . In this case, it is clear that harvesting of rainwater would require a basic catchment system.

Harvested rainwater is capable of supplementing town's supply systems for growing estates that are not linked to a water supply network. This study focused on assessing household scale rainwater catchment systems that can facilitate the channelling of water through pipes that are installed on roofs. The pipes then transport the water to elevated or underground tanks which many households in the region have. The system can be used as an alternative to the current private and public supply systems. Additionally, it is capable of reducing water bills while enhancing the supply in some regions. Moreover, the system is an essential investment for the families that purchase water from private companies and for households that have pre-installed tanks.

1.7 Scope of the Study and Limitations

This study will attempt to look at RWH as a way of complimenting other sources of water or alleviating water shortage in Machakos town. The study focused on rooftop rainwater collecting as a way of acquiring water for domestic use and a solution worth assessing, though not projected as the sole solution to resolve the problem of water scarcity, but could solve water shortage if used along other water sources. Considering water scarcity in the town, a substantial amount of households have raised or put underground water storage tanks installed to provide water for their daily use. This practice makes rainwater catchment systems a great option to be measured because the method utilizes the prospects, the city's climate as well as existing setup. The study focused on water supply and demand management in regard to domestic use in Machakos town. Although water demand management is an important part of sustainable development and economic growth, the study could not exhaustively address all issues related to domestic and commercial uses of water in Machakos town. It paid particular attention to the main sources of water, causes of water shortage and strategies in place to adapt to the water shortage in the town.

The study did not include the policy guidelines by the government to coordinate water harvesting practices and development. It did not consider the quality and the socio economic repercussions of rainwater gathering and reliability of rainwater harvesting systems among the varying unconventional tools to supplement freshwater assets, rainwater collecting and use is a dispersed, ecologically comprehensive solution that is capable of avoiding the many environmental issues that often result in conventional large-scale schemes using centralized methods.

CHAPTER TWO: LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 Introduction

The aim of the review was to check on the documented work on rainwater harvesting and the current information on the same in Machakos town. This helped the researcher to evaluate the role of rainwater in enhancing the supply of water supply in urban areas. The review took into account what has been studied in other urban areas of the world concerning water supply. It was meant to ensure that there is no repetition of the same study. This chapter has the theoretical and empirical literature starting with global, regional, local and then the specific area of study.

2.2 Literature Review

2.2.1 Water Supply

Water supply is considered the most pressing issue in the 21st century across the globe. Evidently, water related stress and scarcity are now the greatest hazard to environment, human health, universal food supply and economic and social advancements (IDRC, 2000) "Of the entire social and natural crisis that individuals face, water catastrophe are crucial to the survival of the planet and human beings (United Nations Educational Scientific and Cultural Organization (UNESCO) director, Koichiro Matsuura 2003). By concentrating the globes attention on water, the need to protect sustainable fresh water use and the importance water plays to human lives, the survival of the planet and international security has been increasingly recognized. It is evident that having access to safe drinking water is a basic human right. In this case, denying people from this right constrains their freedom and subjects them to poverty, ill health, and susceptibilities.

Water is a renewable natural resource whose use is a major element in the growth of livelihoods and as such, the equitable distribution of basic water needs is crucial (Hardin, 1965). The world is facing intensifying demands for moral quality water as present use from both ground and surface outdoing supply. Regions that have adequate supply of water are also found to have constraints based on the need to balance the present supplies with the increasing demands. Additionally, natural circumstances such as droughts increase the need to protect, conserve and supplement the water sources.

Fifty years ago, it was believed that water is an unlimited resource based on the fact that there were a large number of people on the globe. Therefore, they only need a third of the volume that we currently consume from rivers. Currently, water is a critical resource that has led to competition, which is intense especially due to the increased population, biofuel crops and urbanization. Evidently, urbanization has played a crucial role in increasing the competition for water resources due to the increased contamination and management issues.

According to the Stockholm Environmental Institute, it is estimated that close to 4.4 billion people could be subjected to livelihoods under severe circumstances of water stress particularly in the Middle East, Africa, and South East Asia by 2025. The UN indicated that water security is one of main resource issues that are facing mortality next to the issue of population growth. Water security is about ensuring that every individual has consistent access to sufficient safe water at a reasonable price to result in a healthy decorous and fruitful life.

There is rapid urbanization that has created a global urban crisis, especially demand for water, which is a major contributor to water stress in those areas. Increase in urban population especially in third world countries and Africa in particular where up to 150 million urban inhabitants on behalf of about 50% of the urban population do not have a adequate water supplies to meet their demand. For instance, regions such as Nairobi and cities like Dakar and Johannesburg have surpassed their volume of local sources to provide satisfactory provisions and are subjected to source water as far as 200 and 600km away (The Daily Nation, March 21st 2003) thus spreading their ecological foot prints (Gerardet, 1996) on the environment further afield while creating potential for future conflict (UN-HABITAT, 2001).It has been projected that by 2025 about one billion people will be living in cities experiencing water stress and possibly chronic water supply. It has been documented that larger metropolitan areas and mid-sized cities in LDC's are barely coping with rapid urbanization. Some projections suggest that population in LDC's will reach 4billion people by 2025. Some higher estimates reach 5billion, which would be 60 per cent of projected future world population (Gleick et al. 2002).

In 2001, New York City announced the first drought emergency since 1989. The emergency was influenced by the fact that the cities reservoir reduced to 40% below normal leading to the need for obligatory use restraints. As a result, a resources group was founded to respond to the drought year. Since then, WRG have developed 35 rainwater-harvesting systems within the city to collect over 422,900 gallons of storm water annually. In this case, it is clear that the gathering and storage of rainwater is capable of supplementing the present water provisions as a means of addressing some of these issues. Rainwater use is an effective method for recuperating natural hydrological cycles and assisting in the defensible urban growth (Kim et al. 2005a).

RWH has conventionally been utilized in varying parts of the globe since the commencement of the history of human beings, without any posing any challenges. Lately, people began to deliberate of this overlooked insight as the primary choice to solve the globes water problem. A new model for the management of rainwater is needed to meet the needs of the SDGs, diminish drought and flooding and conserve sustainability during shifting climate and energy catastrophes. With this new hypothesis, several actions are obligatory. These comprise the participation of diverse investors, research and growth of tools, establishing a reasonable background and backup resources for the decision makers, training and public mindfulness and building global networks. The visualization of rainwater collecting is to establish consistent surroundings by appropriately and intelligently using rainwater.

Rainwater harvesting is an antiquated practice. Wide ranges of cultures have utilized this innovation for horticultural purposes. The Philippines have been utilizing precipitation water for rice patios for a great many years now. Indians have utilized it as aeration and cooling systems. In spite of the fact that rainwater collecting was a noteworthy and effective outline previously, its notoriety has declined throughout the hundreds of years. Anyway, because of innovative water pollution and dry spell because of environmental change rainwater reaping methods have returned into training once more. For example, India and Sri Lanka RWH have expressly been incorporated into the water approach as a non-traditional resource of water next to surface and ground water.

In some Indian urban areas, like the declaration of the Kenyan government, RWH was influenced obligatory for every new working, to be it isolated or open. In Sri Lanka, the rooftop top water is even viewed as a private water source. Besides, in Thailand, environmental water is said as a water resource in the Water Act (Mutua 2010).

In Africa, more than 33% of the populace needs access to safe water stock (DFID, 2001). These statistics are set to deteriorate as interest for water is expanding at a disturbing pace. Throughout the following twenty years, the normal supply of water per individual is relied upon to decrease by a third. At present, 14 out of 53 nations are delegated water focused or water rare. A water focused nation has water accessibility of under 1,700 cubic meters for every individual every year and a water rare one under 1,000 cubic meters for every individual every year. The vast majority of the nations frequently encounter outrageous water lack amid droughts. It is assessed that the quantity of nations in Africa in this circumstance could be twofold by 2025 to about half overall.

The report's general decision is that Africa is not water rare. The rainfall commitment is more than sufficient to address the issues of the present populace a few times over. For instance Kenya would not be sorted as a 'water focused on nation' if rainwater reaping is deliberated. The water emergency in Africa is a greater amount of a monetary issue from absence of venture, and not a substance of physical shortage''.

Rapid population development and incompetent use of resources increase the shortfall between the accessible water supplies and the necessities of individuals. As resources diminish and water request expands, extensive scale water supply ventures end up unviable. There is have to decentralize water supply to family and little network level. There is awesome potential to improve utilization of water resources and harvesting rainwater and putting away it locally for family unit profitable purposes. Absence of water is the biggest prevention to economical vocations in numerous parts of Africa. Fast overflow amid the stormy season regularly results in a high extent going to squander or notwithstanding getting to be ruinous. Harvesting precipitation water where and when it falls presents chances to address water shortage.

In the focus on the natural resource of fresh water, the economic system is dealt with in so far as it generates both the demand and means for fresh water resource exploitation (De vries et. al. 1997). Rapid urban population increase is putting intense tensions on water resources and environmental safeguard competences of many cities. The existence of these urban centres is threatened by one critical problem-how to acquire an adequate supply of water and to what extent can water demand be met and under what condition (UN-HABITAT 2003). One of the targets of the MDGs was for the world governments and international community to decrease by half the proportion of people who do not have access to bearable, safe water for consumption by the year 2015 (UN-HABITAT, 2003).However, this was not achieved by 2015.

In Africa, the vast majority lacks have access to adequate portable water to meet their basic needs. Unlike the north that is characterized by formal settlements complete with utilities, for most third world cities, and particularly in Africa, residents of informal settlements and those in the lower middle-and lower-income brackets residing in peri-urban areas form the bulk of the urban population. In these areas, no services exist and if provision is made, especially for water and sanitation, one standpipe or toilet is likely going to serve an overwhelming number of people (UN-HABITAT, 2003) as in the case of the slums in the developing countries. It is in this underprivileged areas where ironically people pay up to ten times what their affluent counter parts in formal settlement pay for water despite their meagre resources, whereas the latter have “unlimited” access to water through taps located within their homes. The former have to spend a substantial amount of their time and energy, in line of economic productivity, to fetch small quantities of water often in 20-litre containers. Poor residents are by nature not wasteful on the account of their meagre resources and it therefore becomes difficult and sometime impossible, to “preach” new water-use ethics to people who do not have water in the first place and who have to pay dearly for the commodity from vendors!

Over the coming years we will require a scope of processes and innovations to catch water and support supplies. Saving and restoring lakes, swamps and other freshwater biological communities will be fundamental. Dams, assuming they are professionally and reasonably outlined and developed, might be a piece of the condition as well.

Rainwater gathering can be a support against drought occasions for urban regions while additionally fundamentally supplementing supplies in them and regions associated with the water lattice. Dennis Garrity, Director General of the World Agro ranger service Center, stated: "In the well-known personality, Africa is viewed as a dry landmass. Nevertheless, largely, it really has more water possessions per capita than Europe. In any case, quite a bit of Africa's rain comes in blasts and is quickly cleared away or is never gathered (Ngigi, 2003). Time has come to understand the considerable potential for enormously upgrading drinking water provisions and smallholder rural generation by harvesting a greater amount of the rain when and where it falls."

A few nations are currently misusing their rainwater. In South Australia, more than 40 for every penny of families utilize rainwater put away in tanks as their principle wellspring of drinking water. Germany has over a large portion of a million rainwater-harvesting plans thus this is certainly not an inferior innovation yet a top notch, minimal effort one. It is an innovation that need not hold up additionally innovative work so with little adjustment it is accessible now (Belmont, 2009).

Water is a nationwide social, cultural, and economic good and Kenya has the ability to enhance the external and groundwater resources and purified seawater. Some developments in the sector for WRM have copied from UN Water Conference of 1977; a wide range of international summits on water resources and setting; the Dublin Report on water and maintainable development of 1992.

The Kenyan economy is expected to grow at 10% per annum in accordance with Vision 2030. To realize this growth rate, provision for adequate water for various uses is paramount. The country is urbanizing at fast pace with all the attendant challenges: outstretched infrastructure for basic utilities, overwhelmed authorities and unplanned developments. This project addressed rainwater potential as a way of enhancing water supply in Machakos town. It was observed that 16.1% household toilets were informally connected to public sewerage system.

Compared to other countries, Kenya is reflected on as a water scarce nation with per capita water of 6.1 M^3 which is far below the endorsed global standard of 1,000 M^3. South Africa, with similar rainfall variability, has a per capita storage of 655M^3.

As a worst scenario where no intervention is done, the scarcity is expected to deteriorate further by the year 2030 when per capita will be very minimal at less than one cubic metre per person. The existing total water storage in the country is estimated at 181 million cubic meters. This amount falls short of the required 3.4 billion cubic meters of storage for reliable water supply by the year 2010 and the deficit is expected to be 7.6 billion cubic metres by 2030(National water policy 2010). This is because of anthropogenic exercises causing declining vegetation decent variety inside the six vital water catchments, powerlessness to take full preferred standpoint of green water incomes; deforestation of cover from 17% (in 1990) to 1.2% of the land delegated timberland against a global seat characteristic of 10%, absence of exhaustive profluent treatment and reusing methodology and uneven circulation of water resources prompting serious shortages in specific territories because of inadequate between bowl water exchanges. There is likewise expanding pollution of water resources rates in dismissal of general wellbeing dangers and the water prerequisites of downstream populace, deficient surge and tempest water administration, lacking acknowledgment of environmental change issues, powerless direction and implementation, insufficient data sharing and announcing, insufficient financing of WRM and advancement and clashing institutional orders.

According to the Kenya National Water Development report (2005), Kenya has an annual surface water runoff of about 20 billion cubic metres. In the year 2003, it had a total storage capacity of only 181 million cubic metres, which represented storage per capita of 6.1 cubic metres.

Nevertheless, rainwater gathering is winding up more boundless in Africa including Kenya. Since the late 1970s, numerous tasks have risen in various fragments of Kenya, each with their own particular outline and execution methodologies. These tasks have been in charge of the development of a huge number of rainwater harvesting tanks all through the nation.

In the year 2014, Kenya's minister for water declared plans to necessitate every new working to incorporate rainwater-harvesting methods. Comparable designs have been actualized in India, where through work facilitated by the Barefoot College, somewhere in the range of 470 schools and network focuses now gather 29 million liters of rainwater in districts where ordinary supplies are risky because of saltiness made by compound and metals defilement. There is have to address the overabundance request over supply occasioned by populace development and monetary advancement and additionally poor access to clean water. This has additionally been credited to debasement of condition and sea-going frameworks causing flooding, diminished ground water energize, and lessened stream base stream. Poor development, deforestation, and overgrazing have additionally had comparative impacts. A UNEP report states that the quantity of rain dwindling across the globe is equal to the needs of nine billion people (UNEP, 2006).

2.2.3 Country Studies (UNEP 2006)

Around 33% of Africa is esteemed appropriate for rainwater gathering if an edge of 200 mm of rainfall a year is utilized. 200mm is thought to be at the lesser end of the scale. Ethiopia-the rainwater reaping potential is assessed at more than 11,800 cubic meters for every individual contrasted and yearly inexhaustible waterway and ground water supplies of just around 1,600 cubic meters.

Uganda the rainwater-harvesting probable is assessed at more than 9,900 cubic meters for every individual contrasted and the yearly inexhaustible water accessibility of 1,500 cubic meters while in Tanzania the potential is evaluated at more than 24,700 cubic meters for each individual when contrasted and the yearly sustainable accessibility of around 2,200 cubic meters. In Kenya, it is evaluated at more than 12,300 cubic meters for every individual contrasted and the momentum yearly inexhaustible water accessibility of a little more than 600 cubic meters.

2.2.4 City Studies (United Nations Human Settlements Programme, 2010)

Kampala city has the ability to sustain the water needs of the population of amid 3.5 million and 5.5 million with 60 liters a day per person if rainwater were professionally and effectively gathered. In November 1980, the United Nations propelled a global drinking water and hygiene Decade, 1981-1990. In its action plan and in response to the UN move, the Kenya government proposed to provide safe and adequate drinking water to every home by the year 2000. Indeed both of these are ambitious proposals, whose attainment and fulfilment would require the expenditure of large sums of money and the exploration of all available water resource (Rainwater Harvesting for Domestic Water Supply, 1984). In fact, this argument is only plausible to a certain extent in parts of the developed and third world countries, where most people already have access to piped portable water in their homes, (UN-HABITAT, 1996)

Nairobi city has the ability to maintain the water needs of a populace that ranges between 6 and 10 million by using 60 litres a day per person. However, this is only achievable if rainwater were proficiently and efficiently harvested. The present population is around three million of which only 21,000 are aided under the prevailing quantity system.

Water is most expensive where it is delivered to the household by vendors, a situation at Machakos town. It can be hundred times higher than the supplier's tariff. People selling water from their own connection to others will normally operate as small business and charge an enhanced price (Water and Sanitation for Urban Poor, 1997). An unfortunate result of the above is that those who rely upon a supply from others will pay a higher unit rate for their water supply than higher income groups. One of the main difficulties is that the metropolises have not been able to enlarge their services in fraction to promptly rising needs and strains. Kenya although water scarce, has room for widespread development towards attaining maximum utilization of the renewable fraction of the fresh water resources. Rainwater harvesting strategies for instance have not been fully capitalized upon and yet these can be instrumental in enhancing water security.

Where the government is unable to provide acceptable and reliable water supply to its citizens to meet basic domestic need, then there is great need to promote an alternative, which allows people to be self-sufficient a pre –requisite for better livelihoods. Various housetop spill over rainwater accumulation frameworks are presently being built the world over for non-consumable uses, for example, can flushing and garments washing. Nations across the globe have positioned themselves as pioneers in the establishment of frameworks for gathering of rainwater from housetops with capacity zones and conveyance lines inside individual family units (Albrechtsen, 2002).

Kenya, albeit named a water rare nation has space for broad improvement towards accomplishing most extreme use of the inexhaustible part of the crisp water resources. Rainwater harvesting is one sustainable strategy that can be employed to raise the amount of available water.

Chapter four of the Vision 2030 provides a long-term strategic plan for the growth of the entire nation and addresses water and hygiene. The flagship projects for water and hygiene are mainly big projects such as the construction of a 54 kilometres canal from Tana River to Garissa or the construction multi-purpose dams along the rivers Nzoia and Nyando (the two rivers are situated in the southwest of the country, where water scarcity is the least severe). Nonetheless, 22 medium-sized dams in the ASAL are also planned. Besides, the Vision 2030 explicitly mentions that "the country aims to conserve water sources and Start new ways of harvesting and using rain and underground water" (GOK, 2007:18). Thus, RWH is also represented in this long-term national plan, which can be seen as a reference point for the development of the entire country of Kenya. It is aimed at ensuring that Kenya a newly industrializing, "middle income country providing high quality life for all its citizens by the year 2030".

The Kenya Vision 2030 comes after the fruitful usage of the Economic Recovery Strategy for Wealth and Employment Creation (ERS). The Kenya Vision 2030 is to be actualized in progressive five-year Medium Term designs with the principal such arrangement covering the period 2006-2012. The nation expects to ration water resources and begin better approaches for harvesting and utilizing precipitation and underground water. The main aim of the study was to analyze the viability of using rainwater catchment on roofs in Machakos town and storing it for household domestic uses. Being the capital of the county the town is rapidly growing and the current water supply system is not adequate to provide water for the growing population.

2.2.5 Rainwater

As the demand for clean water increases due to the increase in population growth, numerous methods have been introduced to combat the chronic problem of obtaining clean water. One such method is rain water harvesting (RWH) from roofs.

Rain water harvesting in its broadest sense can be characterized as the catch of rainwater before it achieves the ground and its stockpiling on tanks for its utilization. Water harvesting frameworks, which collect run-off from roofs or ground water fall under the term rainwater harvesting. In this examination, the fundamental spotlight was on rainwater harvesting from the roof surfaces at family level for residential reason like drinking, cooking and washing. It is the interference of rainwater that would some way or another end up in surface or groundwater. Rainwater catchment should be possible at a local level for family unit utilizes, modern for use in production lines or at an agrarian level for irrigation purposes .Sometimes rainwater is even utilized for groundwater revive (Ferrera, 2010).

2.2.6 Rain Water as the Source of Water

All the water sources, surface water and groundwater start from rainwater. Coordinate accumulation and utilization of rainwater cannot just spare the vitality required for water treatment and transportation, yet in addition increment wellbeing factors in contrast to harm by flooding, water deficiency, pollution or fire. Rainwater collecting ought to be viewed as the principal alternative for water supply for current and new water supply framework.

Rainwater is viewed as the cleanest water accessible in light of the fact that it is just powerless to airborne defilement before coming into contact with a catchment surface (Water AID, 2011). High saltiness levels, which regularly render groundwater a non-consumable water source, are absent in rainwater (Water AID, 2011). Rainwater can be utilized for consumable and non-consumable utilizations, contingent upon the surface from which it is gathered

Rainwater harvesting is regularly alluded to as a "rising innovation"; be that as it may, Rainwater storages are not another idea. In the Middle East in 2000 B.C., regular white collar class residences put away rainwater in reservoirs for use as a local supply and additionally private showering offices for the rich (Consulting-Specifying Engineer, 2011).

The innovation requires satisfactory roofs with hard, impermeable surface and capacity tank as just water from roofs can be gathered and in this manner does not require substantial regions to work. It is an elective that can be effectively introduced and kept up as it gives great quality water specifically to homes and if legitimately kept up it speaks to no danger.

Despite the fact that this might be a productive innovation, it is considered as supplement to other techniques for gaining water. It ought to be joined with different sources and advances, which are as of now being utilized, particularly in dry, dry territories (Ferrera, 2010). It's not considered as another innovation since it has given a water source to networks the world over going back to around 1500 BC (Hunt and Laura).

As Lehmann et.al. (2010) bring up; the reception of RWH "makes some huge commitments to accomplishing the MDGs." The 8 MDGs that were figured in the year 2000 by operators of the UNO, World Bank, OECD and a few NGOs are: went for annihilating outrageous poverty and hunger; accomplish general essential instruction; advance sexual orientation fairness and engage ladies; decrease youngster mortality; enhance maternal wellbeing; battle HIV/AIDS, Malaria and other extreme illnesses; guarantee natural supportability. Lehmann et al. (2010), the accessibility of water spares vitality, time, consequently work, and cash, since water does not need to be supplied to family units from far off sources. While the gathered water prompts more solid and more prominent yields, the individuals from the families can utilize their spared time to go about other work, in this way producing more income.

RWH at schools enhances cleanliness and nourishment and students can invest more energy learning, as they do not have to convey water to the school. "Ladies are for the most part accountable for the family water supply" (Lehmann et.al.2010:3). RWH enables women since it gives them the likelihood to get paid work where the nearness of nearby markets permits it. In any case, RWH gives them additional time available to them, which can be put resources into different exercises. Consequently, their rank as basic leadership performers in the family unit increases.

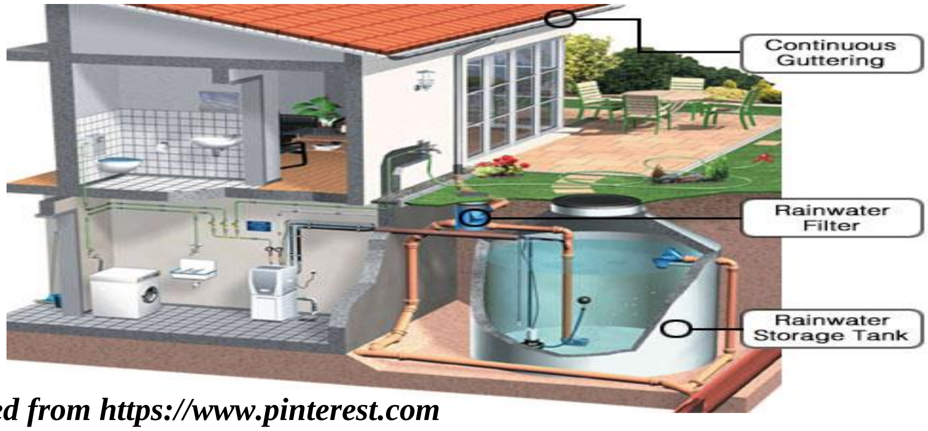
Combined with the ongoing acknowledgment of the significance of rainwater gathering (RWH) at the world summit meetings composed by World Water Forum and UNEP, the advancement of RWH is developing quickly all through the world. RWH is accepted to have a noteworthy part in empowering creating nations to meet the Millennium Development Goal by 2015, which will divide the quantity of individuals who do not approach safe drinking water. RWH is likewise viewed as a reasonable innovation for created nations.

Another worldview is recommended, the fundamental ideas of which are to think about rainwater as the principle wellspring of water, to oversee by zone on a decentralized premise, to control water close to its source and to include local activists.

Historically, harvested rainwater provided water for drinking, landscape watering, and for agricultural uses. Once urban areas started to develop, centralized water supply systems replaced the need to harvest water. More recently, people have become acquainted with residential and commercial landscapes. Harvesting rainwater can reduce the use of drinking water for landscape irrigation. It is also an effective water conservation tool and proves more beneficial when coupled with the use of native, low-water-use and desert-adapted plants. Additionally, rainwater is available free of charge and puts no added strain on the county supply or private wells. There are many water harvesting opportunities on developed sites and it can easily be planned into a new landscape during the design phase. Homes, schools, parks, parking lots, apartment complexes, and commercial facilities all provide sites where rainfall can be harvested. Even very small yards can benefit from water harvesting.

Rainwater harvesting systems channel rainwater from a roof into storage via an arrangement of gutters and pipes. The first flush of rainwater after a dry season should be allowed to run to waste, as it will be contaminated with dust, bird droppings etc. Roof gutters should be large enough to carry peak flows. Storage tanks should be covered to prevent mosquito breeding and to reduce evaporation losses, contamination and algae growth.

Figure 2.1: Diagrammatic representation of a RTWHS



Adopted from https://www.pinterest.com

2.2.7 Rain Water Harvesting System

As water needs become critical in Kenya, areas that are not automatically semi-arid also find themselves in need of simple techniques to harvest rainwater in order to attain a sufficient level of water. Various forms of water harvesting have been practised for thousands of years. (UNEP, 1979).They involves simple but effective technologies of interception of rainwater before it reaches the ground. The collected water may be stored in a tank or reservoir. The quantity of water that can be harvested is determined by the amount of rainfall and size of area from which the water is collected. Use of roofs for water collection is widely practised. Corrugated galvanized iron roofs have been used to harvest rainwater in humid and semi-humid regions. These roofs are cheap and when used with gutters can collect water without exorbitant maintenance costs.

Costs can be kept down by the increased use of local materials e.g. tiles, which are durable, and requires little maintenance. They produce less noise during rains than iron sheets. Rainwater harvesting mechanism in all domestic roofing systems in each household, can meet most if not all domestic water demand thereby reducing government and local authority involvement. Rainwater is generally clean and safe for drinking, cooking and washing but appropriate treatment involves simply boiling and cooling it.

Rainwater harvesting system research indicates that the amount of rainfall on roofs annually in the rainy seasons that is April-May and October –November in Kenya is sufficient to cater for all domestic needs and that the irrigation of a small patch of urban agricultural garden all year round if effectively harvested and stored (Kalberttan, 1980). A rough estimate of the required minimum roof area to harvest enough water to meet daily need can be made using the following formula: A=450 multiplied by DIR; where A is the minimum roof area in square meters; D is the total water demand in litres per day and R is the 90 per cent probable annual rainfall in millimetres (GOK, 1978).

Rainwater harvesting frameworks can be introduced with negligible aptitudes. The framework ought to be estimated to take care of the water demand all through the dry season since it must be sufficiently enormous to help day-by-day water utilization. In particular, the rainfall catching territory, for example, a building roof must be sufficiently vast to keep up satisfactory stream. Similarly, the water-stockpiling tank ought to be sufficiently expansive to contain the caught water.

Each rain water harvesting framework comprises of three essential segments Catchment or roof surface to gather rain water; conveyance framework to transport the water from roof to the capacity repository; stockpiling supply/tank to store the water until the point that its utilized and the capacity repository has an extraction gadget that relying upon the area of the tank might be a tap rope and basin or a pump. The catchment of water harvesting framework is the surface that gets rainfall specifically and channels it to the framework. RWH Surface is on most cases not reasonable for household purposes since the water quality isn't sufficient. Electrifies, folded press sheet, layered plastic and tiles make great roof catchment surfaces. Level bond or felt-secured roof can likewise be utilized given that they are spotless.

Largely, groundwater or surface water might be inaccessible for drinking. The groundwater level might be too profound or polluted with minerals and synthetic substances, for example, arsenic or salt simply like surface water. In these cases, rainwater that falls on roof is quite often of amazing quality, powerful and minimal effort arrangement.

A few examinations have demonstrated that water from very much kept up and secured rooftop tanks mostly meets drinking water quality models. It empowers family units and in addition, network structures, schools and centers to deal with their own water supply for drinking water, household utilize, and wage producing exercises.

It gives the advantage of "water without strolling", diminishing the weight of water conveying, especially for women and kids. Every 20-liter holder of clean water may spare kilometers long stroll to the closest source of clean water and as bringing water on chilly, wet and elusive days is especially upsetting, even this little yield is much esteemed. In Uganda and Sri Lanka, rainwater is customarily gathered from trees, utilizing banana leaves or stems as brief drains. This comfort is accessible at each house on which rain falls, regardless of whether on a peak or an island in a salty ocean.

The conveyance framework from the roof top catchment framework more often than not comprises of canals dangling from the sides of the roof slanting towards a down pipe and a tank. This conveyance framework is utilized to transport the rainwater from roof to the capacity repositories.

A very much planned and deliberately built drain framework is on account of the guttering, is frequently the weakest connection in a rainwater harvesting framework. As much as at least 90% of the rainwater gathered on the roof will be depleted to the capacity tank if the drain and down pipe framework is legitimately fitted and kept up. Regular materials for drains and down channels are metal and PVC.

On Storage supplies the water-stockpiling tank as a rule speaks to the greatest capital speculation component of a household RWH framework. It requires the most cautious outline to give ideal stockpiling limit and organized quality while keeping the expenses as low as could reasonably be expected. Basic vessels utilized for little scale water stockpiling away in creating nations incorporate plastic dishes, cans, jerry cans, dirt or artistic containers for putting away bigger amounts of water the framework will require a tank above or underneath the ground..

Rainwater harvesting at a household level improves the affordability of water consumption irrigation and drainage facility of the site and structure. Harvesting rainwater is capable to combat water crisis and serves as an alternative water resource during water shortage. This ancient technology continues to serve populations today mainly in dry regions of the world (Hicks, 2008). Basically, RWH is a technology used for collecting and storing rainwater from roof tops, land surfaces, rock catchments using simple technology. The greater attraction of a rainwater harvesting system is low cost, accessibility and easy maintenance at household level (Fayez 2009).

The existing water supply in Machakos town include of the following sources, namely: dams, rivers, boreholes, and rainwater harvesting. There are two main dams, namely Maruba Dam and Nol Turesh Water Supply.

Maruba Dam is located about 4km to the Southwest of Machakos town. The dam, which has a capacity of 1.4 million m3, is currently being raised by the National Water Conservation and Pipeline Corporation (NWCPC) in order to increase its storage capacity to 2.45 million cubic metres. The water abstracted from the dam is treated in a conventional water treatment plant located about 300m from the dam on the downstream side. This treatment plant, with a design capacity of 3,500m3 per day, is only able to produce on average 1,000m3/d, occasionally reaching a maximum of about 1,700m3 per day. This is mainly due to its old and dilapidated state. A composite treatment plant, with a capacity of 600m3 per day, was later constructed adjacent to the old plant. The treatment units consist of six vertical flow sedimentation tanks and four rapid gravity sand filters. Treated water is stored in a clear water tank where it is chlorinated before being pumped to Iveti tank. There are 3 pumps (one standby) which operate for 18-21 hours a day although they were originally designed for 24-hour operation. There is no standby generator.

The quality of the raw water is poor, with high turbidity due to siltation of the dam. As a result, large quantities of alum are used for coagulation. In addition, there are no jar test facilities and the quantity of alum required is estimated. The treated water is pumped via two rising mains from which there are consumer connections: one consisting of a 150mm diameter uPVC line and another one varying in diameter from 150mm to 250mm to the 1,140m3 Iveti Tank. A 150mm diameter uPVC branch from the former is connected to a 225m^3 tank in Kiima Kimwe. However, this line is currently not in use. The Iveti tank is a circular, concrete tank located to the north of the town from which water is supplied to the town by gravity.

Nol Turesh water supply system currently supplies about 1,300 m^3/d to Machakos town, although it was originally designed to deliver more. The Nol Turesh system draws water from a spring on the foot of Mount Kilimanjaro in Oloitokitok. The water is of good quality and the only treatment provided is chlorination at source. The water is transmitted by gravity via a 550mm diameter steel pipeline to Pumping Station number one. One at Kiima, a distance of about 125km away. The water is then pumped for about 10km to a 500m^3 reservoir at Kiima-kiu near Salama where booster chlorination is carried out. From this reservoir, the water then flows by gravity to Machakos town via 400mm and 300mm diameter mains of total length 35.3km. The water is stored in twin 3,000m^3 rectangular reservoirs adjacent to each other in Katoloni to the south of Machakos town. These reservoirs, with a total capacity of 6,000m^3, were constructed in 1989 and are in good structural condition. However, only one of the reservoirs is used regularly due to the high demand in the town.

It was reported that the water depth in this tank is hardly ever more than 1metre. Another 225m3 tank is located about 100m to the southeast of the 6,000m^3 tank. This smaller tank is located at a higher elevation at the foot of Kiima Kimwe hill, the difference in elevation being about 25m. Due to high demand in the areas along the pipeline, route from Mount Kilimanjaro, less than 1,000m^3/d eventually gets to Machakos. At the time of preparation of this report, there was no supply from Nol Turesh as the pumps at Kiima Pumping Station were said to have broken down. It is noteworthy that the dams are not able to meet the current water demand and as a result, serious water shortages are experienced. As such, boreholes also become another source of water in the town.

Machakos Town has six boreholes out of which only three are operational. There are five boreholes located to the Northeast of the town. However, only two of these are in use at present; one of the non-functioning boreholes has been vandalized and all cables and pipes stolen, while the others were never equipped or have no power. Five of the boreholes (1 to 5) are located to the north of Machakos Town on the western bank of the seasonal Iiyini River. Boreholes 1 to 5 are each located within a distance of less than two hundred metres apart. The water from the 5 boreholes was designed to be pumped via a common rising main to Iveti Hills tank.

The production from the two boreholes that are in use is about 120m3/d and 150m3/d respectively. Water from these boreholes is pumped to Iveti Tank, which also receives treated water from Maruba Dam.

A new borehole has recently been drilled to the west of the Show Ground next to the main Machakos - Nairobi Road. This borehole, drilled by NWCPC, is fully equipped but requires an elevated storage tank. The major rivers within the municipality are Iiyini to the East of Machakos

Town and Rivers Maruba, Miwongoni and Mitheu which join to the Southeast of Kiima Kimwe to form Mwania River.

2.3 Theoretical Framework

This study adopted the water demand management approach which is a key component of integrated water resources management. Freshwater scarcity is a growing concern worldwide .Globally water use for domestic and industrial use quadrupled between 1950 and 1995 and the future of water is uncertain due to population growth and climate variability (world water and food to 2025). United Nations (UN) classifies Kenya as water scarce country with the country's surface water coverage of only 2%, a water scarce category of 647m3 per capita against the global benchmark of 1000m3.(integrity in water supply 2012) This coverage, according to the Ministry of Water and Irrigation (MOWI) has been increasing in recent years. Urbanization has worsened the situation with an annual growth of not less than 5% where the population in towns is increasing three times the normal population. Kenya's vision for water and sanitation sector is to ensure water and improved sanitation availability and access to all by the year 2030. The vision's goal for the water and sanitation sector is "to ensure water and improved sanitation availability and access to all by 2030."

The nation's surface water scope of just 2%, a water rare classification of 647m3 for every capita against the worldwide benchmark of 1000m3. This scope, as indicated by the Ministry of Water and Irrigation (MOWI) has been expanding as of late. Urbanization has declined the circumstance with a yearly development of not less than 5% where the populace in towns is expanding three times the ordinary populace. Kenya's vision for water and sanitation segment is to guarantee water and enhanced sanitation accessibility and access to all continuously 2030. The vision's objective for the water and sanitation area is "to guarantee water and enhanced sanitation accessibility and access to all by 2030."

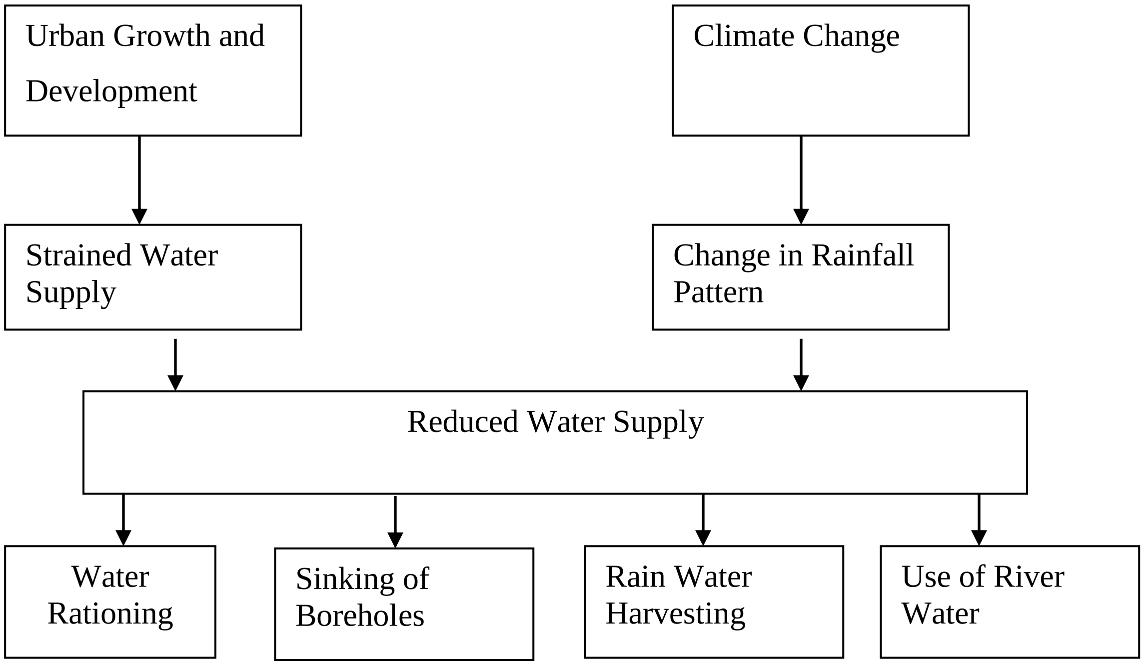
In Machakos province albeit each individual has the privilege to spotless and safe water in satisfactory amounts and to sensible benchmarks of sanitation as stipulated in Article 43 of her Constitution. Most of the current water and sanitation offices in the district are old, run down and desperately require refurbishing. A standard study that was completed by the Institute of Economic Affairs Kenya (IEA-Kenya) in 2012 demonstrated that lone 6 for every penny of the respondents announced having steady supply of water, 87 for each penny revealed that they got water intermittently and 17 for each penny detailed that they never water streaming to their homes or premises (Integrity in Water Supply - 2013). This is because of deficient budgetary provision, offices have not been moved up to adapt to expanding interest, and decrease in specialized execution with expanding period of gear and insufficient support. Uncontrolled sand collecting in the district has prompted serious natural corruption bringing about change in the administration of a portion of the streams and loss of maintenance limits of a portion of the occasional waterways.

A majority of organizations in Machakos town announced that they got their water from drilled holes that they had bored. A large portion of these foundations communicated absence of enthusiasm for the administrations of the public water part as their organizations, however associated with the public supply never had water streaming in their taps. Some of these establishments revealed that they had asked for detachment from the gathering to prepare for being charged for administrations that were not being rendered. Rainwater gathering is one of the promising methods for supplementing the surface and underground rare water assets in the area and particularly nearby that is encountering quick development. It is one of the measure for lessening effect of environmental change on water supplies.

2.4 Conceptual Framework

In this study water scarcity is characterized by inadequate supply due to increased population and prolonged dry spells respectively. Most of the installed pipes which used to have running water in Machakos town are now dry. This has led to most of the installed taps running dry and most people turning to bore hole water. Where the taps are not dry water rationing is a common feature .The main cause of water scarcity is competing needs. Rapid increase in population growth leads to greater demand for water not only by the population but also industries, agriculture and other human activities that support urban living. The problem is compounded further by the insensitive use of water. Research indicates that the amount of rainfalls on the roofs annually in 2 rainy seasons specifically the April- May and October –November seasons in Machakos is sufficient to cater for all domestic needs and that for irrigation of a small patch (urban agriculture) all year round, if effectively harvested and stored (Kalbermatten, 1980).Water scarcity is growing

Figure 2.2: The Conceptual Framework for Roof Top Rain Water Harvesting



Source: Researcher (2018)

2.5 Research Gaps

Drechsel et.al (2005.2) conducted a study on rainwater harvesting for enhancement of food security in arid and semi-arid areas of sub Saharan Africa. The study pointed out that there are theoretical advantages of these technologies. UN Environment Programme (UNEP) Executive Director Achim Steiner through a study, compiled by his agency, on massive potential in rainwater harvesting in Africa urged governments and donors to invest more widely in a technology that is low cost, simple to deploy and maintain, and able to transform the lives of households, communities and countries (13th November, 2006). He said that African countries suffering or facing water shortages as a result of climate change have great potential of rainwater harvesting with nations like Ethiopia and Kenya capable of meeting the needs of six to seven times their current populations.

Stephen Ngigi did a research on Rainwater harvesting and management as one of the land use changes driven by the need to improve agricultural production and livelihoods by retaining additional runoff on agricultural lands for productive uses. He noted that it might reduce river flows for downstream users and lead to negative hydrological, socio-economic and environmental impacts in a river basin. Some land use changes are driven by the need to improve agricultural production and livelihoods. Rainwater harvesting and management is one such change. It aims to retain additional runoff on agricultural lands for productive uses. This may reduce river flows for downstream users and lead to negative hydrological, socio-economic and environmental impacts in a river basin.

Mulenga, did a research on locating new untapped sources to increase the amount of water in urban areas whose population is growing fast compared to available water sources. He researched on rivers, which may be financially prohibitive and limit exploitation. The remaining alternatives for many expanding cities are rainwater harvesting, re-use and exploiting ground water. A cost-benefit analysis to support the decision makers in adapting the suggested new paradigm is required. Other water supply options, such as gray water systems, desalination systems, and the traditional centralized water supply system, should be compared with implementation of a RWH system to cope with increasing water demand.

The benefits of rainwater harvesting for enhancing food security in Arid and Semiarid Lands, and poor knowledge with regard to the real causes of low adoption rate and/or failed adoption process due to inadequate participation by local farmers cannot be again said. The researcher chose to undertake the study in order to determine the challenges, constraints and potentials for the adoption of the in Situ rainwater harvesting systems and to analyse how the implementation process and community's perception of the technology's characteristics might affect their adoption decision Biazin et.al (2012). The paper outlines various rainwater harvesting management techniques in Sub Saharan Africa, and reviews centre research results on the performance of the selected practices. The study indicates that micro-catchment and In Situ rainwater harvesting techniques are more common than rainwater irrigation techniques from macro catchment systems. The rainwater harvesting techniques could improve the soil water content of the rooting zone, nearly six fold of crop yields have been obtained, reduces risk of crop failure due to dry spells but also improving water and crop productivity(2012:147). Ngigi (2003) did an analysis on the limit of up-scaling (re-designing) rainwater harvesting on an on-going research project, on Upper Ewaso Ng'iro river basin water resource management. The most important and efficient way to solve the world water problem is to teach the next generation when they are in school by including it in their educational course. In Japan and Korea, rainwater museums are open to students and the public, showing the importance of rainwater harvesting by displaying different technologies as well as cultures. The best way to inform the current generation is to use mass media, such as TV, newspapers and the internet.

With new paradigm, various activities are required, which include the involvement of different stakeholders, research and development of technology, developing a logical background, supporting materials for the decision makers, education& public awareness and constructing worldwide networks. The vision of rainwater harvesting is to create a harmonized environment by properly and wisely utilizing rainwater, appreciating that it is a gift from heaven. This study identified the following gaps which need to be researched on:

- Promoting alternative sources of water through recycling and reclaiming of water to reduce the reliance on main water sources.
- Continuous capacity building for the various water institutions to be carried out on a phased basis. This will assist in effectively implementing water strategies and regulating the water sector.
- Encouraging adoption of alternative sources of water; Rain water harvesting, recycling and reclaiming.
- Enhanced integrated management of water as a resource to address the issue of water resource depletion.
- Integrating demand management options into water resources plans and long-term operational and investment plans.
- An integrated water demand management plan for Machakos town specifying clear roles of the various stakeholders and how these roles are to be effectively coordinated.
- The use of computer controlled management systems by Machakos water and sewerage company leak detection and combating fraudulent meter by passing.

CHAPTER THREE: THE STUDY AREA

3.1 Location and Size

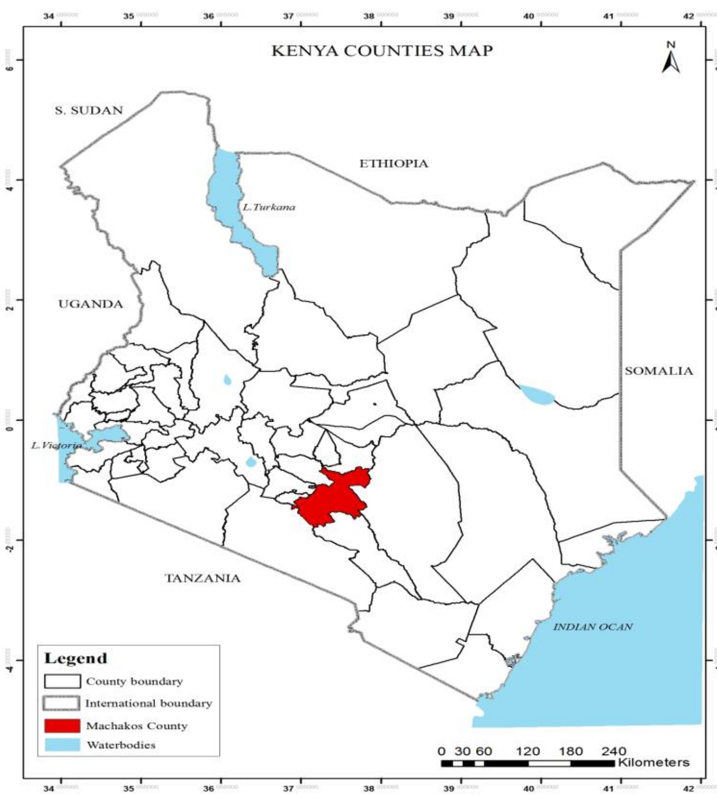
The study was conducted in Machakos town, the capital of Machakos County.

3.1.1 Machakos County

The county of Machakos borders Kiambu and Nairobi to the West, Embu to the North, Kitui to the East , Makueni to the South, Kajiado to the South west and Muranga and Kirinyaga to the North west.

Figure 3 (below) shows the map of Machakos County in relation to neighbouring counties and the entire country. It is borders Kitui county to the East, Makueni to the South, Kajiado to the West and Kiambu to the North

Figure 2.3: Map of Kenya showing Machakos County.



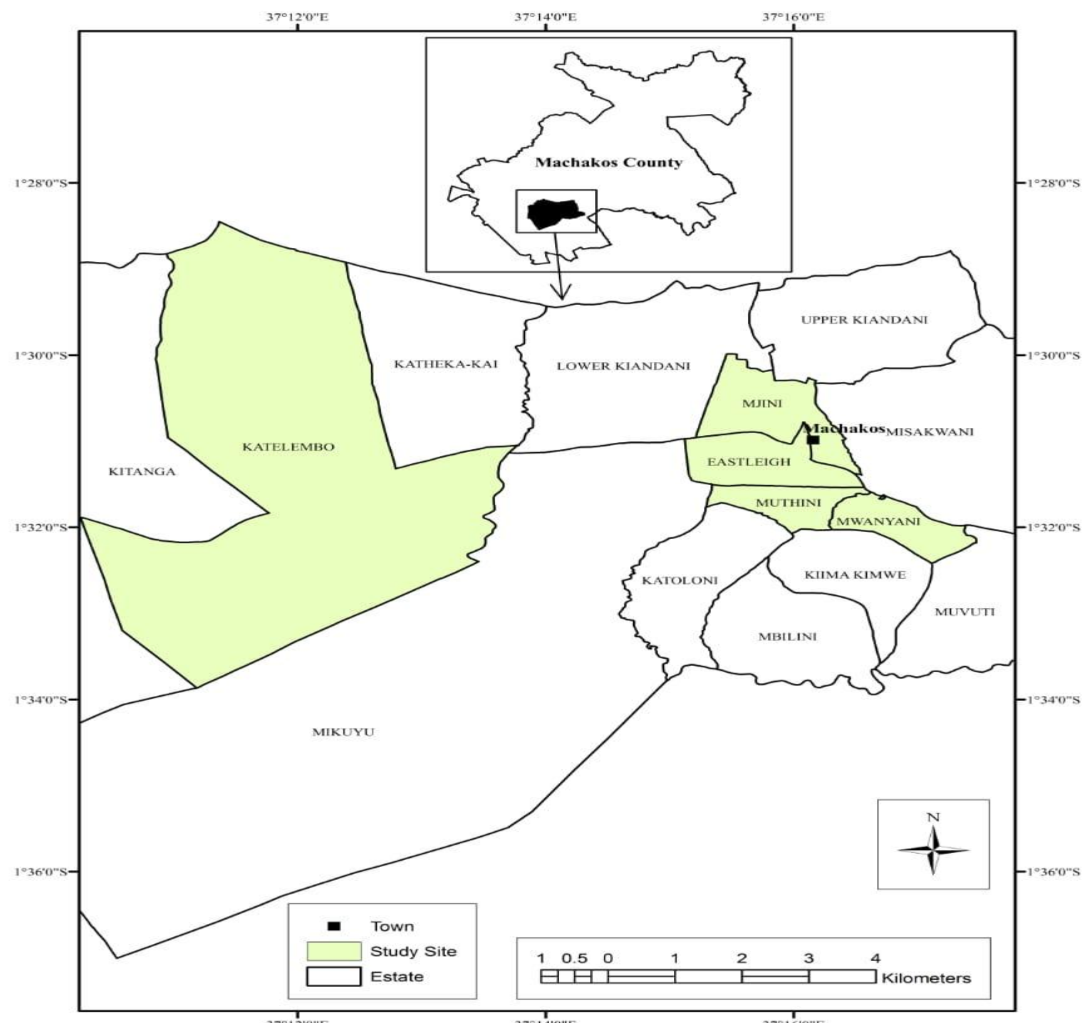
Source: Researcher (2018)

3.1.2 Machakos town

Machakos town is located about 67 km southeast of Kenya's capital, Nairobi. Bound between

Latitude -1^{0}31'0.01'' S and Longitude 37^{0}16'0.01''E, the town lies within a U-shaped ridge of hills comprising the Iveti Hills and the Mitaboni plateau (2,100 m A.S.L) to the northeast and the Mua Hills located to the North and Northwest (about 2,080m A.S.L) and Kiima Kimwe which rises up to about 1859 m A.S.L.

Figure 2.4: Map of Machakos Town



Source: Researcher (2018)

3.1.3 History of Machakos Town

Machakos town was started by the British colonialists as an administrative headquarters when the founders of the British colony of Kenya reached there and pitched camp in 1889. The colonialists found the area suitable as their headquarters. But when the builders of the Kenya-Uganda railway reached the area, they gave Machakos a wide berth of about twenty kilometers towards Nairobi [started six years later]. Nairobi thus prospered to become the capital of Kenya confining Machakos town to obscurity. The name Machakos is a configuration of the name Masaku the famous Akamba chief who ruled the people who indigenously inhabited the area when the British colonialists were arriving at the site.

The town portrays an ideal urban structure with Central Business District at the centre, followed by transition zone, Industrial zone, Residential zone and Commuter zone at the far end. It has eight estates namely: Eastleigh, Muthini, Miwani, Katoloni, Kariobangi, Kathemboni, Kenya Israel and Mjini. Mjini estate is within the industrial zone. From the interrogation of the water engineer, the town used to get enough water from the former council supply but with the expansion of the town, the supply declined leading to rationing which is a common practice today. Some of the estates stretch outwards to the rural areas and therefore lack piped water totally; like the Kenya like Israel estate. Machakos town is not a home to many industries, a major discouraging factor being water shortage. However, it has a sizeable informal economy. Commercial and non-commercial activities are concentrated in the CBD of Machakos Town.

3.1.4 Administration

Indigenously inhabited by Kenyans of the Akamba community, Machakos town is the administrative headquarters of Machakos County. The town is located in Machakos sub-county, which is divided into seven (7) wards. These are: Kalama, Mua, Mutituni, Machakos Central, Mumbuni North, Muvuti/Kiima-Kimwe and Kola. It also has twelve (12) locations (Kalama, Katheka Kai, Kiiima-Kimwe, Kimutwa, Kola, Lumbwa, Masaku, Mua Hills, Mumbuni, Muvuti, Mutituni and Ngelani.)

3.2 Physiographic Characteristics

3.2.1 Geology and Soils

The geological formation of Machakos town consist of intensely folded Basement Rock system of gneisses and schist which include limestone, amphibolites and quartzite as well as the predominating biotite granitoid gneisses. The rocks have been metamorphosed and granitized to a considerable degree. Overlying the Basement system rocks to the western part are the Kapiti Phonolites, lava of Miocene age. There are five major soil types in Machakos Sub County. These are alfisols, acrisols, ferrasols, vertisols and andasols. The soils found within the Municipality are of Alfisols and Acrisols type which are brown to reddish brown, well drained and friable **.** The rocks in this area are not particularly permeable to contribute to ground water, but fractures zones and weathered layers form zones for groundwater (Chimba, 2009).The groundwater may be saline or hard with concentration of chloride, sulphate and fluoride**.** These soil types are inherently low in fertility with low water holding capacity, low organic matter content, and highly erodible. Metamorphic rocks form the basements of the hills that surround the town mainly the quartz rich granitized gneisses that were metamorphosed during palaenzoic folding.The rocks allow1 occurrence of ground water through the fractures though not so much.

3.2.2 Drainage

There are four major rivers within the Municipality: River Iiyini, which is to the East of Machakos Town and Rivers Maruba, Miwongoni and Mitheu, which join to the Southeast of Kiima Kimwe to form Mwania River. Mwania flows in an easterly direction, is joined in its course by tributaries from Kiima Kimwe to its North and Kimutwa to the South, and becomes Ikiwe River. Ikiwe River eventually joins River Thwake to the east of the municipality. The general drainage pattern is from West to East. Kariobangi settlement slopes towards the Iiyini River. Some of the rivers provide water to Machakos residents especially River Liyini.

3.2.3 Climate

Based on the Miller's Climatic Classification Scheme, Machakos County experiences a tropical continental climate with a clear wet and dry season dominantly influenced by the Inter Tropical convergence Zone (ITCZ) which creates a bimodal rainfall pattern consisting of a long rain season [March-April-May] followed by the short rain season [October-November –December] separated by the coolest months of June and July where temperatures fall to as low as 18^0C. **.**The climate has been changing over the years and the mean monthly rainfall for the last 50 years is as in shown Table 1.This indicates that mean annual rainfall for the last 50 years is 695mm.According to Republic of Kenya (2002a) the rainfall is very unreliable and varies from year to year hence affecting water availability within the town. Rivers provide water to Maruba dam which is the main source of country water has water fluctuating levels leading to water rationing.

Table 1 provides a detailed description of historical precipitation and temperature data for Machakos town.

3.3.1 Rainfall and Rainfall Variations

As discussed above, Machakos town experiences a bimodal pattern of rainfall annually with the long rain season coming between March and May while the short rain season comes between October and December (Wambua et al 2014). However, the rain is erratic and unpredictable. Like is common with other ASAL areas the rain does not 'fall down; it beats down' (Kitonga, 2013). The short rains are more reliable than the long rains. The annual average rainfall for the larger Machakos county ranges between 500mm to 1300mm while the mean annual rainfall for the municipality is about 771mm majorly influenced by its location at a higher elevation behind the Iveti hills which rise upto 1933m above sea level.

There are significant regional and seasonal variations within the county and rainfall reliability is quite low. The high altitude areas of Matungulu, Kangundo, Kathiani, Central and Mwala divisions receive slightly higher rainfall than the low land areas, and are more suitable for rainfed agriculture practice. Machakos town is within the high altitude areas, though it seats in the leeward side on higher elevation in the form of Iveti hills, reducing the amount of rainfall received compared to the windward sides of the same hills. Table 1 shows that there is adequate amounts of precipitation to warrant a rooftop rainwater harvesting strategy in Machakos town.

3.3.2 Temperature and Temperature Variations

The greater Machakos County has a mean monthly temperature ranging between 18^0C and 25^0C while the municipality has a generally dry climate characterized by hot days and cold nights with temperatures varying from minimum and maximum of 13.7^0C and 24.7^0C respectively. Machakos town experiences a regular cycle of meteorological drought, which is severest during the months of June, and September where days are sunny, nights are very cold and the weather is described as hot (Wambua et.al, 2014).

Table 3.1: Historical Weather Data for Machakos Town

Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Avg. Temp (^{0}C)	19.5	20.3	20.7	20	19	17.4	16.5	17	18.5	20.1	19.4	19.2
Minimum temp. (^{0}C)	12.3	12.7	14.1	14.2	13.1	11.1	10.5	10.8	11.3	13.1	13.6	12.9
Maximum temp. (^{0}C)	26.8	28	27.3	25.9	25	23.8	22.5	23.2	25.7	27.1	25.2	25.5
Precipitation (mm)	47	49	107	179	69	9	5	4	8	53	191	109

Adapted from www.climate-data.org

Between the driest and wettest months, the difference in precipitation is 187 mm. The average annual temperature variation is about 4.2 °C.

3.3.3 Wind Speed

The average wind speed is estimated at 7.5 mph rising in the months of August-October to a high of 10 Mph and slowing down in the coldest months to a speed of 5 mph (www.climate-data.org)

3.4 Sources of Water in Machakos Town

The single largest source of water for Machakos town is the famous Maruba dam. This is a 17 m high dam constructed in the 1950s to serve the water needs of the town and supplies about 1, 300 m^3 of water per day today. The other source is the Nol Turesh water supply pipeline system that draws water from Nol Turesh springs in Ol-Loitoktok springs near Mt. Kilimanjaro and supplies the town with about 800m3 of water per day. There are also supplies supported by ground water (boreholes and wells) which provide about 120 m^3 of water daily. Thus, Maruba dam is the main source of water for Machakos town (plate 1 below.) However, Maruba dam is facing a serious challenge of siltation, which has affected its storage capacity, and thus its yield from the initial $4000m^3$ daily when it was built in 1950 to the current level of less than $2000m^{3.}$ (GoK, 2015)

Plate 1 (below) shows Maruba dam, which is the main source of piped water in Machakos town The water level, has gradually reduced to climate variability evidenced by long dry spells .The catchment area of Maruba river which feeds the dam has also been cleared for settlement.

Plate 1: A Section of Maruba Dam as it Appears Today

Source: Researcher (2018)

Most of the subterranean water supply is harvested along dry river beds such as the seasonal Iini River. According to the UNDP (2010), the total daily water supply to Machakos town is about 2100$m^{3,}$ against an estimated daily water demand of 14,769 m^3 creating a daily deficiency of about 12,000m^3 of water. The current demand is estimated to be between 15,000 m^3/d and 20,000 m3/d (GoK, 2015). Thus a strategy to meet this supply gap is necessary. To ensure equity in the supply of water to residents of Machakos town, shortages are programmed daily for the entire city by a process popularly known as water rationing. Inhabitants do not have enough water to meet their daily domestic water thus; rainwater harvesting is presented in this study as a strategy that can improve the current water supply scenario in Machakos town.

The County in its Strategic Plan seeks to achieve up to 90% access to safe and reliable water in urban areas and 70% for rural areas by the year 2017 (Machakos CIDP 2013-2018). It is believed among other factors, the uncontrolled sand harvesting has led to severe environment degradation leading to change in the regime of some of the rivers and loss of retention capacities of some of the seasonal rivers. The socio-economic baseline survey revealed that 76% of households in the settlements use water kiosks as primary source of drinking water, 9% of the households purchase from water tanks / vendor and about 5 % get from neighbor (borrowing).Some boreholes have been sunk, both for individual and municipal water supply. To the west of the Machakos town are also shallow hand dug wells with water found at depths of up to 25 metres below ground surface.

3.5 Socio-Economic Characteristics

3.5.1 Demographic Characteristics

According to KNBS (2009), the total population of Machakos County is 1,098,584. 31.7% of this population (347,835) lives within the borders of the old Machakos municipality while 150, 041 (14%) lives in Machakos town'; the area of this study. Urban population of Machakos County is 52.0%, which is significantly higher than the Kenya's average urbanization rate of 29.9%. Table 3.2 below provides other characteristics of this population.

Table 3.2: Demographic Characteristics of the Study Area

No.	Location	Male	Female	Total	Households	Area	Density
1.	Township	7,186	7,512	14,698	4,327	5.0	2,938
2.	Ngelani	5,097	5,669	10,766	2,503	15.2	707
3.	Muvuti	4,482	4,706	9,188	2,023	21.1	436
4.	Mutituni	6,270	6,700	12,970	3,088	11.6	1,121
5.	Mumbuni	22,732	23,419	46,151	11,652	48.1	960
6.	Kimutwa	6,871	6,935	13,806	3,242	333.7	41
7.	Kiima Kimwe	11,420	11,805	23,225	6,766	16.0	1,455
8.	Katheka Kai	9,337	8,483	17,820	4,087	131.8	135
9.	Kalama	20,197	22,637	42,834	9,535	292.5	146
10.	Central	77,252	79,125	156,377	39,444	632.7	247
Total		**170,844**	**176,991**	**347,835**	**86,667**	**1,507.7**	**Av. 819**

Adapted from KNBS (2009)

The population of Machakos municipality is estimated to be 189,578 (Census Report, 2009).This is projected to increase to 215,100 in the initial year (2012), 327,706 in the year 2022 and ultimately 499,260 in the year 2032. (Feasibility study Report, 2009). This high population growth is expected due to the fact that Machakos town is close to Nairobi city and has been proposed as part of the Nairobi Metropolitan area. This increased population is expected to demand more water. At the built-town level, the population dynamics of selected estates are described in the table 3.3 below.

Table 3.3: Demographics of Selected Machakos Estates

Estate	**Male**	**Female**	**Total**	**Households**	Area	**Density**
Eastleigh	3,002	3,282	6,284	1,366	2.3	2,747
Muthini	5,285	5,340	10,625	3,616	1.4	7,585
Mjini	4,184	4,230	8,414	2,961	2.7	3,100
Katoloni	3,038	3,382	6,420	1,780	4.5	1,414
Katelembo	3,303	3,111	6,414	1,477	31.9	201

Adapted from KNBS (2009)

3.5.2 Poverty and Income Levels

Machakos County has a significant percentage (59.6%) of its population living below the poverty line as against the national poverty rate of 47.2%. The Socio-economic survey revealed that nearly 84% of the households had a monthly income of Kshs 22,500 or less. The survey revealed cases of extreme poverty which accounted for a fifth of the households in Kariobangi settlement. These are households that can afford to spend on average Kshs 1,985 per capita per month. Employment for the majority is in the informal sector, others venturing into small enterprises and informal trade.

CHAPTER FOUR: METHODOLOGY

4.1 Study Design

This study was based on a sample survey of households to determine the water potential in terms of current water supply situation. To do this, the study relied on comparing the variables on water sources, causes of water shortages, coping strategies, and rainwater-harvesting practices considered in terms of the current water situation in Machakos town. The sample survey acquired information on the stated variables using a multi-stage design to derive the sample data.

The sample data were then subjected to exploratory analyses to reveal the distribution tendencies necessary in providing relatively accurate description of the survey data. The distribution tendencies were then used to decide the type of inferential statistical techniques that could be used to provide a comparative measure of differences in water supply situation in Machakos town. Differences in means between two samples were specified using student's t-test statistic, independence between household samples were specified using chi-square test statistic and strength of associations were measured using Pearson's correlation statistic. Significance tests in all cases were at α 0.05.

The results of the analysis procedures were discussed in the context of the study objectives, which covered issues on the main sources of water in Machakos town, the causes of water shortage in Machakos town, the adaptation strategies and rainwater potential in Machakos town. For this reason, the survey obtained information on bio-data which was central in water supply trend in Machakos town, household data was collected to determine water demand and water supply data was also collected to obtain water availability. The resultant data was then analysed where by distribution tendencies was done for sources of water, causes of shortage, the adaptation strategies and rain water harvesting potential. The results were subjected to inferential analyses significant difference. For simple sample survey, chi-square and statistical independence tests were done. The results were to be used in variable association using chi-square test. The strength of association between variables was measured using Pearson correlation statistics where variable measurement levels were at interval at ratio scale. The nature of association was determined using Pearson's simple linear association. Significant tests in all cases tested were at α 0.05.

4.2 Data Types and Sources

In order to address the study problem, meet the objectives and test hypotheses, data was collected from households in Machakos town on sources of water, causes of water shortage, water shortage adaptation strategies and the rain water potential, all of which constituted primary data. The secondary data was obtained by reading the publications of KNBS in which census report of 2009 is well analysed. The information constituted of bio data in which information was collected on the gender, duration of stay, the number in every household and the location in Machakos town, which were necessary to identify water supply details in the town. To estimate water used in household level there was need to get information on the quantity of water used. Information was collected on ownership of the house, how much water was used, water deficit and the cost of water. The bio data variables were generally used to determine water supply problem in Machakos town. This information was used to determine the demographic trend characteristics in relation to water deficit and the location of households.

Water sources and causes of water shortages in Machakos town information were derived from data collected from the field through simple sample survey on water supply sources and rainwater potential. The water sources information was further refined by collecting data on reliability as measured by types of water used, their reliability, and potential rooftop rainwater harvesting and water scarcity. Adaptation to water scarcity was addressed using information gathered on the inadequacy of water. This was used to find out whether the sources were adequate. On adaptation, variables included the type of storage facilities used duration of stored water availability and opinion improving water supply.

4.3 Data Collection

4.3.1 Pilot Survey

At the initial stage of the field study, pilot survey was done to familiarize the researcher with the area of study. The reconnaissance survey was important to identify the location of the estates, the possible routes within the estates. It was also to check the possibility of visiting the Water Resource and Management Authority (WARMA) offices for purposes of gathering relevant information on the study. The survey was also used to test the data collection instrument, whether it would capture the desired information. The instrument was modified, leaving out some areas and adding questions, which captured all the required information in accordance with the objectives. Other methods of data collection were included during the pilot study like counting the members of the households. The reconnaissance survey provided data for computation of appropriate sample size. During pilot survey, the researcher visited the estates of Machakos town to identify location and extent of each estate. A few questionnaires were administered to a few household heads to test the suitability of the data collection instruments. The researcher visited the Kenya Bureau of Statistics (KBS) offices at the county quarters to collect data from 2009 national census to help get the target population. This would help get the preliminary information required in determining appropriate sample size.

4.3.2.Target Population and Sample Size

The target population is the population, which contains the information required to address the study problem. The sample size is the data acquired to appropriately represent the target population .During the reconnaissance survey, the KNBS census report (2009) was identified as the best representation of number of households' in the county and therefore constituted the population in the study. From the census households' data, only those households that were within Machakos town were to be used in this study on rainwater harvesting and therefore formed the target population. The target population was then organised in terms of residential estates thus constituting the sampling frame made up of 11583 households as shown in the table below.

Table 4.1: Number of Households for Selected Estates in Machakos Town

Serial No.	Estate	No. of Households
1	Eastleigh	1366
2	Muthini	2961
3	Mjini	3616
4	Katoloni	1780
5	Katelembo	1477
6	Kariobangi	2163

Source: *Adopted from KNBS (2009)*

From this sampling frame, a representative sample size of 207 was derived using the formula

$$n = \frac{z^2 p.q.N}{e^2(N-1) + z^2 p.q}$$

Where,

N	=	Population Size
n	=	Sample Size
P	=	Sample Proportion
q	=	1-P
e	=	Acceptable error level at 0.05
z	=	Standard variant value = 1.96

4.3.3 Data Collection Instruments

The study used a number of instruments during data collection, which included a questionnaire, camera, observation data sheet and notebook. The questionnaire was the main instrument in the sample survey and it was designed to capture information on sources of water, causes of water adaptation strategies and water potential. The questionnaire was structured into three sections (Appendix II) where the first section was dealing with bio data, which included the gender, time of arrival in Machakos, the duration of stay, the estates and size of households.

The second section of the questionnaire was on household data, which captured data on house occupation status, size of the house, daily water consumption on the household, adequacy of daily water supply, initial water consumption level, change in water availability over time, roofing suitability for rainwater harvesting, water expenditure payment and cost of monthly water needs. The third section of the questionnaire focused on water supply and addressed water sources, reliability of piped water, reliability of water source by quantity, prevalence of roof top rainwater harvesting, prevalence of water scarcity, causes of water scarcity, strategies employed by household to cope with water shortage and scarcity, containers used in rain water harvesting, relative quantity of harvested water, duration of harvested water; ways of increasing and improving water harvesting.

The questionnaire was composed of both closed ended and open-ended questions. The open-ended type was used to not only get specific information but also solicit information that could be used in result discussion. The closed ended questions were encouraged where there were only two possible answers or where the respondents were to assist in ranking some known answers to a question. The open-ended questions were used to relate the collected data on some new variables depending on the depth of the information given by the respondents. The camera was used to record visual information on presence of water sources including rivers, boreholes, water pipes, shallow wells, dry riverbeds, roof structures, rainwater harvesting practice and indicators of water shortage including water vendors and dry riverbeds. Other forms of information recorded in the camera included large tanks donated to schools for storage of rainwater.

The observation sheet was designed to collect data on the actual sources of water in Machakos town like the rivers, dams, government boreholes and the county water supply. Roof structures rainwater-harvesting systems, storage containers like plastic containers, the barrels and the tanks. Methods of conveyance were captured using this method. The data sheet captured information on household sizes and types of sources available in different households. Information extracted from KBS formed the secondary data. The visual data was useful for discussion.

The researcher and the assistants familiarized with the data collection instrument through a pre-survey training for two days and during the pilot survey for data integrity.

4.3.4 Data Collection Procedure

This study used multistage sampling technique to acquire data using the questionnaire, the camera and the observation sheet. For a household to be included in the sampling frame, it had to be within Machakos town and fall in one of the designated residential areas. The residential areas were assumed to be homogenous units and therefore the basis of stratification into eight strata and these were Eastleigh, Muthini, Miwani, Kariobangi, Kenya Israel, Mjini, Kathemboni and Katoloni. Each household in the strata was assigned a random number from the random number table to be used in simple random sampling of the household.

The random number assigned to the household was placed in a common pool where each element had equal chance to be included in sample data. Each stratum was randomly sampled by drawing the numbers with the replacement for each stratum and any household whose number appeared was included in the sample data. Since there was a chance of a number of a household appearing more than once in sampling with replacement, then any number that reappeared after it had been drawn was excluded to avoid double sampling. This was repeated until the sample size for each of the eight strata as indicated sample size determination was attained.

At each of the randomly selected household, the study interviewed the head of the household as it was assumed that decision making on resource use was largely controlled by whoever headed the household. This was therefore purposive sampling. This was because the head of household was likely to be the custodian of information. In cases where there was no response of required information, replacement was sought in the immediate neighbourhood. To avoid influence of other household members the interview was conducted using isolation during which time other visual information was captured using camera. The researcher and the assistants assisted the respondents in recording information required and were available for questions that were not clear to the respondents and could avail information. This repeated until all the households were interviewed.

For proportional distribution of the households in Machakos town, the estates were stratified into eight based on water demand. A simple random sampling was done to select the households where 207 households were chosen. Purposeful sampling was done only to the designated house heads that were available at the time of data collection. The study targeted the decision maker in resource planning in the household. A copy of questionnaire was administered in each selected 207 households within the eight estates. Some questionnaires were left to the respondents to fill and later collected, as most of the respondents were literate. The researcher also conducted interviews with household heads using the guided interview schedule approach. Observations were made and photographs taken on key features like boreholes, rivers, storage facilities among others. The data was then recorded in details in the field notebook.

4.4 Data Processing and Analysis

4.4.1. Data Processing

Data collected from the field using questionnaires, other instruments were systematically checked by questionnaire number, stratum and completeness, and this resulted in 207 accepted for analysis therefore 100% return. The accepted returns were matched by observation records from the field as well as associated visual images. On each questionnaire the individual questions assigned variable names v1, v2, vn and associated appropriate labels.

The variable names and codes were used to create a code book were for each variable response and numeric and associated value were created for closed ended variables while for the open ended variables all possible answers were listed, ordered and assigned meanings according to the section of questionnaire and observations made in the field. The resulting open-ended information was then assigned numeric code and the associated values. The coding results were then transferred to codebook entry sheet.

The codebook entry sheet and the associated field observation were used to design a data entry data face in the Statistical Package for the Social Sciences (SPSS) software environment. The design in SPSS was in designed variable v and specifies the variable name type, decimal places if numeric, with label value and measurement level (scale, string date and memo). The design was completed with variables in the questionnaire, a switch was made to the data view from which individual questionnaire information was recorded in the codebook were entered until all the 207 cases were included. The results were saved at SPSS SAV file to create a data file (that is Machakos .sav).

The resulting data file was evaluated for any data entry error by first running procedure to create frequency tables and flows. These results were scanned for outliers, misplaced entries and wrong responses. This data cleaning procedure was necessary before any statistical analysis could be used to create information to address study problem, objectives and questions. The data entry was repeated and cleaning procedure carried out to create another data file after which the data files were compared for sample size n and entry similarities. It is only after comparison of the two data files that the data file was accepted for analysis.

For the field observation, sheet each observation resulting on a table of field observation matched to individual questionnaires. The tabulated results were used to correct wrong entries and sassiest in interpreting the statistical result in relation to study problem and objectives. The visual images captured using camera was used to assist in the discussion of analysis results and to provide visual information on the study area in the relation to the study areas and objectives. The results of the questionnaire data capture, the observation sheet tabulation and images recording were used to create the study sample survey database that was used in the data analysis procedures.

4.4.2 Data Analysis Techniques

4.4.2.1 Determining Main Water Sources

The procedure used in determining water sources started by running a frequency analysis for all the variables to establish sample distribution tendencies. The distribution tendencies were used to indicate what was typical about sample distribution (mean. median and mode) and how the individual observation varied from the typical distribution. The results of the frequency distribution were used to provide accurate description of the sample data distribution of water sources in Machakos town.

The description provided by the frequency were further refined by cross tabulating the frequency scores by the Bio data variables of how long they had stayed, the number in household, name of the estate. The cross tabulation scores provided indications of differences and association in main water sources by bio data information. The end product of cross tabulation was a contingency table which the information there of was appropriately used in inferential analysis of the sample data.

The inferential statistical technique used in establishing the main water sources in Machakos town was chi- square, which was as:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Where:

χ^2 = the chi-square statistic

O = the observed frequency score and

E = Expected frequency score

The chi square was used because the cross tabulation results were frequency scores and therefore required non-parametric measure of differences or association where in this study the difference tested in the hypothesis was between the observed water sources and expected water sources by already indicted bio data variables. The significant test at all levels was at α 0.05.

4.4.2.2. Establishing Population and Water Shortage Relationship

To compute relationship between population and water shortage in Machakos town there was first the need to establish changes in water supply and population at the household level during the period of initial settlement and the time of survey. Population change was computed by getting the differences between (the household size at the time of survey is (p1) and the household size at the initial time of arrival (p0) and this was expressed as:

hhc = p1 - p0

Where

hhc= household change coefficient

Water deficit was computed by getting the difference between the water used at the time of survey (wu1) and the water used at the time of arrival at Machakos town (wu0) and this was expressed as:

WD= wu1 - wu0

Where WD is the water deficit coefficient

The Non-parametric spearman's rank correlation was used to measure the association between change in household size (proxy of population growth) and change in quantity of water used (proxy of water shortage). The Spearman's Rank Correlation was expressed as:

$$\rho = \frac{6\sum d_i^2}{n(n^2-1)}$$

Where

ρ = correlation coefficient

d = difference in paired ranks and

n=number of cases

The significant test of the correlation result was carried out using the *t* statistics, which was computed using the formula

$$t = \frac{\rho}{\sqrt{\frac{1-\rho^2}{n-2}}}$$

Where n is the sample size.

Significant test in all cases was at α 0.05

CHAPTER FIVE: RESULTS AND DISCUSSIONS

5.1. Water Sources in Machakos Town

Urban populations are increasing three times faster than normal population: 4.7 per cent compared to 1.6 per cent especially due to rural – urban migration as well as rapidly increasing birth rate in the urban population especially in the developing world (Asit K. Biswas and Juha I. Uitto).

The 21st century marks the first time in history that half of the global human population resides in urban areas and by the year 2025, it is estimated that more than two-thirds will be urban dwellers Coping with the growing needs of water and sanitation services within urban centres is one of the most pressing issues of the century .The rapid growth of urban centres places tremendous stress on the environment especially provision of sufficient water and preventing pollution. Worldwide pressure on water resources is mounting as populations grow, causing consumption per capita to increase [*United Nations Population Fund* 2007]. The tightly coupled relationship between human and natural systems in urban areas makes management and prediction of urban water very complicated. Consequently, many residents do not have reliable water supply. Cities cannot be sustainable without reliable access to safe drinking water and adequate sanitation. Sustainable, efficient and equitable management of water in cities has never been as important as in today's world

In Africa, many cities face mounting challenges of providing their increasing populations with adequate and sustainable water services. In Machakos town just like many other urban areas residents face water shortage. They have inadequate water from the sources especially those connected to the piped water. In Eastleigh estate, located in Machakos Town Constituency residents are forced to wake up early in the morning in search of the most precious need, as there has been a shortage of water that is being widely experienced even in the County. On Saturday 8th of October 2016, residents of Eastleigh were seen lining up very early in the morning in a long queue waiting for water which is not only hard to find but also very expensive as one vendor confirmed selling a 20 litres jerrican at 30 Kenya Shillings.

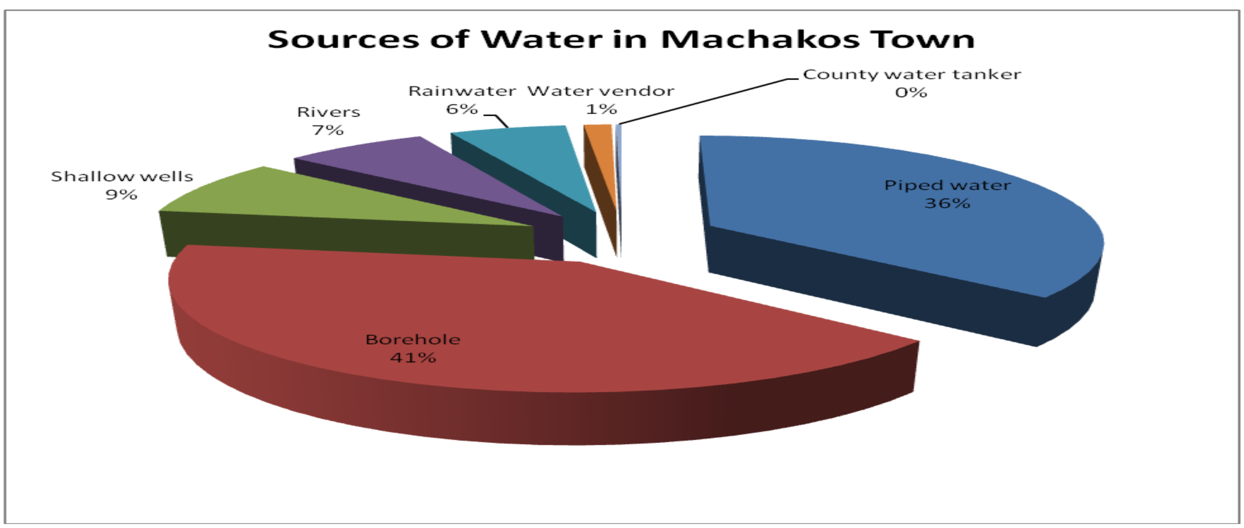
From the results of this study, the main source of water for domestic purposes in Machakos town is underground water in form of privately owned boreholes. 41.1% of the households depended on this source of water for their daily water demands while 36% of the participating households mainly depend on the County Government water supply system by pipes. There are households, which get their water from shallow wells (8.5%) while (6.9%) get water from rivers and streams within Machakos town. A small fraction of the households (0.3%) depend on water supplied by private investors in the water business who use tanks mounted on lorries to vendor water from one estate to another. 61% of the participants admitted that Machakos town acute perennial water shortage and scarcity despite the above efforts (refer table....and figure....)

Table 5.1: Sources of Water for Domestic Purposes in Machakos Town

What is your main source of water for domestic purposes?		Responses	
		N	**Percent**
Options	County Government Piped water	136	36.1%
	Borehole	156	41.4%
	Shallow wells	32	8.5%
	Rivers	26	6.9%
	Rainwater	21	5.6%
	Water vendor	5	1.3%
	County water tanker	1	0.3%
Total		377	100.0%

Source: Researcher (2018)

Figure 5.1: Sources of Domestic Water for Machakos town's Households



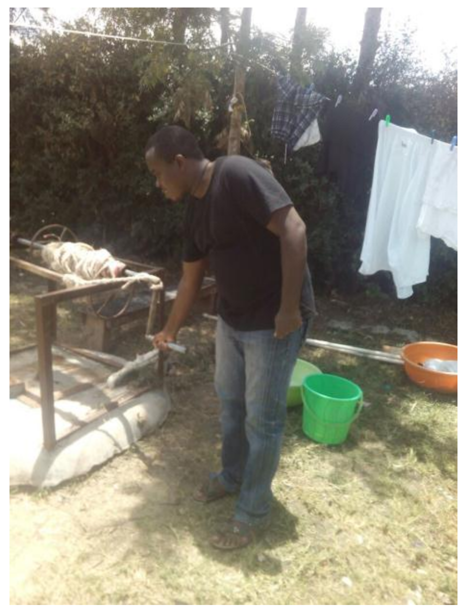
Source: Researcher (2018)

The boreholes are individually owned, most of which are constructed to exploit money-making opportunities created by water inadequacy. Most of the estates have numerous boreholes with higher concentration in areas away from county council water supply. Water vendors buy water from the boreholes as shown by plates 2 and plate 3. Most of boreholes are installed with pumping system to help access the water in large quantities.

In plate 2 residents are queuing to fetch water from a private bore hole as the inadequacy bites. In plate 3 a resident is trying to pull water from a shallow well. The leading source of water is borehole.

Plate 2: Community members line for water at a Borehole Plate 3: Operating a private shallow well

Source: Researcher (2018)



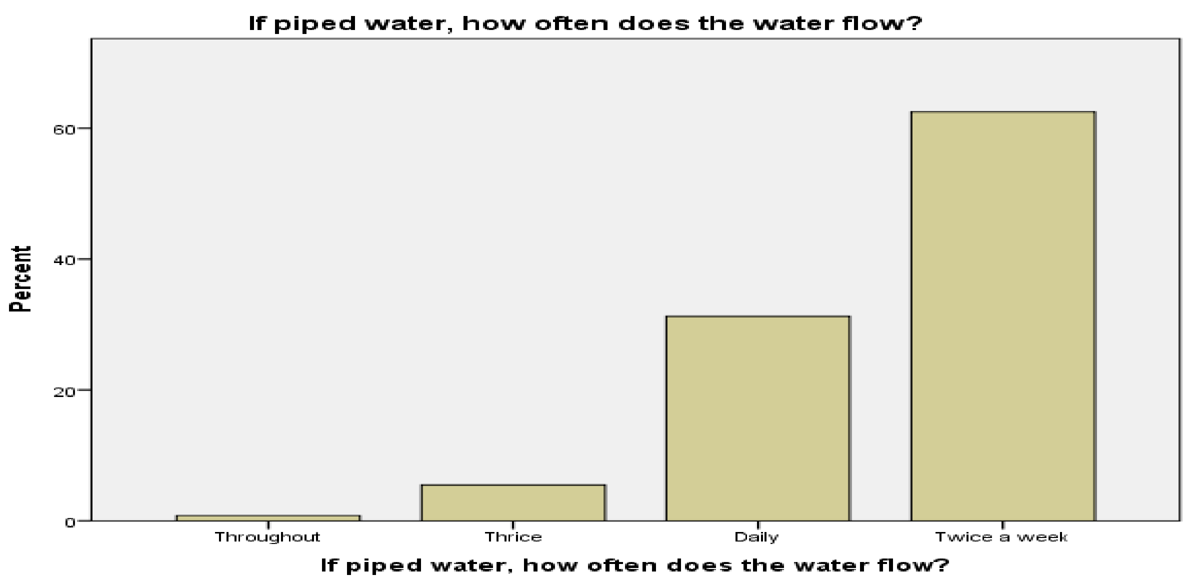
Source: Researcher (2017)

Plates 2 Shows residents queuing for water in Mjini estate from a private borehole, which they pay for. In plate 3 a resident pulls water out of a shallow well.

Piped water, which is the second major source of water, did not flow through out but at varying frequencies. It is intentionally rationed by the managers. 58% of the interviewed participants indicated that they receive piped water twice per week while 19.3% said that their pipes run two times weekly. Residents living close to the county water supply office indicated that their pipes run all the time. However, this is the lowest proportion at 0.5% but there are those (3.4%) who informed the study that they have water running in their pipes three days a week. Please see figure 4 below.

The main cause of variations in the water supply by pipe was found to be intentional water rational by the water managers. However, there are respondents who could not associate the variations to anything apart from mismanagement, poor supply systems (such as broken pipes) and vandalism of supply network infrastructure. High population, dry spell and poor supply are the other causes of water supply variations. The residents indicated that the major water supply was not adequate to provide water to expanding estates. Kenya Israel estate does not receive any piped water and therefore relies on borehole water and rooftop rainwater harvesting only.

Figure 5.2: Frequency of Flow of Piped Water to Pipes



Source: Researcher (2018)

5.2 Main Cause of Water Shortage

From the results, it was established that there is water shortage in the estates of Machakos town, which was evidenced by rationing of the piped water in most of the estates. The study found out that the main cause of water shortage in all the estates was increased population (37.4%) which strained piped water. This was clearly shown by increased number of members in every household. In the households studied, it was established that the daily water supply was not adequate and that most of the households required more water than others. From the study, it was clear that urban influx, a common phenomenon in urban areas was evident and a major cause of increased population.

The household sizes gradually increased where some households comprised of nuclear members and of extended family members. Increased population was confirmed from county water offices where the minister for water indicated that the water was not sufficient for the increased. 25.6% of the respondents indicated that drought was the cause of water shortage. Frequent droughts had caused drying of some boreholes thus reducing the water amounts. Other causes of water shortage identified are increased household demand (14.6%), poor water management (5.9%), lack of other sources and lack of tap water in some of the estates like Kenya Israel (2.3%).

Table 5.2: Causes of Water Shortage in Machakos Town.

Causes of water variation		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	N/A	1	0.5	1.0	1.0
	Poor power supply	1	0.5	1.0	2.1
	Dry spell	6	2.9	6.3	8.3
	High population	16	7.7	16.7	25.0
	Poor supply	23	11.1	24.0	49.0
	Rationing	49	23.7	51.0	100.0
	Total	96	46.4	100.0	
Missing	System	111	53.6		
Total		207	100.0		

Source: Researcher (2018)

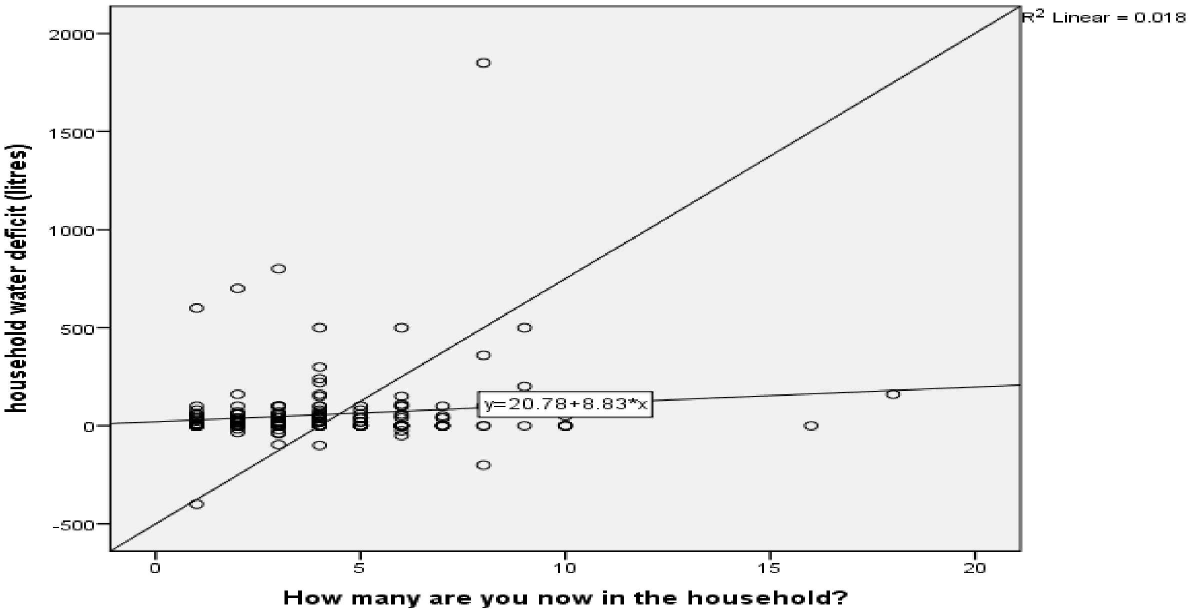
Table 5.3: Causes of Water Supply Variations in Machakos Town.

Causes of water supply variations in Machakos town		Responses		Percent of Cases
		`0	Percent	
Causes of increase or decrease	Drought	56	25.6%	28.4%
	Poor management	13	5.9%	6.6%
	High population	82	37.4%	41.6%
	Damaged pipes	3	1.4%	1.5%
	Increased domestic demand	32	14.6%	16.2%
	No other supply	8	3.7%	4.1%
	No tap water at beginning	5	2.3%	2.5%
	Tap water now available	18	8.2%	9.1%
	Drilling of borehole	1	0.5%	0.5%
	Piped water supply	1	0.5%	0.5%
Total		219	100.0%	111.2%

Source: Researcher (2018)

The study computed household size against water adequacy to find out deficit levels. The results indicated that as household sizes went up, inadequacy levels increased. Over the years as household sizes increased the amount of water available in the houses decreased as indicated by the two tables above. It was clear that majority of households with adequate water were the small households with fewer members like only one person and where the number of household members increased water deficit was high. The study established that those houses owned by individuals had their own boreholes especially in Miwani estate, which contributed to increased number of boreholes.

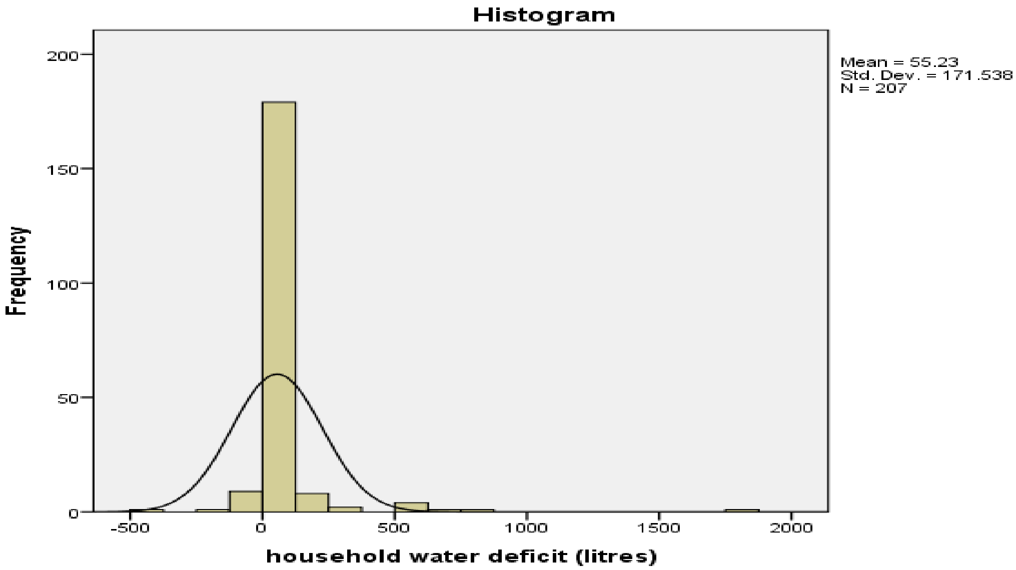
Figure 5.3: Household Sizes in Machakos Estates



Source: Researcher (2018)

Miwani estate comprises of natives who have sold land to some developers and therefore comprises of natives and urban dwellers. When the water demand and availability data were compared with the data on household size of all the estates in order to evaluate the deficit, the results tended to be similar to the pattern of mean household sizes. Larger households tended to have higher demands than smaller households The T-test results used in assessing the significance of the observed variations indicated that the water deficit was statically significant at 95% confidence levels.

Figure 5.4: Household Water Needs



Source: Researcher (2018)

5.3 Adaptation strategies to water shortage

In response to the strategies used to manage water shortage, most of the residents indicated use of alternative sources of water or limiting the water use in the household .The adaptation strategies seemed to be influenced by the common sources of water and the location. The leading strategy is buying water from vendors. (40.2%) who mostly buy from private boreholes and sometimes from water kiosks. 31.7% indicted that they minimise the water use so as to manage and cope with the shortage.6.9% practise rainwater harvesting though most of them do not have large storage containers to sustain them as majority (41.6%) indicated that the water only lasts for three months or less. Other adaptation strategies included sinking more boreholes, buying from water trucks, increase the storage facilities or ration the available amount.

Table 5.4: Coping Strategies for Water Shortage in Machakos Town

Strategies to address water shortage in Machakos		Responses N	Responses Percent	Percent of Cases
Dealing with water scarcity	Minimize use	60	31.7%	34.1%
	Rationing	5	2.6%	2.8%
	Buy from vendor	76	40.2%	43.2%
	Buy from Water tank	7	3.7%	4.0%
	Rainwater harvesting	13	6.9%	7.4%
	To Sink borehole	12	6.3%	6.8%
	More water storage	6	3.2%	3.4%
	Buy from borehole	8	4.2%	4.5%
	Buy from sources	2	1.1%	1.1%
Total		189	100.0%	107.4%

Source: Researcher (2018)

5.4 Rooftop Rainwater Harvesting Potential for Water Supply in Machakos Town.

The county government has advised all building and construction plans to be designed in a manner to ensure rooftop rainwater harvesting in upcoming and recent buildings. This will ensure 2000 litres water above can be harvested in every building is done. The government is also creating awareness on the need to harvested and increased storage capacity of rainwater. This is especially because rainwater is pure as it falls. The first two rain falls are allowed to clean the roofs after which cleaned reservoirs connected to collect water. The water is useful for domestic and industrial activities particularly from galvanized iron sheets. Asbestos and painted iron sheets can collect water for cleaning flushing of toilets and irrigation.

Plate 4: RTRWH as Practiced by Machakos Primary School

Source: Researcher (2018)

Water harvesting is already an old practice in Machakos town. Some institutions and households in town such as the Machakos hospital and Machakos Academy among others have been harvesting rainwater from their roof for a long time now. People that are able to get water from Machakos water and Sewerage Company are 6,000 as explained by the water engineer. Geographic Information System (GIS) has been installed to monitor water movement and any challenges associated with water distribution. The program was started last year as a pilot study of water reform sector to ensure efficient water services in the town. As a result, the company has been able to reduce non-revenue water from 83 % to 57%. Initially they were not able to identify faulty metres and therefore get readings from all metres. Faulty metres have been identified and corrected through GIS, leakages and bursts have been repaired. They have generated account numbers and maps to help identify the location of metes either for billing or for disconnection.

CHAPTER SIX: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS OF THE STUDY

6.1 Introduction

The chapter presents a summary of the study findings based on the data collected and analysed. The conclusions of the study are also presented based on the research themes. The study recommendations are categorized into policy recommendations and suggestions for further research. The suggestions for further research have been developed based on the gaps identified after the interpretation of the study findings.

6.2. Response Rate

The study found out that more males 115(55.6%) than females 92(43.4%) participated in the study. The study found out that 56(27.1%) of the people had lived in Machakos town for a period of 1-5 years, while 58(28.0%) had lived in the town for more than 21 years.

The study findings on household size indicated that the average number of individuals per household was eight persons. However, most 39(18.8%) people indicated that they were living alone. Households with two people were 37(17.9%), those with three 29(14.0%).

The study found out that there were several estates in the town. The notable ones were Miwani with 52 (25.1%) individuals and Eastleigh estates with 25(12.0%).

Majority 145(70.0%) of the respondents were living in rental houses, while 58(28.0%) said that they lived in their own houses. Most people either lived in a one bedroom 61(29.5%) or two bedroom 50(24.2%) houses.

6.2.1 Water Consumption

Nearly half of the respondents used 50-100 litres per day as reported by 86(41.5%). At least 77(37.2%) of the people said that they used less than 50 litres per day with 17(8.2%) reporting 101-200 litres of water per day.

Most 118(57.0%) of the respondents were of the opinion that the available water was inadequate. On the other hand, 85(41.1%) felt that the water was adequate. An equal number of respondents 64(30.9%) were of the opinion that they required less than 100 litres, while 34(16.4%) felt that they need up to 200litres per day.

It was the opinion of 126(60.9%) that the supply of water had decreased over the years. On the other hand 70(33.8%) said that the supply of water had increased. The change was majorly attributed to increase in household size 73(35.3%) and increased domestic use 27(13.0%).

6.2.2 Rain Water Harvesting

Most people 137(66.5%) said that the roofing structure allowed for rainwater harvesting. However, roofing made of iron easily rusts 79(38.2%); there is lack of gutters as indicated by 41(19.8%) individuals. Majority of the residents pay for water as indicated by 131(63.3%) of the respondents. However, 64(30.9%) do not pay for the water supplies.

The expenditure on household water use ranged from 200 to 1000 shillings per day. Wide variations were noted with a slight majority of 115(55.6%) spending less than 200/- on water. There were also monthly variations. The study indicated that 16(18.4%) people paid more than 5000/-, while 3 (1.4%) paid 4001-5000/- as 6(2.9%) paid 3001-4000/-.

The study found out that majority of the people depend on piped water as reported by 108(52.2%), with 84(40.6%) using borehole water. The reports indicated that the water was availble on daly basis as reported by 44(21.3%) and twice per week as said by 66(31.9%). This was attributed to the fact that water is pupmed twice per week 7(3.4%), as 5(2.4%) attributed this to high running costs.

6.2.3 Practice of Roof Top Water Harvesting

About 62.8% of the respondents indicated that they faced the challenge of water scarcity. In order to store adequate amounts of water, most residents have jericans (42.5%) and water tanks (32.4%). Responses from (46.4%) individuas indicated that harvested water was more than the other sources. Some (41.1%) pointed out that the water lasts up to the end of the rain season. The water lasts for one month (13.5%), 2 months (7.7%), 3months (4.8%) and 4 months (2.4%). According to (54.1%) of the respondents, there is need to increase the water storage facilities, and construct more dams (6.3%).

The main interventions were contruction of dams (28.5%) and provision of water tanks (33.8%). Other interventions include proper roofing, guttering and storage facilities (10.6%) as well as sensitization of the people (7.2%) on the benefits of rain water harvesting.

6.3 Conclusions of the Study

Based on the study findings, the study concluded that:

The average household size is eight people per house within the residential areas. This has huge implications on the water supply versus the demand. The daily water requirements are high and thus the available water supplies cannot meet the demands.

Most people living in Machakos town rely on piped and borehole water supply system. The cost of the water supply is basically very high, considering that residents in other towns pay as low as 200/- as total expenditure per month , while these is the average amount spend on daily basis in the town. The statistics indicate that there are people in Machakos town who spend as high as 5000/ per month. Evidence adduced from the study also indicates that a majority of the people use the water for domestic purpose with only a few individuals using the water irrigation and that rain water harvesting is an important economical and viable activity, if appropriate done.

Increasing population pressure has a direct influence on the supply, availability and use of rainwater. However, suitable measures need to be undertaken to protect reserve and conserve water catchments within the region. Since water supply dependents on the area, size of the containers and use. Most people in the area must seek to enhance the roof catchments by proper roofing, guttering and collection.

The water supply system in Machakos town does not sufficiently meet the water requirements of the populace in the town.. With proper collection, piping storage and preservation, the available sources of water can help address the perennial water shortage problem in Machakos town.

6.4 Policy Recommendations

Based on the foregoing findings and conclusions, the study recommends that the Machakos County moves with speed to enhance the provision of clean water to its increasing population. The implementation of the rainwater harvesting programme should be a key priority for the county government. This move will lead to increased food production through irrigation, thus food security will be realized.

i. There is need for proper management, repair and maintenance of the existing dams, cisterns and water systems in the area. This will help reduce the county government's burden. The County government should realize that the high potential of rainwater harvesting in Kenya lies in three factors namely: reliable seasonal rainfall, the quality of roofing materials, and the high demand for clean water supplies, as well as the housing quality in Kenya based on roofing materials. As such, seek to implement suitable policies that will ensure conservation and preservation of water catchments in the area.

ii. There is need for the National Government, local community and the Non-Governmental Organizations (NGOs) to collaborate in ensuring that water harvesting programmes are prioritized, properly managed, monitored and evaluated to ensure sustainability. There is need for willingness by all stakeholders to participate in rainwater harvesting.

iii. Due to the changing technologies, there is need for proper redress of technical issues surrounding water harvesting. Since many water harvesting projects are not particularly sustainable or replicable as there are often inadequate technical interventions. For instance, choice of guttering, roofing materials and water piping equipment require expert support, which is never available, or it is inadequate.

iv. The County Government must institute more sensitization programmes in rainwater harvesting on usage and selection of water harvesting materials and equipment. This often leads to inappropriate designs, constructions and guttering systems leading to reduced water supply.

v. There is need for the county government to sink more boreholes and improve on the piping system as well as encourage more of rainwater harvesting

6.5. Suggestions for Further Research

The study suggests that:

i. A study to be carried out to determine the mechanisms that can be used to enhance water harvesting programmes in the country.

ii. A study to be carried out to establish reasons why inadequate managerial and technical skills influence implementation of rainwater harvesting in Kenya.

iii. A study should be carried out to determine suitable interventions that may be used to enhance water harvesting in Kenya.

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APPENDICES

Appendix I: Introduction Letter

I am a post-graduate student pursuing a Master of Arts degree in Environmental Planning and Management at the University of Nairobi. I am conducting a research on Rainwater Harvesting and Water supply in Machakos Town.

This is to kindly request your participation in the research by completing the questionnaire for me. The information obtained will be used for the purpose of this research and will be treated with utmost confidentiality and for the purpose of this research only.

Thank you in advance for your cooperation and assistance.

Yours sincerely,

Annastacia N. Kyalo.
MA Student

APPENDIX II: QUESTIONNAIRE

i. This questionnaire is divided in to three sections. Section A, B and C. Please complete each section according to the instructions.
ii. Do not write your name to ensure complete confidentially. Please respond to all the questions. (Tick where applicable).

Section A

1. What is your gender? Male [ ] Female [ ]

2. What is your marital status? Married [ ] Single [ ]

3. How long have you lived in Machakos town? ______ _ Months/ years.

4. How many are you in the house? [1-3] [4-6] [more than 7].

5. Where in Machakos town do you specifically reside? Within the town [ ] residential estate [ ] suburbs [ ] any other [ ]

6. Do you live in a rented house or your own house? Rented [ ] Own house [ ]

7. What is your status of employment? [Employed] [Self-employed] [Unemployed]

8. If employed, does your work require use of water? [Yes] [No]

9. If yes, about how much water do you require in a day? [5-10ltrs] [10-40ltrs] [more than 50ltrs]

10. Do you harvest rainwater to supplement the water source? [Yes] [No]

Section B.

11. Do you have variety of water sources near your household/premise? [Yes] [No]

12. Which is the main water source for use during dry season? [County Government] [borehole] [rainwater] [Any other source. Please specify…………………………………….

13. Which is the main source of water for use during wet season? [County Government] [borehole] [rainwater] [Any other source. Please specify…………………………………….

14. Averagely how long do you take to travel to fetch water during dry season? [Less than 5 mins] [5-10mins] [10-20mins] [20-30mins) [more than 30mins]

15. Averagely, how long do you take to travel to fetch water during rainy season? [Less than 5 mins] [5-10mins] [10-20mins] [20-30mins] [more than 30mins]

16. What is the main mode of water transport? Piped) (water trucks) (handcarts) (bicycles) (any other-specify

17. How do you pay for the water you get? (Cash on delivery) (Through a bill) (No payment)

18. If piped, how is the water supply (flows throughout) (twice-thrice in a week) (once in a week) 9any other-specify

19. If not piped how regular is the water supply? (Quite regular) (Not so regular)(Not regular at all)

20. If not regular, why?

…………………………………………………………………………………………………

……………………………………………………………………………………

21. How reliable is your current water source in terms of quantity?(very reliable)`not so reliable)(not reliable all)

22. Do you supplement the water source with harvested rainwater?

23. How do you use the harvested water?--

----

24. Would you consider rainwater harvesting as a measure to reduce water shortage? (Yes) (No)

Section C

25. Do you practise rooftop rainwater harvesting? (Yes) (No)

26. How many rainfall months are experienced in this area?

27. How do you store the harvested water? (In a built tank) (In barrels) (In jerricans) (Any other means

28. What is the volume of reservoirs used to store harvested water?

29. How much is collected? ....

30. How many drought months are experienced?

31. How long does the harvested water last you? ....

32. Is the harvested water enough? [Yes] [No]

33. What roofing material has been used in the building? ....

34. What does the quality and quantity of the harvested water compare with the water from other sources? ....

35. How can quality of harvested water be improved at household level? (Collection) [Preservation] [Filtration] [Disinfection] [Proper roofing material]

36. How can the quantity collected be increased? [Proper guttering] [Proper roofing] [Proper storage] [Proper pumping]

37. What is the minimum storage required to meet your needs? ....litres.

38. What roofing materials should be avoided?..

39. What are the benefits of rainwater harvesting system?

....

Thank you for your cooperation and assistance.

Appendix III: NACOSTI Research Authorization

THIS IS TO CERTIFY THAT:
MS. ANNASTACIA NUNDU KYALO
of UNIVERSITY OF NAIROBI, 77155-611 NAIROBI,has been permitted to conduct research in *Machakos County*

Permit No : NACOSTI/P/18/48107/27222
Date Of Issue : 6th December,2018
Fee Recieved :Ksh 1000

on the topic: *RAINWATER HARVESTING AND WATER SUPPLY IN MACHAKOS TOWN*

for the period ending:
6th December,2019

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014.

CONDITIONS

1. **The License is valid for the proposed research, location and specified period.**
2. **The License and any rights thereunder are non-transferable.**
3. **The Licensee shall inform the County Governor before commencement of the research.**
4. **Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies.**
5. **The License does not give authority to transfer research materials.**
6. **NACOSTI may monitor and evaluate the licensed research project.**
7. **The Licensee shall submit one hard copy and upload a soft copy of their final report within one year of completion of the research.**
8. **NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice.**

National Commission for Science, Technology and innovation
P.O. Box 30623 - 00100, Nairobi, Kenya
TEL: 020 400 7000, 0713 788787, 0735 404245
Email: dg@nacosti.go.ke, registry@nacosti.go.ke
Website: www.nacosti.go.ke

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH LICENSE

Serial No.A 22239

CONDITIONS: see back page

Appendix IV: NACOSTI Research Clearance Permit

NACOSTI

NATIONAL COMMISSION FOR SCIENCE,
TECHNOLOGY AND INNOVATION

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

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/18/48107/27222**

Date: **6th December, 2018**

Annastacia Nundu Kyalo
University of Nairobi
P.O. Box 30197-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Rainwater harvesting and water supply in Machakos Town"*** I am pleased to inform you that you have been authorized to undertake research in **Machakos County** for the period ending **6th December, 2019.**

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

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Machakos County.

The County Director of Education
Machakos County.

National Commission for Science, Technology and Innovation is ISO9001:2008 Certified

Appendix V: Turnitin Originality Report

Document Viewer

Turnitin Originality Report

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http://www.newsecuritybeat.org

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"Handbook of Climate Change Adaptation", Springer Nature America, Inc, 2015

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http://en.wikipedia.org

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Submitted to Technical University of Mombasa on 2018-10-03

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http://www.unep.org

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http://machakosmunicipal.or.ke

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http://startinternational.org

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Department of Geography and Environmental Studies UNIVERSITY OF NAIROBI

DEAN FACULTY OF ARTS UNIVERSITY OF NAIROBI 29 NOV 2018 P.O. Box 30197, NAIROBI

DEAN FACULTY OF ARTS UNIVERSITY OF NAIROBI 29 NOV 2018 P.O. Box 30197, NAIROBI

29/11

Appendix VI: Research Permit Letter

UNIVERSITY OF NAIROBI

Department of Geography & Environmental Studies

Telephone: +254 2 318262
Extension: +28016
Fax: +254 2 245566

P.O. BOX 30197-00100
NAIROBI
KENYA

12 January, 2015

TO WHOM IT MAY CONCERN

This is to confirm that **Ms Kyalo Annastacia Nundu** (Reg. No. C50/64874/2010) is a postgraduate student at the Department of Geography and Environmental Studies, University of Nairobi. She is pursuing her Master of Arts Degree in Environmental Planning and Management and is currently undertaking a research project on **"Source of water in Machakos Town: A case study of rainwater harvesting".**

Any assistance accorded to her will be highly appreciated.

CHAIRMAN
Department Of Geography
and Environmental Studies
UNIVERSITY OF NAIROBI

Dr. Samuel Owuor
Chairman, Department of Geography & Environmental Studies

Appendix VII: Declaration of Originality Form

Declaration Form for Students

UNIVERSITY OF NAIROBI

Declaration of Originality Form

This form must be completed and signed for all works submitted to the University for examination.

Name of Student:	KYALO ANNASTACIA N
Registration No:	C50/64874/2010
College:	NAIROBI UNIVERSITY
Faculty/School/Institute:	ARTS
Department:	GEOGRAPHY AND ENVIRONMENTAL STUDIES
Course Name:	ENVIRONMENTAL PLANNING AND MANAGEMENT
Title of the work:	RAINWATER HARVESTING AND WATER SUPPLY IN MACHAKOS TOWN

DECLARATION

1. I understand what Plagiarism is and I am aware of the University's policy in this regard.
2. I declare that this ......PROJECT.................(Thesis , project, essay, assignment, paper, report etc) is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work, or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.
3. I have not sought or used the services of any professional agencies to produce this work.
4. I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her own.
5. I understand that any false claim in respect of this work shall result in disciplinary action in accordance with University Plagiarism Policy.

Signature: ....

Date: ....12/9/18..........