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SCHOOL OF ENVIRONMENTAL STUDIES

DEPARTMENT OF ENVIRONMENTAL PLANNING AND MANAGEMENT.

THE POTENTIAL OF ROOF CATCHMENT AS A FLOOD MANAGEMENT STRATEGY AT MAVOKO SUB-COUNTY IN MACHAKOS COUNTY.

BY

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DECLARATION.

This research study is my original work and has not been presented to any other examination body. No part of this research should be reproduced without my consent or that of The Kenyatta University.

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Signature________________ Date ______________

Declaration by the Supervisor

This research has been submitted with my approval as the Kenyatta University Supervisor.

Mr. Kirui

Signature ________________ Date _______________

DEDICATION

This work is dedicated to Kenyatta University; Department of Environmental Planning and Management and Mavoko sub-county in the County Governments of Machakos.

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ABSTRACT

The traditional approach for coping with urban flooding has been linear whereby all the rainwater that has fallen over a wide area is conveyed to and managed by sewers or rivers lines. When the carrying capacity is insufficient, possible counter measures are considered only to the line; denoting the upsizing of the sewer, widening of the rivers or increasing the pumping capacity. Due to heavier and unpredictable rainfall, the water conveyance system in the whole sub-county is limited, thus requiring upgrading of another method of containing the excess water.

The water management approach worldwide is currently in transition, with a shift evident from purely centralised infrastructure to greater consideration of decentralised technologies, such as rainwater harvesting (RWH). Initiated by recognition of drivers including increasing water demand and increasing risk of flooding, the value of RWH is beginning to filter across the academic-policy boundary. However, in Kenya, implementation of RWH systems is not straight forward due to social and technical barriers, concerns and knowledge gaps exist, which currently restrict its widespread utilisation. (Ward, S., Butler, D., Barr, S. and Memon, F.A. 2009)

Rainwater harvesting as a supplementary source of water has not received any serious attention. This research investigates the potential of roof catchment collection, storing and using rainwater in Mavoko sub-county, Machakos County.

The importance of this study lies in severe flooding in some areas of Mavoko particularly in its satellite town which are experiencing rapidly population and development growth in the sub-county. So many people are affected when floods occur and furthermore the current water supply system is not adequate to provide enough water for the growing population.

Mavoko has a tropical climate, with rainy months from March to May and October to December, with approximately 118 days of rain in the year and an annual precipitation of 40 inches (Kenya Meteorology Department, 2011). Considering the chronic water scarcity in the sub-county, a considerable amount of homes have elevated or underground water storage tanks installed to provide water for their daily use. These two observations make rainwater catchment systems a great option to be considered because the approach takes advantage of the opportunities the town's climate as well as existing infrastructure.

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ACRONYMS

ADC- African District Council

DEAP- District Environmental Action Plan.

DMCs- Disaster Management Committees.

DOC- Disaster Operations Centers.

IWRM- Integrated Water Resource Management.

LNC- Local Native Council.

KMD- Kenya Meteorological Department.

KRA- Kenya Rainwater Association.

MDGs- Millennium Development Goals.

MWI- Ministry of Water and Irrigation.

NLM- New Life Mission.

RHM- Rainwater Harvesting and Management.

RWH- Rain Water Harvesting.

WASREB- Water Services Regulatory Board

WRM- Water Resource Management.

WRUAs- Water Resource Users Associations.

UN- United Nation

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Operational terms.

- Aquifer- underground formation / soil/ rock which can yield water.
- Artificial recharge- any man made scheme of facility that adds water to an aquifer.
- Bore well- small diameter wells which are generally deeper than open wells.
- Catchment area-
- Dug wells- traditionally used large diameter wells. A pit excavated in the ground until the water table is reached. Usually supported on sides by brick or stone wall.
- Ground water- the water retained in the inter-granular pores of soil or fissures of rock below the water table.
- Rainwater harvesting- the capturing of rainwater before it reached the ground and its storage on tanks for its use. Is also the deliberate collection of rainwater from a surface (catchment) and store it to provide a water supply.
- Run off- water flowing on the surface after a long rain within.
- Recharge- the process of surface water percolating naturally to the ground
- Water table- the level of water within it granular pores of soil or fissures of rock, below which the pores of the rock are saturated.

Chapter Outlines

Chapter one gives an in-depth overview of the background to the problem, statement of the problem research questions, objectives, premises significance, and justification of the study and the scope of the study.

Chapter Two provides a critical review of the existing relevant literature, culminating in the identification of gaps and the conceptual framework.

Chapter Three outlines the area of study in terms of its physical and socio-economic set up.

Chapter Four discusses the research methodology, focusing on the nature of data, sampling procedures and methods of data collection and analysis.

Chapter Five deals with data analysis and discussions and finally;

Chapter Six give the summary, conclusion and recommendations.

CHAPTER ONE:

INTRODUCTION.

1.1 Background of the study.

Among the natural phenomena, flood is one of the biggest destroying factors in developing countries which always bring numerous people's life, property and assets to the hazard. The growing population, urban development and industrialization are the main factors that have undesirable consequences in the hydrology of watershed region in the cities. developing countries experience urban flood during rain seasons due to the limited water percolation to the earth's surface as a result of impermeable surface which a has been introduced by man. It is therefore tangible that we require some construction of transition and collection of surface runoff and integrated management to reduce the flood (Ngigi, 2003:944).

According to Singh *et al* (2005:214), Water-related disasters such as floods, droughts and water-borne diseases affect more than 200 million people each year and claim more lives than war. The damage done by water-related disasters thwarts sustainable development and perpetuates poverty. Over the last 10 years, disasters of hydrological, meteorological and climatic origin have been responsible for over 90% of all deaths due to natural disasters. More than 2,000 water-related disasters on all scales occurred during the last decade. Asia and Africa were the most affected continents, with floods accounting for half of these disasters and water-borne and vector-disease outbreaks accounted for a significant fraction of remaining disasters. In term of lives claimed, floods accounted for 15% of all deaths related to natural disasters.

According to RELMA, (2007), Africa is considered a water-scarce continent with most of countries regularly experiencing extreme water shortage during periodic dry spells. Rapid population growth and inefficient use of resources increases the deficit between available supplies of water and the needs of the people.

As a resource dwindle and water demand increases, large scale water supply projects become unviable. There is need to decentralize water supply to household and small community level. There is great potential to make better use of water resources by harvesting rainwater and storing it locally for household and productive purposes (ibid, 2007).

The lack of water is the largest constraints to sustainable livelihoods in many parts of Africa. Rapid runoff during the rainy season frequently results in a high proportion going to waste or even becoming destructive. Harvesting rainwater where and when it falls presents opportunities to address both water scarcity and floods at local level (Vohland & Barry, 2009: 120).

Many cities in Kenya, especially Nairobi suffers from the same malady. Nairobi is blessed with two monsoon seasons and receives more than 1000mm of rain spread out comfortably across the year, yet if suffers from severe water shortage. Flooding in Nairobi has become an annual ritual causing deaths and massive destruction. Eleven people were killed by floods in Nairobi in 2001; exact numbers of the people who drowned not confirmed and 21 more people have been drowned in flood waters since then (Anon, 2000).

Mavoko sub-county also faces regular floods which when they occur brings the area to a standstill. Crossing roads during the rain seasons becomes impossible especially in areas with marrum roads making rains in this area are more of menace than a relief. Rain water is allowed to go to waste instead of it being utilized to meet the water demand ion this water scarce area.

The rainwater harvesting in Mavoko sub-county can serve dual purpose of controlling floods and reducing water scarcity. If the rainwater harvesting potential in this area is utilized optimally it would be possible to meet as much as 42% of the water demand.

1.2 Problem statement.

Floods have been major problems to residents of Mavoko sub-county. Every time it rains the area is full of floods, life are disrupted, dirty and unhealthy as rain water mixes with sewer waste from sewer lines, septic tanks, and soaks pits and flows through the rapidly upcoming residential and industrial areas. Rain literally becomes a curse but once rain and the water logging are far behind the same area will be thirst again

The rapid expansion of the town has led to sealing off of large surface areas, increasing the speed and volume of storm water run-off. Furious flooding damages property, consumes people's lives, exposes and damages water pipelines and chokes drainage channels with debris, spilling raw sewage into the streets which has health implications such as cholera. As a result of increasing surface cover, rain water is prevented from percolating into the ground. Some of the town residents have opted for boreholes as an alternative to the intermittent water supply. However the boreholes are now experiencing inadequate yields due to poor recharge of the water table. The urban-industries, residential and commercial sectors demand for water is growing by leaps and bounds yet these sectors do little to augment its water resources. Therefore this research tries to answer the question that why rain has become a curse in Mavoko sub-county by assessing the potential of roof catchment as a flood management strategy.

1.3. Research questions.

The main questions of this study will be; how can rainwater be effectively utilized to reduce flooding in Mavoko sub-county.

The following specific questions will arise to answer this main question.

a) What are the causes of floods in Mavoko sub-county?

b) What are consequences of floods in Mavoko?

c) What is the potential of roof catchment as a flood management strategy?

d) Do the relevant institutions have the capacity of supporting roof catchment?

1.4. Research objectives.

The main objective of this research is to propose measures that can be effectively used to curb flooding of Mavoko sub-county.

a) To assess the causes of flooding Mavoko sub-county.

b) To examine the consequences of flooding in Mavoko.

c) To assess the potential of roof catchment to address flooding in Mavoko.

d) To evaluate the institutional capacity to support roof catchment as a flood management strategy.

e) To recommend appropriate measures of managing floods in Mavoko.

1.5. Research premises.

a) Rapid urbanization is the cause of floods in Mavoko sub-county.

b) Floods have no consequences in Mavoko area.

c) Roof catchment has no potential as a flood management strategy.

d) Relevant institutions have no capacity to support roof catchment.

1.6. Justification.

Water is an integral part of ecosystems functioning as its presence or absence has a bearing on the ecosystems services it provides. Relatively larger amount of water is used to generate the ecosystem services needed to ensure provisioning of basic supplies of food, fodder and fibers. Today rainfed and irrigated agriculture use 7,600 litres of freshwater globally to provide food. During the 2000 UN Millennium Summit, world leaders from developed and undeveloped countries committed themselves to eight time-bound goals as a blue print to accelerate development. The resultant plan is set forth in the Millennium Development Goals (MDGs). Goal 7 of MDG addresses the environment and water with targets that provide the goal to *"halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation*". In relation to water, this implies provision of safe water for drinking as well as for hygiene. Therefore roof catchment it plays a critical role in meeting the millennium development goals, especially those concerning hunger, poverty, health and biodiversity. An additional of 1,600 km3 of water is required annually to meet the millennium development goal on hunger reduction which addresses only half of the people suffering from hunger. (Jennie Barron, 2009).

In the present scenario management and distribution of water has become centralized. People depend on government system, which has resulted in disruption of community participation in water management and collapse of traditional water harvesting system. As the water crisis continues to become severe, there is a dire need of reform in water management system and revival of traditional systems. Scientific and technological studies need to be carried out to assess present status so as to suggest suitable mitigation measures for the revival to traditional system.

Mavoko sub-county acts as a dormitory for the people working in Nairobi, Machakos, Kajiado County among other counties contributing to increased human population and rapid residential, commercial and industrial developments have led to increased paved area which reduces the rate of water percolating to the ground resulting to floods which causes massive losses in terms of life, property, destruction of settlement, facilities and agricultural products and economic burden to the community, also flooding water carries with it sewerage waste from default sewer lines which has health effect on people, causes siltation of water bodies and deposition of invasive plant species. Therefore there is need to manage flooding in order to be able to stabilize the sub-counties economy, reduce massive deaths and health effects, increase agricultural production and reduce damage of settlement and other facilities.

Mavoko area receives plenty of rain as it is blessed with rain regime, the long rains during April to June and the short rains between October and December. It receives an average rainfall of 750mm. in spite of this, the sub-county faces water shortage, which is attributed the fact that the sub-county acts as a dormitory for workers in Nairobi and other nearby centers such as Machakos town contributing to the current population of 137,211 people making it almost impossible for the sub-county to adequately meet the escalating water demand. Also many areas in Mavoko sub-county depend on borehole water and an average of 3500 cubic meter of water is extracted daily, leading to a decline in groundwater level (Machakos DEAP 2009-2013). Water harvesting will provide means of recharging ground water thereby maintaining the balanced situation of the resource.

This project done now will help in preventing floods in low lying areas, replenishing of ground water table, enabling dug wells and bore wells to yield in a sustained manner, provision of water during summer seasons and help in the availability of clean water with reduced salinity and presence of iron salts.

1.7. Significance of the study.

The beneficiaries of this study are the residents of Mavoko Sub-County, real estate and industrial owners who for the past years have encountered great losses as a result of floods. The beneficiaries also will be able to augment the water supplied MAVWASCO during dry season when there is water rationing and also reduce water bills.

There are numerous positive benefits for harvesting rainwater. The technology is low cost, highly decentralized empowering individuals and communities to manage their water. It has been used to improve access to water and sanitation at the local level. In agriculture rainwater harvesting has demonstrated the potential of doubling food production by 100% compared to the 10% increase from irrigation.

1.8. Scope of the study.

Mavoko sub-county covers an area of 693 km^2, with an average population of 137,211. Stretching from KAPA/Airport area where it borders with Nairobi County and covers Katani, Ruai on Kangundo road through Muthwani-Lukenya, Makutano (Kyumbi) where it Borders Machakos Town. It covers Kapiti plains to the south west towards Kitengela area where it borders with Kajiado County, then to Embakasi at Nairobi County border. (USAID, Kenya).

This study focuses on the potential of roof top catchment as a strategy to control floods in Mavoko sub-county. The study will cover the following satellite towns in which hosts half of the population of the sub-county with a population of 111,742 (Machakos DEAP, 2009-2013) namely; Athi river, Syokimau and Mlolongo.

1.9. Limitation.

- Time,

Time has always been a limited factor, especially due to the fact that rainwater harvesting has not been being practiced; it might take long to gather enough data for research.

- Inaccessibity.

Mavoko area has black cotton soil which is inaccessible especially during the rain seasons. Some areas of Mavoko sub-county have no defined access roads.

- Inadequate information.

The meteorological department might not be willing to give information and data regarding the amount and frequency of rainfall received in the area.

Also the community might not be willing to discuss anything related to floods maybe because it reminds them of hoe they suffer every time it occurs, loss of their loved ones or loss of hope in mitigation of this disaster.

- Hostile community.

Community not willing to give information as they believe nothing can be done to help their situation. They argue that so many researches have been done in the past and so far no solutions have been generated to address flooding of this area.

The following measures were taken to address the above challenges. In order to be able to save time I conducted reconnaissance before to familiarize myself with the areas and that made it easier to traverse the area, use of gumboots which made it possible to navigate the muddy roads. As it was not possible to get all the information necessary for the research from meteorological department and the community published information such as DEAPs and internet were used to fill in the gap and lastly, I was able to convince the community who are the key beneficiaries of the project it will highly benefits them if successfully implemented.

CHAPTER TWO.

LITERATURE REVIEW.

2.1 Introduction.

Roof catchment has been practiced over the past 2000 years. The earliest evidence in Africa relates to cisterns in the western Mediterranean Coastal Desert in Egypt which date back to roman times. At present 2000-3000 cisterns in the region are still operational with their sizes ranging from 200-300 cubic meters (Shata, 1982). Tradionally, people have collected and stored rainwater running from eaves of their thatched roofs in earthenware pots.

Along the east coast of Africa, rainwater collection systems known locally as *djabias* have been constructed in several countries and are still in used until today. For example, in Manda, Pate and Wasini islands in coastal region of Kenya. These consist of rectangular tanks made of coral blocks and were traditionally plastered with local cement made from burning and crushing coral. These systems often had a small purpose-built catchment area to complement roof run off. By the first half of 20^{th} century, roof catchments were often build at missions, churches and in schools (ibid, 1982).

2.2 Causes of Floods.

There are numerous types and causes of floods which include; urban flooding is caused by rainfall overwhelming drainage capacity in urban areas, the impact can be very high because the areas affected are densely populated and contain vital infrastructure. Continuing development in flood-prone areas increases the risk.

Future Flooding, Foresight OST, (2004) states that, the cost of urban flooding could rise to between 1-10 billion pounds a year by 2080s if no action is taken to reduce the risks.

The following factors tend to be the cause of increased urban flood; Ageing drainage infrastructure- where by a lot of sewerage and drainage network is old and in poor condition, more buildings- the development of new structures cover previously permeable ground increasing the amount of surface water running off into drainages and sewers, Increased paving- increasing proportions of impermeable ground in existing developments as people build patios and pave over front gardens, and lastly, climate change- wetter winter and heavier summer shower are expected to put more pressure on urban drainage. Climate models predict that winter rainfall will increase by 20-30% by 2080s.

Natural floods: This type of floods is caused naturally by overflow of huge volume of water from rivers, lakes, coastal or heavy rains or downpours, tsunamis and hurricanes. They could be riverine floods caused by rivers. Estuarine floods caused by a combination of sea tidal surges and storm-forces winds or coastal floods caused by tsunamis and cyclones.

Catastrophic floods: This type of floods is caused by significant or unexpected events such as dam breakages. Heavy rains causes rise of water levels in dams, rivers, lakes and water starts to overflow to the adjoining areas causing deluge.

Snow floods: floods caused by snow melting as global temperature rises as a result of global warming making the snow caps to melt faster. Continuous and faster snow melting and rises the level of oceanic water which consequently raises the level of water in rivers causing floods.

The satellite towns majorly experience urban floods due to the increased paved areas, natural floods due to reduced vegetation cover and increased amount of rainfall over the years and catastrophic floods as a result of bursting of Athi-River when heavy rains occur.

2.3 The Consequences of Floods.

Flooding, when the soil percolation capacity is overwhelmed and cannot drain effectively, the surface run-off the overflow travels down roads paths and floods low lying areas causing damage distress and loss of life. (Balmforth, D. et al, 2006).

Extreme floods have serious impacts on social, economic, environmental, political, and cultural factors of a given area, therefore, calling for a need of more coordinated post-audits following extreme floods to provide possible guidelines for communities to implement to limit long term of these impacts. (Friesema et al, 1979).

Economic effect, Economic hardships due to a temporary decline in tourism, rebuilding costs, or food shortages leading to price increases which is a common effect after severe floods. Chronically wet houses, high linked to increased respiratory problems such as asthma and other illnesses which results to increase spending on medical services. (West and Lenze, 1994:127). In developing countries floods have distinctive long-term effects. They can be divided into three categories: first, the consequences for human health which include death, physical injury, disease transmission, malnutrition and loss of morale; secondly, the consequences for agriculture which include destruction of farm products and reduced agricultural productivity; and finally, the impacts on housing and infrastructure which include damage of settlements and utilities such as schools, health facilities and churches. The duration and significance of the impacts depend on the levels of resources available to easy recovery and on the scope of the devastation (Alexander 1993:525).

According to Montz and Tobin (1998) Tobin and Montz (1994a) in evaluating how extreme floods affect real estate prices, they argue that residents with the most severe flooding do experience long lasting impacts on the house price. Estates within unaffected areas and with limited damage seem to be unaffected, however, the prices go up for some estates in affected areas because following the flood, estate owners replace all the appliances, paint and carpets generally increasing the houses in value to reflect the sprucing up.

After a disaster a community goes through four phases that overlap: the emergency, restoration, replacement reconstruction, and commemorative betterment period. Each of these phases takes about ten times longer than the previous one. The rate of recovery is related to the extent of damage, community capacity in terms of the available recovery resources, the prevailing pre-disaster trends, and community leadership and planning (Haas, Kates and Bowden, 1977). Losses of floods are considered to be direct or indirect. Direct flood losses are difficult to quantify and it is even more difficult to evaluate indirect flood losses. Direct losses are the number of business and homes destroyed, while indirect losses include migration from the area as a result of the flood, tax losses as consumers shop outside the damaged area and what are the costs of outbreaks of waterborne diseases (Hanchett. S, Akhter, J. and Akhter, K.R, 1998:226-7).

Lastly, pollution, Surface run-off can be a major source of pollution. It picks up potential harmful substances from surface including; oil, house-hold chemicals, fecal materials among others and transfer them to watercourses. When combined sewer overflows in time of heavy rainfall, excess foul water is discharged directly into water bodies. Untreated discharges pose risks to human health as they may contain toxins and pathogens such as virus that causes hepatitis A and bacterial infection related diseases. (Woods Ballard, B. et al, 2007)

2.4 The Potential of Roof Catchment.

Rainwater harvesting is mostly referred to as an "emerging technology"; despite the fact that rainwater cisterns are not a new concept. In the Middle East in 2000 B.C, middle-class dwellings stored rainwater in cisterns for use as a domestic supply as well as private bathing facilities for the wealthy. (Consulting- Specifying Engineer, 2011).

Rainwater catchment can be done at a domestic level for household uses, industrial level for use in factories or at agricultural level for irrigation purposes. The rainwater can be stored differently for all these uses though, the way it is collected is always the same. (Ferrera, 2010).

Water is one of those resources which have to be used with caution. This is true in countries which have a tropical climate. In particular reference to Kenya, where dry condition prevails, and scarcity of water during dry season is more rampant. The scarcity of water is more felt by those who have livestock and crops. But, this can be overcome by harvesting the rain water during the rainy season. .

A rainwater collection system can be an excellent alternative source for constant supply of good quality water. Like all other sources of water, rainwater harvesting has advantages. The advantages are: Water Quality; rainwater is purer than the water treated with chlorine as rainwater is generally one of the better sources of an alternate water supply when compared with other sources of water that may be available this is because; rain water is created through the natural process of evaporation, contains minerals and compounds necessary for healthy growth of life of both livestock and crops, Savings in terms of water bill. Rainwater is a source of water that can provide a cost effective and alternative source of good quality water, Simple Construction - The construction of roof catchment systems is not complicated and most people can easily build their own system with readily available materials and local people can easily be trained to build one, minimizing its cost. Ease to operate and maintain - The operation and maintenance of a household rainwater collection system is controlled by the individual without having to rely upon the maintenance practices of a municipally controlled water system, Convenience - Rainwater collection provides a convenient source of water at the immediate place where it will be used or consumed. It also provides an essential reserve in times of emergency or breakdown of public water supply systems, particularly during natural disasters. The technology is flexible and adaptable -. The systems can be built to meet almost any requirements. Poor households can start with a single small tank and add more when they can afford them. It is also adapted to suit most individual circumstances and to fit most any household's budget. It can improve the engineering of building foundations when cisterns are built as part of the substructure of the buildings, as in the case of mandatory cisterns. And lastly, the physical and chemical properties of rainwater may be superior to those of groundwater or surface waters that may have been subjected to pollution, sometimes from unknown sources.

2.4.1. Existing rainwater harvesting projects.

John. E. Gould and Erick Nissen- Pertson, (1994), argue that, rainwater catchment systems are probably better developed in Kenya than in any other country in Africa. In Eastern Kenya the history of constructing rainwater catchment system goes back several decades. These include variety of rock, roof and ground catchment systems as well as other related low-cost appropriate water supply technologies such as surface dams and shallow wells. In 1950s, a number of rock catchment systems were build by the local authority in Kitui. Some of these were refurbished in 1980s and still operates up to to-date. The more general use of roof catchment systems began with the increasingly widespread use of *mabati* as a roofing material in the recent decades. Major roof projects began in the late 1970s with the implementation of a number of designs developed by UNICEF at the now defunct village technology unit. In North Kitui the Catholic church promoted cement jars, while Action Aid built hundreds of basket work-framed (*ghala* baskets)n demonstration tanks at schools. Most of these tanks failed after a couple of years due to fungal, bacterial or termite attack of basketworks (Lee and Vesscher, 1998).

Application of an appropriate roof catchment technology can make possible the utilization of rainwater as a valuable and necessary water resource. Rainwater harvesting has been practiced for more than 4, 000 years, and, in most developing countries, is becoming essential owing to the temporal and spatial variability of rainfall. Rainwater harvesting is necessary in areas having significant rainfall but lacking any kind of conventional, centralized government supply system, areas which are prone to floods due poor soils which do not allow percolation and less vegetation cover and also in areas where good quality fresh surface water or groundwater is inadequate or lacking (Vohland & Barry, 2009)

Latin American countries and the Caribbean have annual rainfall ranging from 500 mm to more than 1 300 mm just like in Mavoko sub-county, with falling during a few months of the year, with little or no precipitation during the remaining months. Rooftop rainwater harvesting in this these countries has been effective for more than three centuries, and rain harvested water has been the basis of domestic water supply on many small islands in the Caribbean. Although the use of rooftop catchment systems has declined in some countries, it is estimated that more than 500 000 people in the Caribbean islands depend at least in part on such supplies. Further, large areas of some countries in Central and South America, such as Honduras, Brazil, and Paraguay, use rainwater harvesting as an important source of water supply for domestic purposes, especially in rural areas (Herweg & Ludi, 1999).

Rooftop and artificially constructed catchments, in United States naval at Bahamas, rainwater of average capacities of 70 000 liters is collect from rooftops and store it in cisterns Industries also use rooftop rainwater, and a preliminary assessment has been made of using Nassau International Airport as a catchment. In multi-storeyed apartment buildings and other areas serving large concentrations of people such as hotels and restaurants, water supplies are supplemented by water from rooftop catchment cisterns in this area (Hadwen, P. 1987).

The Islas de la Bahía off the shores of Honduras meet a substantial portion of their potable water needs using rainwater from rooftop catchments. Similarly, rooftop catchments and cistern storage provide a significant water supply source for a small group of islands off the northern coast of Venezuela.

In a recent rural water-supply study, the continued use of rooftop and artificially constructed catchments was contemplated for those parts of rural Jamaica lacking access to river, spring, or well water sources. It is thought that more than 100 000 Jamaicans depend to a major extent on rainwater catchments (Thomas, E.N. 1980).

2.5 Institutional Capacity.

Many institutions and organizations in Kenya support roof catchment, among them include:

2.5.1 Ministry Of Water and Irrigation.

The Ministry was established in January 2003 with the goal of conserving, managing and protecting water resources for socio-economic development. It is in charge of flood management under the department of irrigation, drainage and water storage. It has various units in district level which reports on flood situation.

The Ministry of Water and Irrigation has the following reforms, Water Resources Management Authority and the Water Services Regulatory Board.

Under the water sector reforms, the Ministry transferred management of and operation of water services to the Water Services Regulatory Board (WASREB) from mid 2005 which is now in-charge of providing water services in different regions across the country. NGOs, CBOs and any other community self help groups are required to enter into agreements with the respective regional water service boards with regard to use of water supply facilities owned by the community organisations.

2.5.2 Water Act, 2002.

The water act, 2002, provides for developing Catchment Management Strategy for protection and control of water resources. It specifically provides protection of catchment areas. This is a significant enabling provision, which, in practical application may substantially reduce flood hazards. RBOs are important institutions for IWRM. The regional offices of the WRM are already established in six different catchments. The WRMW regional offices are required to formulate Catchment Management Strategy and facilitate formation of WRUAs to assist in co-operate management of water resource and resolution of conflicts (Flood Management Strategy, 2009).

2.5.3 Kenya Rainwater Association (KRA).

Works in arid and semi-arid areas across Kenya in implementing rainwater harvesting and management (RHM) projects. These projects aim at improving access to water; improve livelihoods, food security; and reduce poverty for rural communities. Community members work in partnership with KRA and donors to ensure a sustainable and successful project. A KRA Technical Assistant is permanently based at every site to manage the project development; oversee construction; build community capacity; liaise with local Government; and generally be a focal point to ensure project success. New Life Mission Water, Food Security, and Child and Gender Rights, Mashuru Division (2010–2013) is one of KRA project which focuses on the promotion of RHM as a means of improving the livelihoods of the vulnerable *Maasai* community in *Mashuru* division, *Kajiado* County. In partnership with New Life Mission (NLM), this KRA/NLM project is targeting over 7,000 beneficiaries in this county. The project has improved water access by constructing farm ponds, school roof catchment systems, shallow wells, and improving livelihood options by integrating vegetable gardens, drip irrigation, and environmental conservation.

2.5.4 Disaster Management.

DOC which is under the ministry of special programmes is responsible for management of disasters through DMCs at district levels. DOC co-ordinates post disasters related activities of various ministries up to the district level, provides drinking water for the evacuated people in relief campus. KMD provides weather forecasts and early food warning DOC makes assessment of magnitude of impending flood and its disaster potential, informs Provincial Disaster Management Committees, which is responsible for rescue and relief operation through multidisciplinary teams at district and community level.(Flood Management Strategy Plan, 2009).

2.5.5 Case study. Nairobi national museum, Nairobi- Kenya

According to the Urban Water Harvesting Manual, 2004, The Nairobi national museum has been used as venue for the rainwater harvesting exposition for the last years. The purpose of the exposition is to demonstrate various water harvesting technologies and products available with regard to the domestic and agricultural sectors. The museum itself had in the past suffered water shortage during droughts when the city council of Nairobi rationed water.

In the museum roof water from the mammalian building and snake park building are diverted to the storage tanks and used for irrigation purpose.

The impacts of these tanks have been enormous. A lot of people from both urban and rural areas have appreciated the technology. Some are even ready to invest in similar schemes.

The tanks fill twice in a year during the long and short rains with total harvested rainwater of 470,000 litres. The Nairobi city council sells water at the rate of ksh 17-34 per cum. Thus saving accruing from water harvesting (Anon, 1998).

2.5.6 Level of institutional Involvement

According to UNHCR, 2008:17, cisterns are principal source of water for residences in several Caribbean islands. The level of governmental participation varies in different countries. For example in Caribbean islands, governments regulate the design of rainwater harvesting systems. In the U.S. Virgin Islands, the law requires that provision be made in the construction of all new buildings for the capture and storage of rainfall coming into contact with their roofs. This law requires that roofs be guttered and that cisterns for storage are constructed having a volume that relative to the roof size, the intended use of the building, and the number of floors the building will have. For a normal single-level, residential building, the law requires that 400 1 of storage cistern be provided for each m^2 of roof area. Cistern construction is further regulated by the Virgin Islands Building Code to insure the structural integrity of these cisterns, which usually form an integral part of building foundations.

Building code, 1996 states that, in Virgin Islands, all new residences in Barbados are required to construct water storage facilities if the roof area or living area equals or exceeds 3 000 square feet. This is also mandatory for all new commercial buildings with a roof area of 1,000 square feet or more. A rebate of $0.50 per gallon of installed tank capacity, up to the equivalent of 25% of the total roof area, will be given as an incentive by the Barbados Water Authority (UNHCR, 2008:14).

2.5.7 Community participation.

Gavida, J. (1993) contents that, community participation, promotion and support of local organizations in planning, implementation and monitoring of rainwater harvesting systems is essential to achieve their sustainable operation. Establishment of partnerships between public sectors, NGOs and community organizations is a requisite to make efficient use of all the capacities available at local level. Effective community participation requires training and support activities to strengthen community organizations and to develop individual and collective skills necessary for planning, construction and operation of rainwater catchment systems. (Mansuri and Rao, 2004:2).

2.6 Gap Identification in the Existing Literature.

In the departments, there is no section to deal exclusively with flood management issues. The procedure for monitoring is ad-hoc and there are no field staffs dedicated to keep track of flood situation or to take preventive or remedial measures during or after floods.

A number of flood protection works were built in different river basins before or immediately after independence. MWI has no financial or organizational mechanism for their routine repairs and maintenance specific schemes for major repairs are planned and implemented from time to time without an overview plan. (JICA 1990), and (National Water Master Plan, 1992). No significant follow up has been taken for the implementation of the proposed flood control measures.

Major floods occur every year. However, there is no comprehensive or organized compendium of research that evaluates the long-term impacts from these events. There are no relocation plans

Studies which have been done, there is no consensus about the long-term social impacts from flood as disasters. A bibliography completed in 1996 identifies few studies on socioeconomic aspects of flooding in the U.S. (Wiener 1996). Descriptive case studies indicate that after a flood, trends already in place are reinforced. The trends, whether positive or negative may be accelerated by the disaster (Haas, Kates and Bowden 1977). A flood in a community that was experiencing rapid economic development would accelerate the trend of economic development.

2.7 Theoretical Framework.

Flood management is an evolving field of science. Hence, it is possible to study the evolutionary possibilities by observing different evolutionary paths, and thus, better understand the evolutionary forces or phase shifts. The natural phase is the phase in which no form of flood management policy exists. Due to shifting anthropogenic pressures (Yin and Li, 2001), climate, the failure of current flood management policy, or the emergence of a dominant worldview, society will evolve or modify a system to cope with floods. Thus, society will adopt one or another evolutionary path, the traditional path or the alternative path.

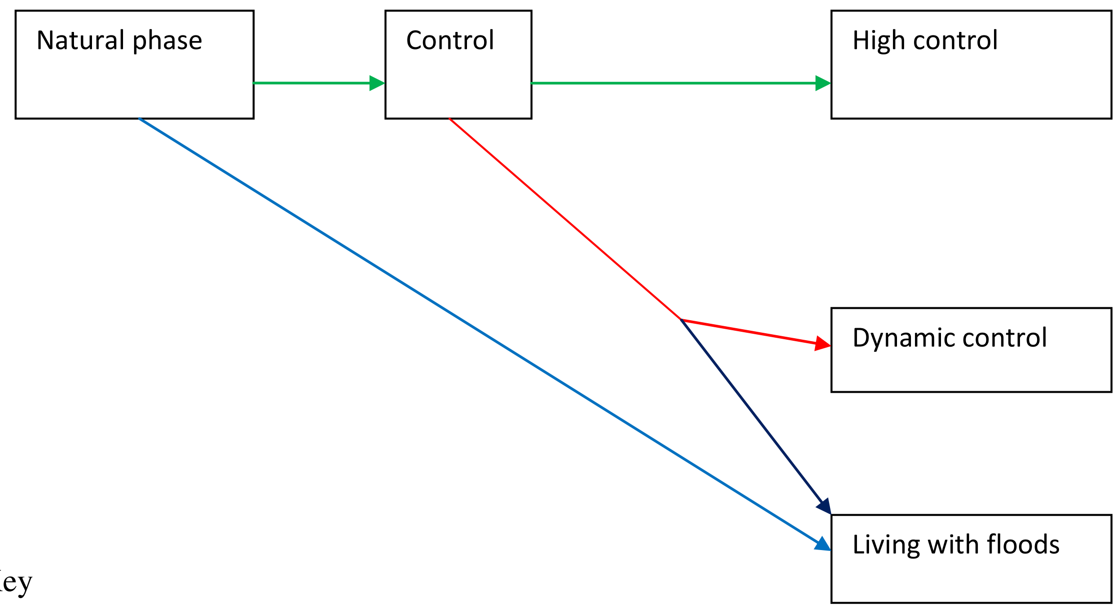
It is assumed that more productivity, resulting from farming and industry, can occur when floods are less frequent. This assumption is based on research conducted in Bangladesh, where it was shown that more productivity occurs in poldered areas (Datta, 1999). Hence, a scenario in which floods are controlled will lead to greater productivity increases. However, this assumption is only true if flood management infrastructure is adequately operated and maintained.

Vis et al (2001) suggest that the central concept of a system of dike compartments is controlled flooding, limiting the affected area and minimising the flood damage. This suggests that even though flooding is allowed the floods are still totally controlled by humans. The principle behind a system of dike compartments is that dikes with an inflow gate and an outflow gate surround each compartment. Compartment has different flooding probabilities based on the value of the land within the compartment. Moreover, considering that such a strategy is utilizing current systems of dikes, the restoration or improvement of the ecology is unlikely to occur. Hence, this strategy aims to: reduce flood risk, both by keeping flood probability low and by reducing the flood damage; maintain economic productivity in the floodplain areas; and minimize social impacts that may arise from more radical strategies.

Living with floods as a flood management policy focuses entirely on a society's ability to live or co-exist with floods rather than fight against floods; any damage that arises from a flood is eliminated. Primarily, society adapts to the natural flood conditions and develops the land in accordance with the prevailing natural conditions. A society that co-exists with floods will;

minimize risk by reducing the damage inflicted by floods to nearly zero; be totally aware of floods as they form a part of the society's daily life; and aim to minimize environmental degradation by maintaining the natural system.

Figure2.1: Theoretical Model



Key

Traditional path/resistance

Alternative path/resistance

Control to dynamic

Control to living with floods

Source: Yin and Li, (2001).a

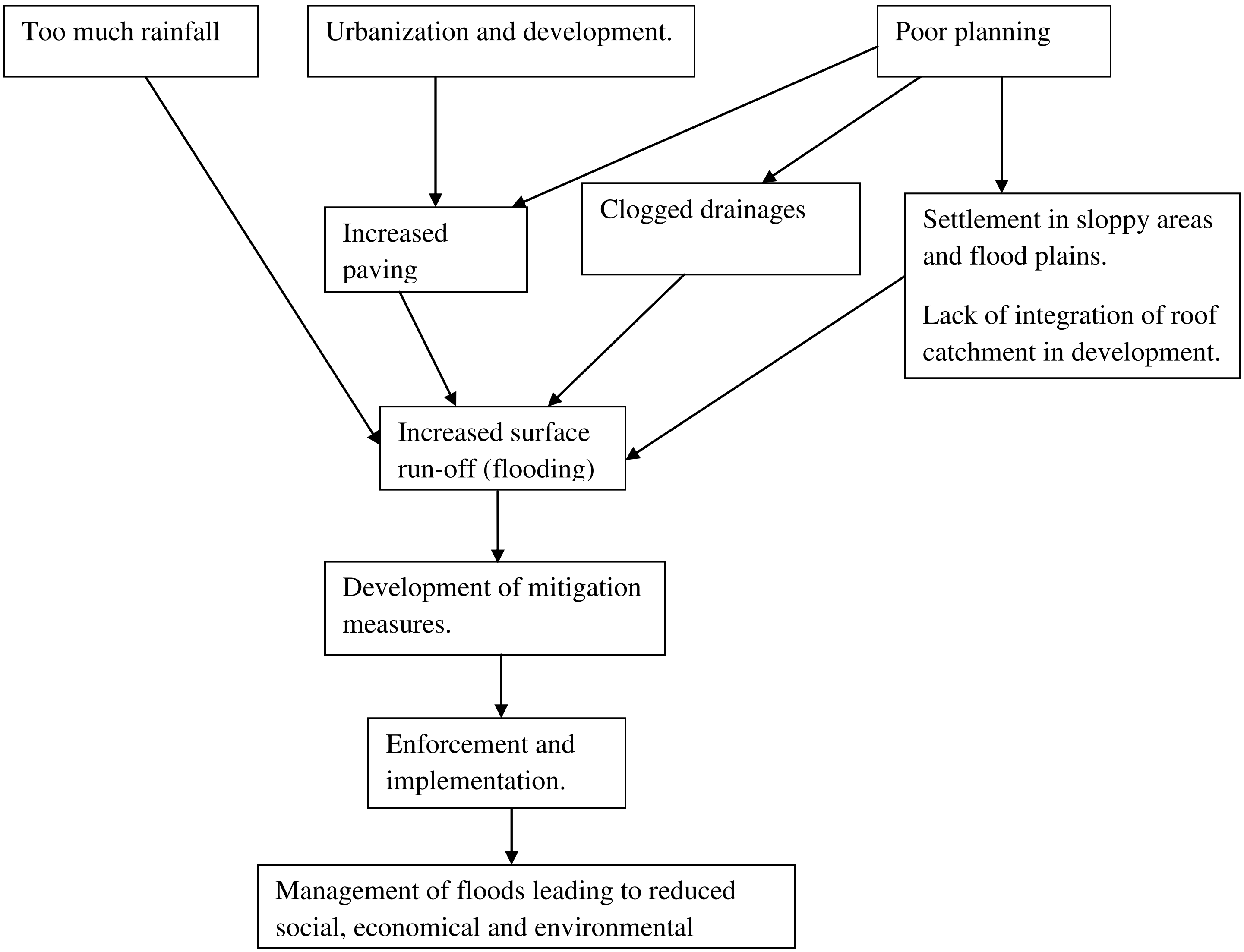
2.8 Conceptual Framework.

Mavoko sub-county acts as a dormitory for workers in Nairobi and other nearby centers such as Machakos town this factor has contributed to the ballooning of populations contributing to the current population of 137,211 people making it almost impossible for the sub-county to adequately meet the escalating water demand and consequently resulting to increased urbanization and development. Many areas in Mavoko sub-county such as Syokimau, Utawala, Sabaki, Joska, Kamulu. Kyumbi, Katani are dependent on bore wells and an average of 3500 cubic meter of water is extracted daily, leading to a decline in groundwater level.

According to the conceptual framework developed, roof catchment and improvement of existing policies and regulations is the key to zero-flooding drive within the Mavoko area. Rainwater harvesting will ensure precautionary measure that will ensure urban floods are managed and support in implementation of different rain harvesting methods.

Efforts from every quarter will be required towards reducing floods within the area with government taking a leading role and supported by private sector and the community.

Fig 2.2: Conceptual Framework.



Source: Author (2014).

CHAPTER THREE.

AREA OF STUDY.

3.1 Introduction.

Mavoko sub-county the former Municipal Council of Mavoko is one of the oldest Councils in the country with its evolution dating back to 1940, when it began as Local Native Council (LNC) then became an African District Council (ADC). The Town came into existence through trading with the main business activity being centred at the old town area next to the railway station. It became an Urban Council, curved from the County Council of Masaku now Machakos County in 1974 and got upgraded to a Town Council in 1987 and to a Municipal Council status in 1993. The Council being a service provider operates under the Local Government Act. The Council has core functions of planning all development activities within its area of jurisdiction (ESIA study, 2010).

3.2. The physical set up.

3.2.1. Location and extent.

Mavoko sub-county covers an area of 693 km sq stretching from KAPA/ Airport area where it borders with Nairobi County, and covers Katani, Ruai, Kangundo Road through Muthwani-Lukenya, Makutano(Kyumbi) to the east where it boarders Machakos Town. It covers Kapiti Plains to the south west towards Kitengela area where it borders with Kajiado County then to Embakasi in Nairobi County and it is located 1° 27′ 0″ S, 36° 59′ 0″ E.The research is intended to cover the following areas; syokimau, Athi river, and mlolongo which are setillite towns of Mavoko Sub-County. This towns according to the (2009) census carries almost 50% the population in Mavoko and due to this they are experiencing rapid development interms of commercial, residential, and industrial development which has resulted to increased paved surface reducing the amount of water percolating to the ground hence urban floods.

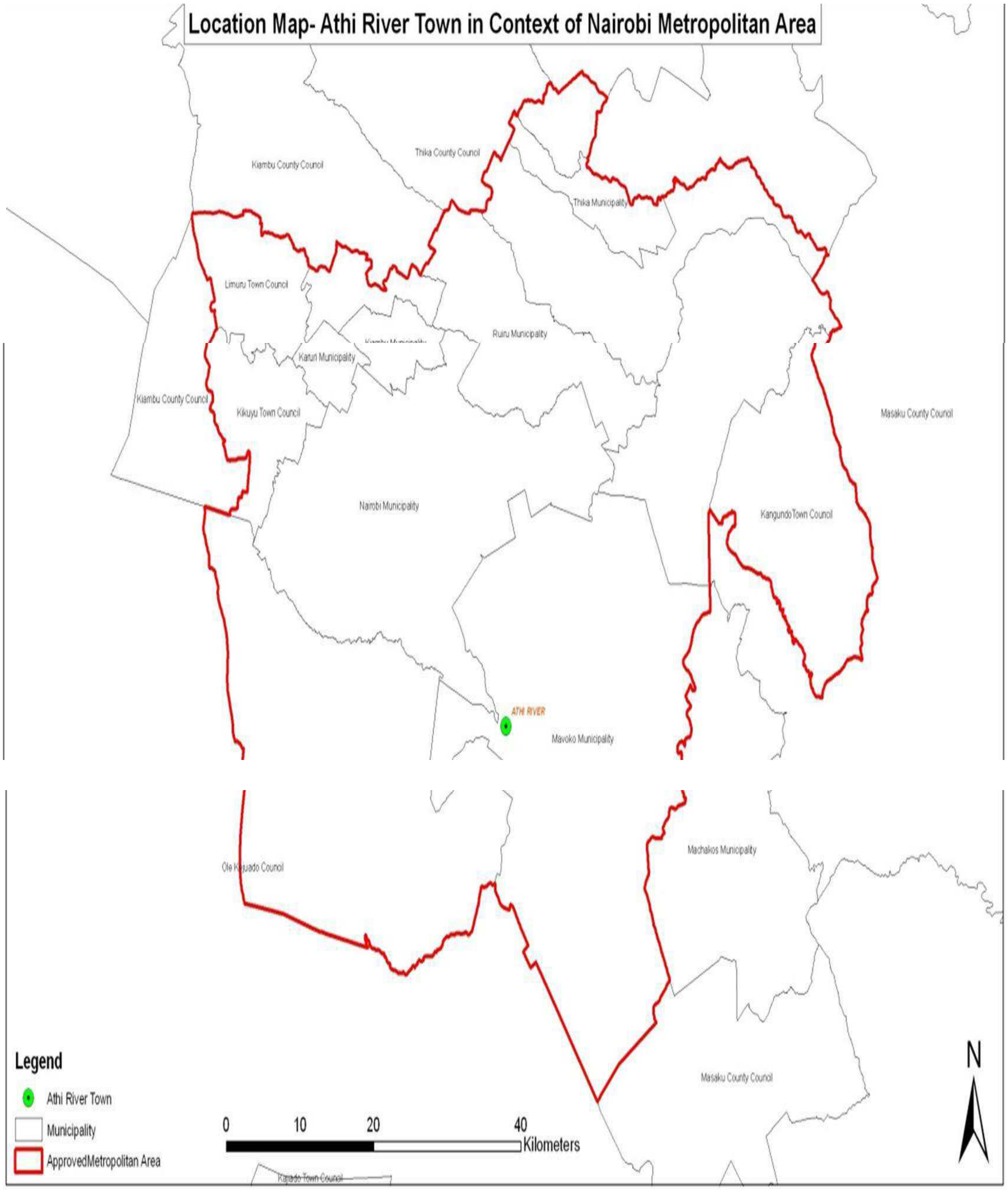


Figure 3.1: Location map of Mavoko Sub-County in the context of Nairobi Metropolitan Area.

3.2.2. Topography and drainage.

The Mavoko area has gentle slope topography which is generally flat in most part of the area with a gradient of not more than 3%, lying at an altitude of 1500m to the east and 1530m towards the west. most of the land area has been under the influence of man due to the development activities mainly from the construction industry to soil deposition from construction sites which has shaped most of the land area giving it a new look. This has actually resulted to approximately more than 70% of the entire area's earth surface is covered by civil and structural works.

Mavoko sub-county in Machakos County is largely in a semi-arid zone and the amount and frequency of precipitation is quite erratic. The sub-county lies within the drainage basin of River Athi. The general drainage pattern is from West to East. Athi River and its tributaries, most of which dry up during the dry spell, Ground water potential in the sub-county ranges from moderate to low. This is because of the massive nature of the parent basement rock. Because the rock bearing formation carries a high quantity of soluble minerals, most of the ground water is saline.

Water Supply the Mavoko Water and Sewage Company is responsible for supplying potable water to the residents and businesses in Mavoko sub-county and its environs. Currently the sub-county receives water from a variety of sources with the bulk of the water coming from Nairobi through a piped system. The other source of water is the Nol-Turesh water pipeline that emanates from Mt. Kilimanjaro, boreholes that the Mavoko Water and Sewage Company contracts out to various service providers. The water from boreholes generally has a high saline content which then requires treatment prior to supply to consumers. The water services company is also exploring ways of rehabilitating a disused dam to generate a considerable amount of water for the growing population in Mavoko sub-county and its surroundings.

Due to increase in population and economic activities, the water resource is continuously becoming scarce. Consequently, conservation measures such as afforestation, construction of sub-surface dams along the river valleys and construction of dams and pans to capture surface water run-off can improve both surface and ground water availability. The community in some areas however are trying to remedy this situation. An example is the community of Muusini village which has constructed a total of 16 sub-surface dams/weirs across rivers Makilu and Syuuni in Kalama division to act as water retention points.

Unplanned development of small scale enterprises (Jua Kali) without proper infrastructural services has led to an increase in pollution of the water courses especially in the major towns. Examples are the garages within Machakos town that are located within Kariobangi and Grogan areas. These cause pollution of the Iiyini River through oil spills, inappropriate handling of the oil residues, exhaust fumes, etc. The problem is especially aggravated during the rainy season when the pollutants find their way into the river courses. (Machakos DEAP, 2006).

3.2.3. Geology and soils.

According to Geaverts, 1964, The lithology of the Mavoko area comprises various geological sequences. The volcanic rocks in the area are represented by Upper Athi Series consisting of sediments and Lake Beds, Athi Tuffs and Kapiti phonolite. The thickness of these volcanic varies decreasing towards the south and southeast as they reach the limit of the lava flows. Immediately below the volcanics are the undifferentiated crystalline rocks of the Mozambique Belt that is the Basements System rocks consisting mainly of gneisses and schists. These are shallow seated and have been encountered by several of the numerous Boreholes drilled in the vicinity of the area.

The Upper Athi Series forms part of the extensive Athi tuffs and lake beds occurring as a result of consolidation of fragmental volcanic material which was deposited shallowly into water after eruption and a series of sediments and tuffs lying between the Nairobi and the Kapiti phonolite. They are also taken to include beds of the Kerichwa Valley series where the phonolite and trachytes are absent. Everywhere with Kapiti Phonolite, the unit underlies associated volcanic rocks and is oldest lava of the succession. This has been confirmed by several borehole sections, which have revealed that the sub-volcanic floor over which the Kapiti Phonolite was extruded was irregular and cut in Precambrian rocks. The lava was laid down on an eroded surface covered in places by Tertiary conglomerates and grits (Fairburn, 1963), formed part of the first Miocene flood eruptions. The rock is distinctive in hand specimens by its large white crystals of feldspar and waxy-looking nephelines which are set in a fine grained dark green to black or dark bluish-grey groundmass. The basement system of this area comprises crystalline rocks of Precambrian age which are exposed in the south west of Kitengela in Kajiado County where the volcanic cover has been removed by erosion. They are predominantly biotite gneises, frequently migmatitic and rich in hornblende.

Vertisols: these are referred to as black cotton soils. They are characterized by cracking clays with low water permeability and high water holding capacity. The soils although moderately fertile, have poor drainage and become water logged when wet. The soils are found on plateaus and low lying flat lands in the district. They are used in production of cotton, chickpea and maize.

3.2.4. Climate and physical features.

Mavoko sub-county climate is semi arid with a hilly terrain with altitude of 1000 to 1600 meters above sea level. It has two rainy seasons, the long and the short rain seasons. The sub-county has a bimodal rainfall pattern with the long rains seasons starting at the end of March and continues up to May, while the short rains season starts at the end of October and lasts till December. The annual average rainfall ranges between 500mm to 1300mm. Mean monthly temperatures vary between 180C and 250C. The coldest month is July while October and March are the hottest.

This area is covered with dry bushes and savanna grassland with scattered trees. The most widespread vegetation type in this area is the semi-arid deciduous thicket and bushland such as acacia. (Aron M, May, 30th.2013 retrieved 31st, 11, 2013).

3.3Ecological set up.

3.3.1. Vegetation and soils

The Athi-Kapiti ecosystem are the Grass plain maim habitat is dominated by Cynodon, Themeda, Cypress, and Digitaria species; Dry forest, Olea Africana, Croton dichogamus, Brachylaena hutchinsii, and Calodendrum; Riverine forest/valley forest, Acacia xanthophloea, Euphorbia candelabrum, Apodytes dimidiate, Canthium schimperiana, Elaeodendron buchananii, Ficus eriocarpa, Aspilia mossambicensis, Rhus natalensis, and Newtonia species. The vegetation cover the area is bushland with predominantly dark grey black cotton soil.

3.3.2. Wildlife.

The Types of Wildlife include;Zebra, Wildebeest, Cokes'heartbeest, Elands, Giraffes, Thomson's Gazelle, Grant Gazelle, Buffalo, Waterbuck, Oribi, Lion, Cheetah, Leopards, Warthogs, Ostriches, Impalas, DikDik, Hyena, Reedbucks.

Wildlife is mostly found in the private ranches such as Maanzoni ranch though they also occur in other areas. The wildlife migrates during dry seasons in search of pasture between Kajiado and Machakos/Makueni counties and their numbers depend on the seasons over the year.

3.4. The economical set up.

3.4.1. Agriculture.

The land with high potential of agricultural production in Mavoko sub-county is in areas such as Athi-river, utawala and Muthwani. There are two types of agricultural systems in the sub-county namely: Rainfed Agricultural and Irrigation Agricultural System. Major crops grown in this area which are rainfed are maize, beans, millet, cowpeas, peas, green grams, chick peas, dolichos, sweet potatoes, arrow roots, Irish potatoes and cassava. Those depend on irrigation are mostly fruits and vegetables. They include; bananas, pawpaw, mangoes, passion fruits, avocados, loquats, apples, tomatoes, cabbage, guavas, onions, French beans, carrots, kales, okra, karalla, duohi, tundoori, turia, valore, thin and big chilies (Machakos District Planning Unit, 2006).

Large scale farming in Mavoko sub-county include flower farms which takes place mostly in Athi-river and Lukenya areas. Some of large farms are Waridi, Primarosa, Banbros and Sun-rose among others. Subsistence agriculture is also practiced, with maize and drought-resistant crops such as sorghum and millet being grown due to the areas semi-arid state. These crops are highly affected by floods as they cannot stand a lot of water especially legumes. Flooding in this area destroy farm products resulting to limited yields, hunger to the affected community which accelerates community susceptibility to disasters.

Livestock production is practiced in both high and low potential areas of the sub-county. Dairy-Farming (mostly zero grazing) is more predominant in the high potential areas of athi-river, Utawala, Ruai, and kyumvi. All ranches are in the low potential areas of Lukenya and Kapiti and most of them keep beef animals. Others include; Goat, Sheep Poultry farming, Pigs, Rabbit, Donkey, and Bee Keeping. Annual occurrence of floods affects the growth of pasture and increases animal water borne related diseases leading to massive deaths of livestock.

3.4.2. Trade and commerce and industry.

The sub-county is relatively industrialized with cement industries, meat processing, quarrying, manufacturing industry, real estate, hotel industry and flower farms. The Cement industries are: Bamburi cement, Portland cement, Mombasa cement, Savanna cement, National and Athi river mining cement. Manufacturing industries included; Devki steel millers, Saj ceramics. Real estates are; Sunset blouvered, Jam city, 360. Green Park, Lukenya Hills, Moke Gardens, Delta plains, Sheshe, Parkview among others. The Hotels are; Millennium hotel, Green Gardens, Connection Hotel, Interchange motel, and Intercontinental Hotel. Mavoko is also the home to farmers Kenya meat commission (KMC).

However, the sub-county also plays host to the open air market concept with major market days where large amounts of produce are traded. Fruits, vegetables and other food stuffs like maize and beans are sold in these markets.

3.4.3. Transport and communication.

Approximately 510 Ha of land comprising 5% of total land area was provided for transportation. This encompasses land set aside for roads, railway, petrol services stations, lorry parks and car parks. The main routes include; Nairobi – Mombasa highway (A109) which carries a significant amount of daily traffic, Nairobi-Namanga Road (A104). (ESIA Study April, 2011), there are also unclassified roads minor roads linking minor centers within the area. Mavoko sub-county also has a railway station built in 1920 along the Mombasa Nairobi line. These minor roads linked to the satellite towns under the study are constructed using murram which is oftenly washed away by surface run-off when it rains. This makes it impossible to access the remote areas and rescue flood victims.

3.5. Social set up

3.5.1. Population.

The sub-county satellite towns are growing residential area due to its proximity to the Nairobi city hence acting as a dormitory to workers working in the city. The population growth rate for the sub-county is 1.7% and for Athi River Township is 5.2%.With the most populated areas of the sub-county being towns of Mlolongo, Athi-river and Kyumvi (ESIA study, 2010).

According to the population census of (1999), Mavoko had a population of 48,260 where by 22,000 people of this population lived in urban areas of the sub-county. The Physical Development Research Project which was done in 2004 the total population was 61,809 people, 2008 estimates the population within the jurisdiction of the Mavoko sub-county was approximately 65,000 and in 2009 census the population had tremendously increased to 137,211 people. The population growth rate for the town is 1.7% while for Athi-river township which is highly populated in the area is 5.2% (source; USAID, Kenya).

The study area is mainly dominated by residential, industrial and commercial activities. The population growth of this in sub-county being at 1.7 per cent annually and it has led to tremendous pressure on the natural resources particularly land where sub division is now a common phenomenon. Encroachment of fragile areas such as water catchments, forest, wetlands, and conservation areas and further to marginal areas enhances advance of desertification in the and break down of natural ecological cycles.

This tremendous growth has led to rapid development of commercial, residential and industrial developments increasing paved surface and reducing amount of uncovered land for surface run-off to sufficiently drain underground resulting to flooding of the area.

3.5.2. Housing.

The Mavoko sub-county acts as a dormitory town for Nairobi city, nearby growing centers such as Kitengela and also provides housing for the local industrial workers. Land Use Plan (1970) contents that, residential use was divided into three subcategories which were; low, medium and high density and allocated approximately 2722 Ha of land comprising approximately 27% of total land area. However there has been significant development since then that did not entirely conform to the planned land use.

Housing is a challenge in both rural and urban centers in Kenya. According to the Ministry of Housing, the country currently has a requirement of 200,000 new medium and low cost houses annually. Unfortunately such housing cannot be provided in not only in the country but also in Mavoko as the land prices are extremely exorbitant with house prices being beyond the reach of many residents. Subsequently as Mavoko provide an opportunity for housing the hundreds of thousands of people that work in the city. With the dual carriage way between the Jomo Kenyatta International Airport and Mlolongo, Mavoko provides an ideal location for developers to construct affordable housing for people who work in Nairobi. On the ground it is observed that several developers have already constructed housing estates in this area. (Survey Report, 2011). Despite the fact that, many residents can afford to built more durable houses which can stand floods, there are some especially in slummy area of Athi-river and Mlolongo whom their houses are constructed using polythenes and corrugated tin which cannot be used to harvest rainwater nor can they stand floods and every time floods occur their homes are destroyed and forced to migrate to safer areas.

3.5.3. Archeology and cultural heritage

The area around Lukenya hill contains some of the most important Later Stone Age archaeological sites found in Kenya. The variety of assemblages identified in the archaeological record shows that the area was favored for human habitation, and was continuously inhabited for nearly 100,000 years. Artifacts that have been recovered here include stone artifacts, domestic animal remains, iron smelting sites, ostrich eggshell beads, stone bowls, pollen samples, rock art as well as human remains. A survey which has been conducted on the site reveals a scatter of archaeological debris that is similar to other scatters found on the plains surrounding Lukenya hill. However the artifact density are found to be very low and very thinly spread on the surface to warrant further excavation of the site. The rest of the site is totally devoid of any cultural material, partly due to the fact that part of the land is covered by heaps of soil that have been dumped here from elsewhere. The Maasai Manyattas are other evidence of human occupation in this area in early years. (Survey Report, 2010). These artifacts represent historical and cultural background of this area and floods which are known to deposit soils from different areas and invasive species poses a threat of washing away these history and culture.

CHAPTER FOUR.

RESEARCH METHODOLOGY

4:1. Introduction.

Methodology is generally a guideline for solving a problem with specific components such as tasks, methods, phases, techniques and tools. It can be qualitative or quantitative. Methodologies encompass procedures followed, analyzed and interpretation of the data gathered. This chapter therefore describes the methods and procedures used during the study, most significantly in achieving the set research objectives and goals as per the requirement of the study.

4.2. Research Design.

The study was mainly a survey research. This entailed a systematic process of collecting and analyzing data in order to make decisions on how best to solve flooding using roof catchment. A survey obtains information from a sample of people by means of self-report, that is, the people respond to a series of questions posed by the investigator. In this regards, the survey entailed both quantitative and partly qualitative approaches considering the nature of data expected. Denicolo and Becker (2012) define quantitative research as a formal, objective, systematic process to describe and test relationships and examine cause and effect interactions among variables. Surveys may be used for descriptive, explanatory and exploratory research. A descriptive survey was necessary because it provides an accurate portrayal or account of the Characteristics.

4.3. Nature and Sources of the Data.

To achieve the objective of this study, both primary and secondary data were used. Secondary data included published and unpublished information.

4.3.1. Primary Data Sources

Primary data sources will include observation, questionnaires, interviews, and photography, meetings and focused group discussions. Types of activities within the area of interest will be observed and noted and will include topography, infrastructure, services and the authentic environment. Other primary data was sourced from the sub-county and relevant government departments.

4.4. Population Description.

The study was conducted in Mavoko sub-county in Machakos County. The sub-county population is estimated based on 2009 is estimated to be 137,211. The sub-county has a poverty index of 62 percent, predisposing the population to food security-related shocks and hazards. The people in the area mainly practise agro-pastoralism, which is the common livelihood (Short Rains Food Security Report, 2012; German Action, 2006). Jam city, city cotton, bridge 39, Mlolongo, syokimau and Athi-river were chosen were purposively because they are among those that are highly affected by floods

4.5. Sampling Methods.

Simple random sampling technique will be employed to select the households while systematic sampling was used to select the various organizations relevant to our research.

4.5.1. Sample Size

The sample size is method to determine the size of the population. This is done by fishers formula Ker linger [1973] formula states that a sample size of between 10% and 30%is acceptable. Notably, Fisher *et al*; 1998 sampling method provided the sample size of the population to be used in the study.

To determine the number of respondents in area of study, proportionate sampling method was used

$n= (z^2 pq)/ d^2$

n= required sample size

z=Confidence level at 95% (standard value of 1.96).

p=Estimated population in the study. (10%)

d= Margin of error at 5% (standard value of 0.05).

4.6. Method of Data Collection.

4.6.1. Primary data collection.

4.6.1.1. Instruments of primary data collection

1. **Direct observation**- Observation allowed for comparison between the information obtained from the respondents and the reality on the ground. Observation was involve observing the existing land uses, roofing material and design, topography, vegetation cover, drainage condition and paved areas.
2. **Questionnaires-** questionnaires was used to ascertain facts, opinions, beliefs, attitude and practice about the study area. Closed ended questionnaires were used because of the precision and factual nature of answers provided.

A questionnaire is a research instrument consisting of a series of questions and other prompts for the purpose of gathering information from respondents. Structured questionnaires were used to collect population data (structure and sex ratio), education levels, source of water,

water uses, disposal mechanism, roof catchment, relevant authority support, among other parameters.

Type of questionnaires which were used included both open and closed questionnaires. Closed questionnaires included questions with "Yes/No" answer or with a multiple choices. Answers were selected in the quality control check stage was used to develop possible proposals.

Open ended questionnaires included answers from the respondents unlike in closed questions where the questions have specified answers.

3. **oral Interviews-** This involved verbal interaction with the respondents who varied from residents, sub-county, local NGOs to relevant government agencies
4. **Photography-** Photography was used to capture the real situation on the ground such as the types of roofing material used, drainage systems, roof catchment practice, or the slope of the area.
5. **Focus group discussion.** The study attempted to capitalize on group dynamics to allow both large and small groups as sources of information.
6. **Walk-through survey.** This involved field survey of the area making observations on topography. Soils, drainage, roofing materials and type of houses.

4.6.2. Secondary data collection instruments

Apart from primary sources, the study relied on secondary information such as books, existing environment literature. It, however, is important to limit the application of this data sources as most fail to offer consistency of information depending on period of review.

4.6.3. Data Collection Process

Both secondary and primary techniques of data collection were viable and applicable for the dissertation; therefore, the study made use of information sources such as libraries and relevant sources of information.

4.7. Data Analysis and Presentation.

Concept analysis is the process of analyzing verbal or written communications in a systematic way to measure variables. After data collection, they were organized and analyzed based of study guidelines. Analysis targeted respondents' expressions, perceptions, events, questionnaires, behavioral observation, photographs, maps and records.

Arrays of techniques were employed for site analysis and presentation. They include both descriptive and qualitative techniques. In descriptive analysis, proportions, percentages averages were used to arrive at a general picture upon which conclusion were made. Qualitative methods used include statistical tables, bar graphs, and pie charts.

Evidently, successful analysis of data entailed

- **Sorting data:** organizing both coded and random data into categories that best serve the purpose of the study. It also entails prioritizing information based on relevancy and reliability.
- **Quality control check**: this is a control strategy in research that ensures all data collected are important and relevant. In many circumstances, research without quality control systems has flaws that subject them to many questions.

4.8. Reliability and Validity

Reliability is the degree of consistency with which an instrument measures the attribute it is designed to measure. The study measured reliability of data based on the set guidelines and ability to meet objectives. Content validity is the extent to which an instrument represents the factors under study. To achieve content validity, the study relied on current data from relevant stakeholders.

CHAPTER FIVE.

DATA PRESENTATION, ANALYSIS AND DISCUSSION.

5.1 Introduction.

This chapter presents the analysis of data collected from a research conducted in Mavoko sub-county The main purpose of the study was to assess the potential if roof catchment as a flood management strategy. Further the study is aimed at: assessing the causes of flooding, examining the consequences of flooding in Mavoko area, assessing the potential of roof catchment to address flooding in Mavoko, evaluating the institutional capacity to support roof catchment as a flood management strategy, and lastly recommend appropriate measures that can be put in place to manage floods in Mavoko

The study involved administering questionnaires, specifically in satellite towns which are; Athi-river, Mlolongo, Syokimau and also in two real estates in the towns (360 apartments, and sunset which are of the largest estates in Mavoko).

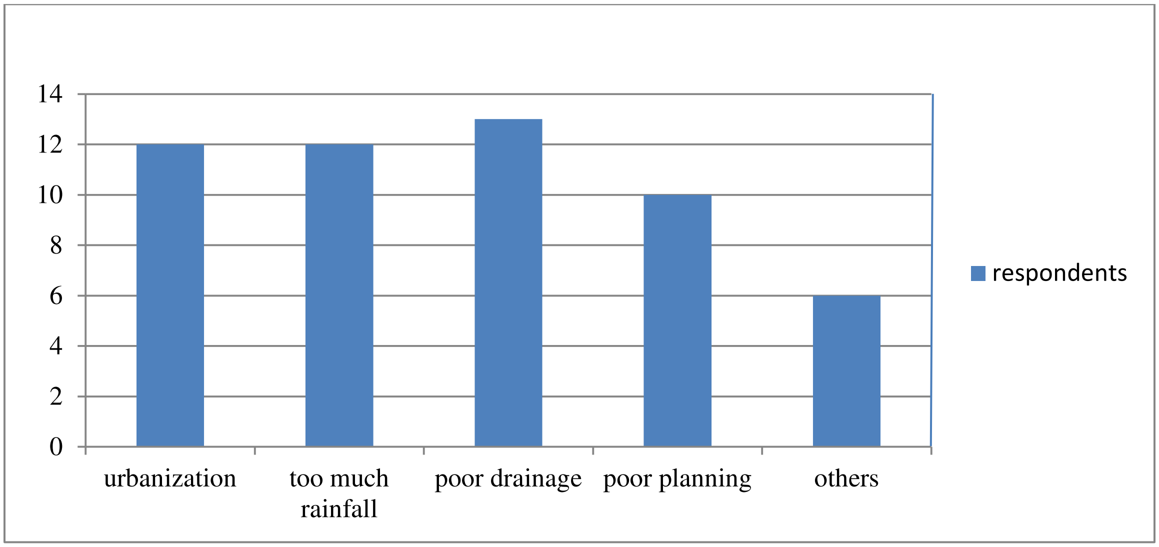
5.2 Profile of the respondents.

The questionnaires were administered to 27 respondents of which 51.8% were female and 48.1% were male even though 70% of households were male headed and 30% female headed. Women are highly vulnerable disaster such as flood and therefore their contribution towards flood management strategy is essential.

According to the field study 2014, 25% have lived in the area for less than 10 year, 25% between 10-20 year, 18% between 21-30 years, 7% between 31-40 years and 22% above 41 years. Despite the fact that even some residents were born in this area and experience floods annually, very few practice roof catchment to manage floods.

5.1. **The cause of floods in Mavoko.**

Figure 5.1: Major causes of floods in Mavoko sub-county.



Source: field study 2014.

Poor drainage is rated as the major cause of floods with many drainages being clogged with solid waste making it impossible for rain water to flow through hence flooding the adjoining area. Rapid urbanization and too much rainfall are rates second; rapid urbanization has led to increased paved land which in return reduces the amount of water percolating to the underground. Increased amount of rainfall as a result of climate change, which exceeds the capacity of the soil to absorb surface running water leading to flooding of low lying areas. Poor planning is rated the third cause of floods in this area, inadequate compliance with zoning and building regulation resulting settlement in flood plains, sloppy areas and lack of integration of rain water harvesting in planning.

Other causes mentioned by the respondents include; poorly drained soils, run off from the airport area and other developed areas which do not practice rain water harvesting, siltation of the nearby rivers and streams.

During the field study, 44% of the respondents argue that floods in this area have increased over years and 22% argues that floods have decreased overtime. The increase of floods overtime is attributed to urbanization, poor planning and increased amount of rainfall while the decrease in floods is attributed to emerging roof catchment practices and other methods of rainwater harvesting such as constructed dams to accommodate excess run off and drain trenches to drain excess water to rivers and streams.

The mostly affected areas are; Bridge 39, City cotton, Jam city KMC, and Kasoitu in Athi-river Syokimau especially areas near the stream and undeveloped areas and Mlolongo in phase iii and Kasina area.

According to the respondents, the floods occur annually both during long and short regimes and takes days to weeks to dry up. The areas affected entirely by floods requiring people to relocate represents 29.6%, areas which only part of them are affected 37% and 25.9% of the areas are not affected by floods.

5.3 Consequences of the floods.

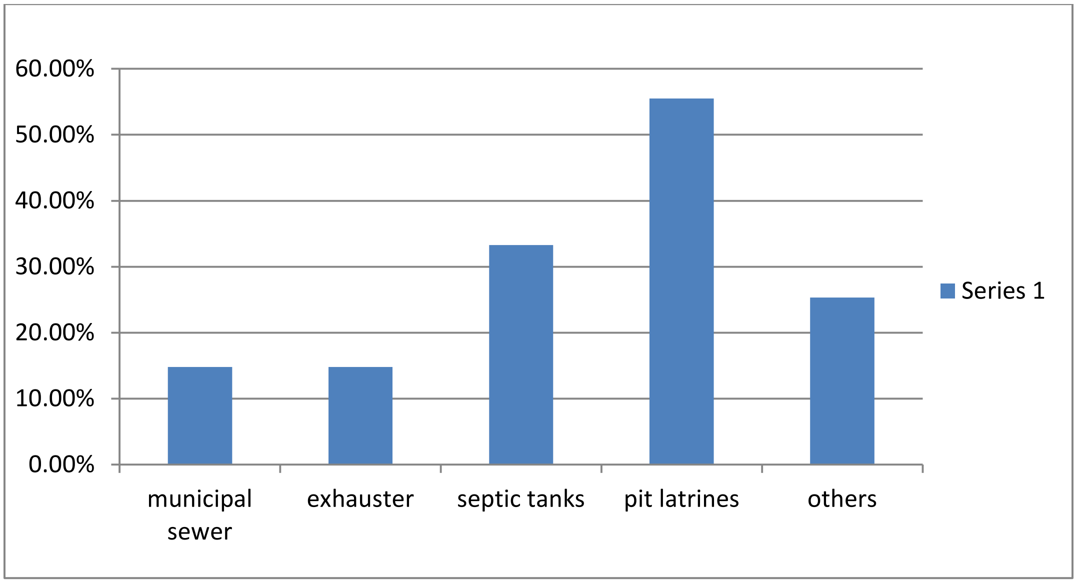
According to the field study, 2014, the following are the impacts of flooding in Mavoko sub-county. These impacts are social, economical and environmental impacts. the social impacts are: migration of people during rainy seasons to escape from losses they encounter when floods occur; reduced agricultural production leading to food shortage as most of crops which are grown in this sub-county are mainly tubers and legumes which cannot stand a lot of water and are high destroyed by floods; loss of life, livelihoods, property and injuries as many people stay behind during floods because of their properties, cultural believes and also not having a place to relocate to; water borne related diseases such as cholera as a result of the dirt contained in run-off water such as sewerage waste, industrial and household waste; and damage of infrastructures such as houses, schools, health facilities churches, septic tanks, and pit latrines which cannot stand the high pressures of the surface run-off.

The economical impacts are: closure of businesses such as shops and groceries as during floods it is nearly impossible to transport shop goods and vegetables. This is due to the fact that, floods damage access roads making it impossible to transact any business and also a lot of agricultural products rot in this period leading to loss of businesses especially small entrepreneurs and hiking in food prices and transportation charges. Also floods creates financial burden to the government as it spends a lot of money in relief foods, medical services and other materials such as mosquito nets, blankets and money meant for other demands is all diverted to address floods,

The Environmental impacts are: flooding has resulted to overflow of waste water from sewers, septic tanks, pit latrines and soak pits posing a threat to the health of the affected community; siltation of water bodies reducing their depth and the capacity of water they can accommodate, forcing the excess water to flood the adjoining lands with human settlements; clogging of available drainage systems with solid waste such as polythenes, metals, plastics and tree leaves and branches. This makes it impossible for surface run-off to drain in the river channels through the drainages and floods the adjoining areas.

However, flooding has the following positive impact such as deposition of fertile soils to flood plains which is as a result of soil erosion in the upper areas of the sub-county which increases agricultural productivity.

Figure 5.2: Methods of sanitation disposal.

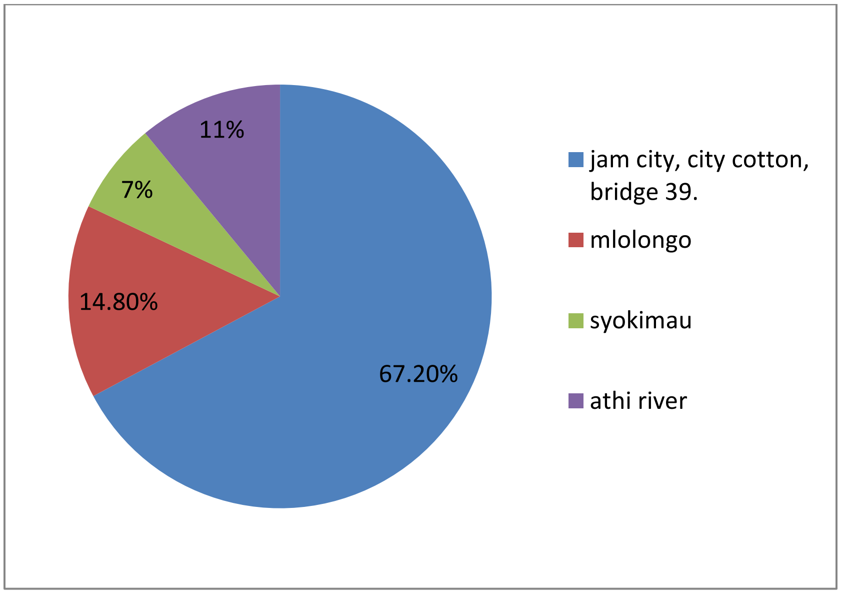


Source: field study 2014.

The highly used disposal mechanism is pit latrine which usually sinks or overflow when it floods also the same applies to septic tanks and soak pits. The sewer pipes bursts releasing sewer waste to the environment. For the exhausters it is nearly impossible to access the residential areas due to muddy roads. According to the respondents, pit latrines are more reliable while exhausters are less reliable.

According to the study, the following numbers of persons are displaced when floods occur and no compensation for the damages encountered.

Figure 5.3: **Percentages of people displaced in different areas.**

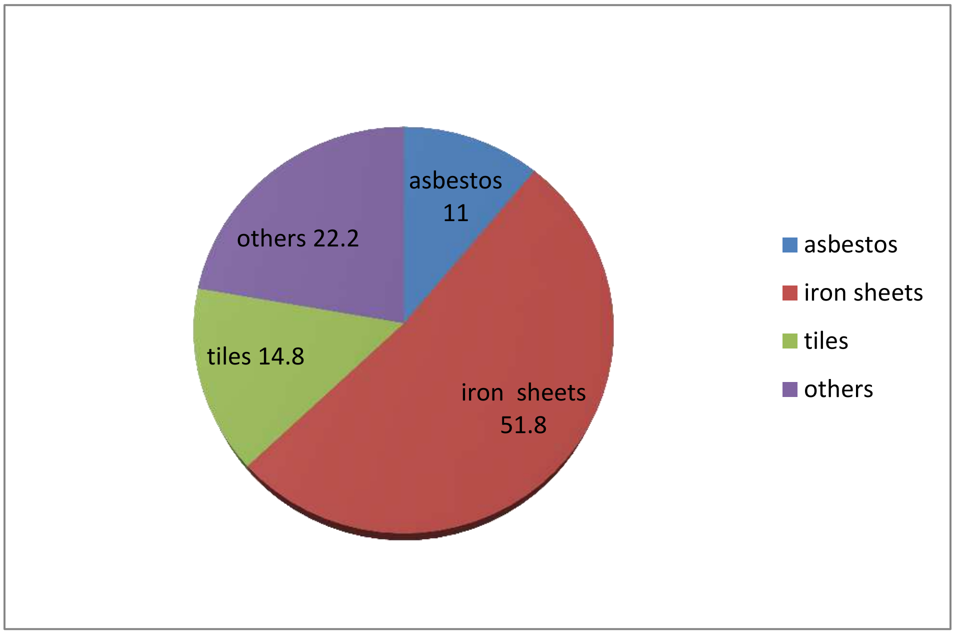


Source field study 2014.

Jam city, city cotton and bridge 39 which are slum areas are the most affected. This is due to the fact that roof catchment is not practiced in these areas as many houses are roofed with polythene bags and corrugated irons and tins and also they the community residing in these areas do less to control floods. Syokimau area which is mainly residential area with both single and multi-dwellings such as real estates is the least affected by floods as roof catchment if highly practiced and various methods of controlling floods such as gabions, drain trenches have been employed.

According to the field study, 2014, 70% of the respondents have knowledge on roof catchment though only 44% practice it. This is due to the fact that most roof designs and roofing material are not favorable for rain water collection as some houses are roofed with polythenes especially in the slummy areas such as Jam city, Kasoitu which are highly affected by floods

Figure 5.4: Different roofing materials.



Source: Field Study 2014.

The most used roofing material in this sub- county is iron sheet which is favorable for roof catchment and therefore if put into practice can result to tremendous reduction of floods, water bills and water scarcity. The others include polythene and tin.

Various methods have been put in place to manage floods in this area, they include: dug wells, gabions, drain trenches and bore wells which help in draining water during rain seasons. The respondents acknowledges that this flood control methods have potential though they have their own challenges such as siltation due to soil erosion, conflicts especially in high density areas, lastly they pose a great threat to children.

The following were the benefits of roof catchment listed by the respondents; Water Quality, rainwater as one of the best sources of an alternate water supply compared with other sources of water as it is free from bacteria and other contaminants, simple to construct, the construction of rainwater collection systems is simple and can easily be built with readily available materials, easy to operate and maintain the operation and maintenance of a household rainwater collection system is controlled by the owner without having to rely upon the maintenance practices of a municipally controlled water system and convenience as rainwater collection provides a convenient source to the consumer.

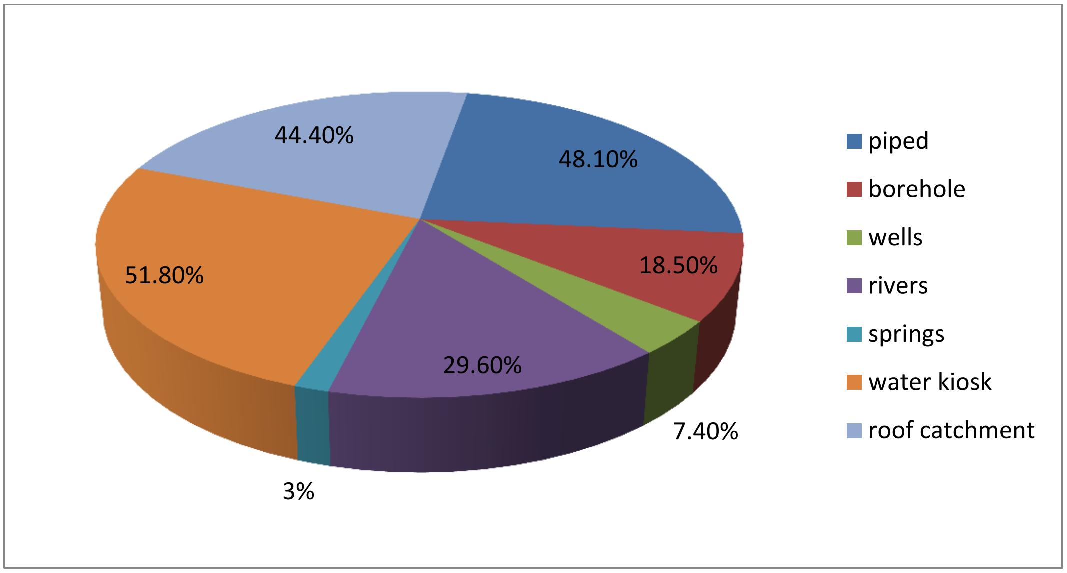
5.4 Potential of roof catchment.

Table 5-1. Sources of water in Mavoko sub-county and uses.

Water supply source	**Uses**	**Quality**		**Reliability**	
		good	**poor**	**Reliable**	**Not reliable**
a) Piped	Gardening, Drinking, washing, bathing, and cooking.	11	2	9	4
b) borehole	Irrigation, cooking, drinking, construction, washing, bathing, drinking, brick making.	3	2	3	2
c) wells	Construction, irrigation, washing.	0	2	1	1
d) rivers	Construction, irrigation, brick making.	0	8	8	0
e) springs	Construction, irrigation, brick making.	0	1	1	1
f) Water kiosks	Drinking, washing, cooking, bathing.	13	1	4	10
g) roof catchment	Drinking, cooking.	12	0	12	3

Source: Field study, 2014.

Figure 5.5. Percentages of water users in different sources.

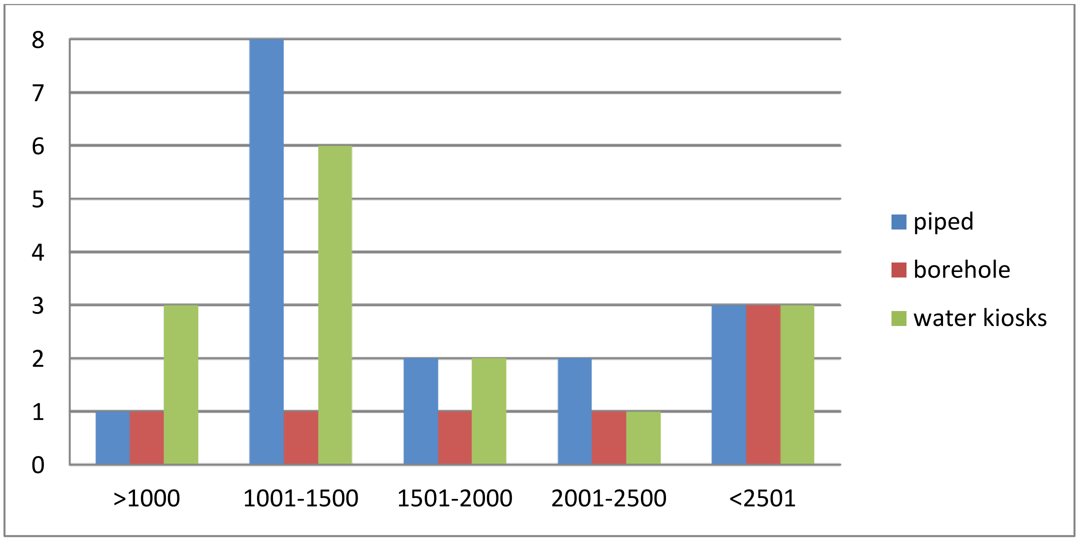


Source: Field study 2014.

Mavoko sub-county has black cotton soil which has very poor water porosity. It gets very sticky when it rains making it hard for surfaces water to percolates to the underground. This has resulted to poor recharge of the underground water leading to less water yield of boreholes and wells. Roof catchment is less practiced in this area due to poor roofing materials such as polythene, limited institutional support and unwillingness of the community to create into other sources of water.

In Mavoko sub-county various sources of water are free apart from piped water from Mavoko Water and Sewerage Company (MAVWASCO), borehole water from private owners and water from kiosks provided by MAVWASCO. The cost paid per month depends on individual usage of water.

Figure 5.6: Water bill per month

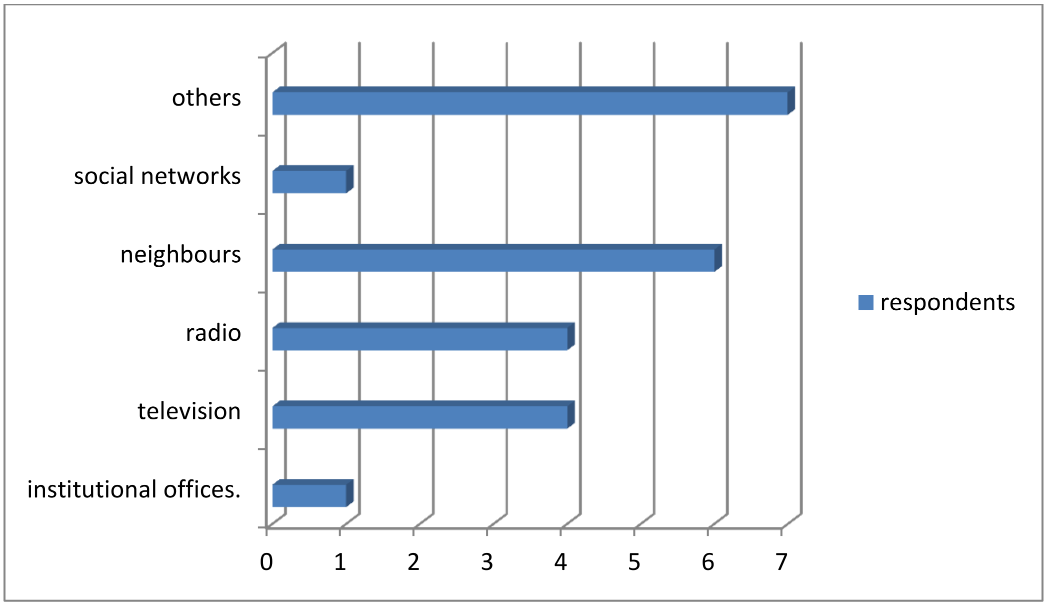


Source: Field study 2014.

The MAVWASCO piped water appears to be more costly than the other sources of water this is due to the fact that this company charges kshs 100 per cubic meter which accrues to large sums of money at the end of the month. The water from the kiosk is the second and the borehole water the third which its cost is attributed to use of the amount of electricity uses in pumping the water to the used. Roof catchment if put into practice has the potential of halving the water bill paid by this community and supplying quality and fresh water for drinking.

According to field study, 2014, 51% have access to disaster management information while 49% do not have access to disaster management information.

Figure 5.7. Sources of disaster information.

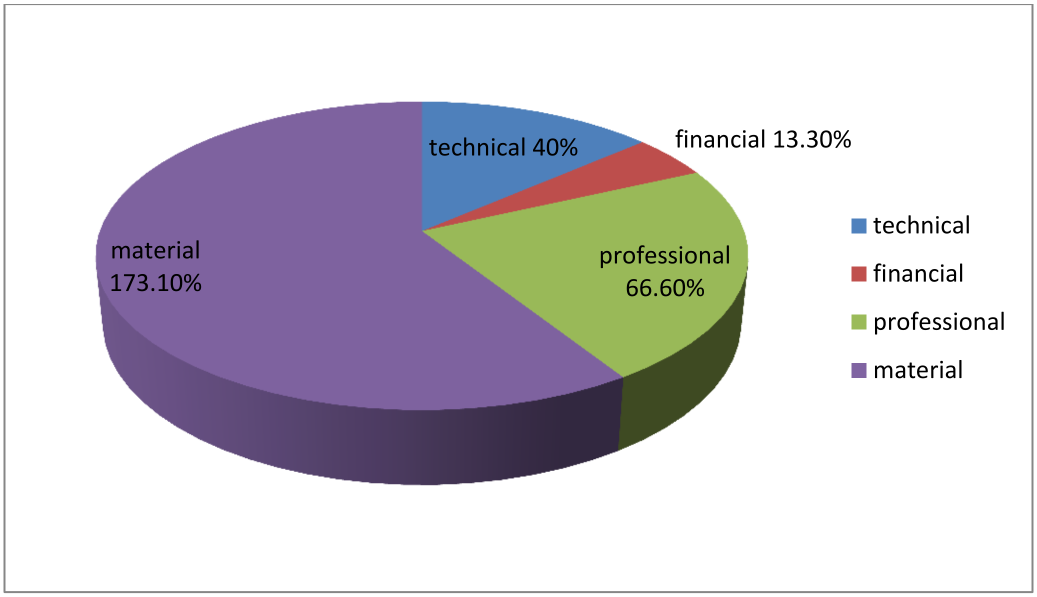


Source: Field study 2014.

The other sources are; red cross, news papers, and family members.

Only 25% of the respondents receive support from the institutions regarding when floods occur while the remaining 75% do not. The type of support received is technical such as evacuation boats, financial, professional such as drill training and material support which include; food stuffs, blankets, medical services, water among other.

Figure 5,8. Support received from disaster related institutions.



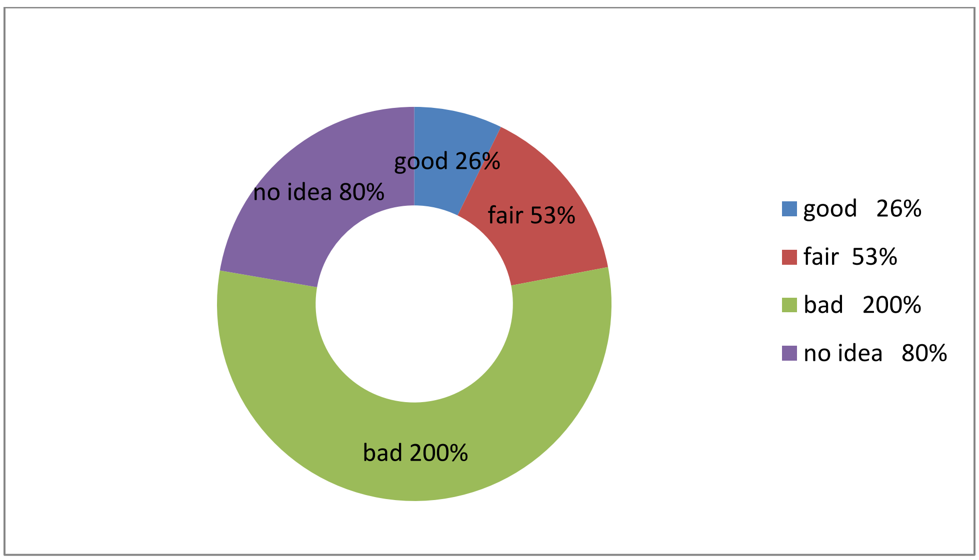
Source: Field study 2014.

25% of the population in this community is involved by the institutions in flood management strategies while 75% are not and yet they are affected by this disaster. The institutions involve the community in drill training, gabion construction, creating awareness on the need to practice roof catchment.

Limited involvement of public who are the victims of the floods has led to derailment of RWH projects which have been proposed in the past. The public should be fully involved in both flood management strategy and RWH projects as they generate indigenous knowledge, providing manual work and develop a sense of ownership at the completion of the project.

According to respondents, 51% acknowledge a gap in existing institutions while 49% are not aware or do not seen any gap in the existing institutions in attempt to manage floods. The gap is due to inadequate of linkage between different institutions. For example the Planning department which is in-charge of all the developments within the entire sub-county has not been working together with the health department on required cleaning and specifying the best roofing material. Rainwater quality is very dependent on the maintenance catchment system, periodic cleaning and roof preservation. Roof materials play an important role in this technology as some are more prone to retaining particles that can be harmful to users. Asbestos roofs present a growing concern as exposure to this material can cause serious health problems which come from constant and long-term exposure to inhaling its fibres.

Figure 5.9: Effectiveness of relevant institutions.



Source: Field study, 2014.

In the field study 2014, 200% admitted that the effectiveness of the existing institutions this is attributed to; Lack of advance warning of incoming floods takes the public unaware leaving no time to take preventive measures, there are no high grounds nearby for immediate shelter and often the people do not leave their homes unguarded, for security of their meager assets, rainwater harvesting technology is not being integrated with development plans. 53% argues that the existing institutions are fairly effective this is due to the fact that, the existing disaster management mechanism is geared primarily to deal with rescue and relief measures and not towards long-term actions to minimize floods. 80% of the respondents have no idea of any existing flood management related institution which is due to the institutions being inactive and therefore unable to reach the affected persons. Finally, 26% of the respondents acknowledge that the existing institutions are effective in flood management and in promotion of rainwater harvesting as the institutions such as MAVWASCO and WRMA promotes rainwater harvesting as an alternative source of water to supplement the existing sources which are not able to meet the increasing water demand to both government and private sector with emphasis on the savings water bills and control urban floods.

CHAPTER SIX.

CONCLUSION AND RECOMMENDATIONS.

6.1 Summary of the findings.

The affected areas of the Mavoko sub-county are the satellite towns especially in slum areas where there is congestion and roof catchment is not practiced, and areas experiencing rapid development due to increased paved ground. Floods in Mavoko occur during every rain season but it is worse during the long rains resulting to massive deaths, injuries and loss of properties.

Many residents depend on water from MAVWASCO, boreholes and water kiosks which is not enough to meet the escalating water demands. Furthermore MAVWASCO contents that, the current water demand is 15,000m3 per day which is expected to rise to approximately over 25,000m3 per day with the increasing population. However, the MAVWASCO currently is only able to supply 3000m3 per day which cannot meet the water required by the community on daily basis and therefore if other alternative sources of water are not exploited Mavoko sub-county will have water scarcity in the near future.

There are no institutional agreements to review and update the early warning system thereby improving the efficiency and preparedness or determine the adequacy and efficient utilization of resources assess the impact of disaster. Management programs on population, economic and environmental and assess the role of effectiveness of various stakeholders in implementation of these programs.

6.2 Conclusion.

Capturing water from the roof tops is an empowering method of bringing greater ecological balance and local resilience to dense cities. This rooftop technology is a sure mark of humanity's evolution towards more alternatives and sustainable water sources.Several actions such as flood mitigation strategy have been taken worldwide to address floods but more actions which puts community participation into consideration needs to be put in place. The relevant institutions to address floods in Mavoko sub-county are adequate but enforcement is ineffective. Anthropogenic activities such as poor farming methods, poor disposal of solid waste, and urbanization have highly contributed to frequent occurrence of floods in this area.

6.3 Recommendations.

Establishment of Sustainable Drainage Systems (SUDs): This is an alternative to conventional drainage is to mimic natural drainage with an aim to reduce floods and improve the quality of water draining from urban surface run-off. This will be able to solve the problem of clogged drainage systems and increase the surface area of ground water percolation. This can be achieved through developing areas of vegetation like grassy banks or green roofs or natural water storage features like ponds. Also use of engineered components such as porous paving which will reduce peak flow rate of run-off, encourage uptake of water by the ground, transfer of run-off in a controlled manner to the other sites and lastly, capturing water directly on site for controlled storage or discharge.

Technological improvement: is an essential aspect in rainwater harvesting which needs to be better addressed. This can be achieved through: Development of first-flush bypass devices which are more effective and easier to maintain and operate than those currently available and in use; involvement of the public health department in the monitoring of water quality to ensure that the harvested water is standard for drinking and to be used in other domestic chores especially during floods; monitoring of building constructions to ensure that roof catchment is integrated throughout the construction process; provision of assistance from governmental sources to ensure that the appropriate cistern sizes which are able to contain the amount of water from the provided catchment are built; provision of assistance to the public in sizing, locating, and selecting roofing and cisterns materials and constructing cisterns and storage tanks, and development of a standardized plumbing and monitoring code and preparation of guidance materials for inclusion of rainwater harvesting in a multi-sourced water reserve sources management environment.

There is need to strengthen linkage between MWI, DOC and KMD to develop an integrated disaster management system, flood forecasting and warning system at the community level and put in place clear definition of roles of various institutions; planning of flood mitigation measures should be forced into the IWRM and entrusted to RBOs which can provide a forum for the effective participation of the communities in planning of flood mitigation measures.

Integration of roof catchment in to planning: by integrating rain catchment system into the design of a home, it will create a cost effective, convenient system where all the components can be located in one area for easy monitoring and maintenance. Integrated home systems are excellent for new construction and a perfect way to save money on municipal or well water costs.

6.4 Areas for further study.

Product innovation: Although there are some innovative systems which are currently being used and developed, greater exploration of other possible system configurations is required to ensure that the systems are adaptable, flexible and affordable to allow implementation in a range of building types and local levels. Further study should also be undertaken into the applicability of first flush devices and examination of maintenance costs of rainwater harvesting systems.

Demand Profiling: Further research should be undertaken on demand profile of different water users to permit the investigation of sub-daily profiles and the need to adopting a range of alternative water resources to augment to existing ones. Further research is also required in this area to develop a portfolio of demand profiles for different building types such as manufacturing industries, schools, supermarkets, residential among others to facilitate system designs and reduce costs.

Tank Sediment Quality study: This research outlined the potential of roof top catchment; however, it does not put into consideration the quality of harvested rainwater at the point of use and also does not encompass coverage of the quality of sediments in the main storage tank. It would therefore be useful to undertake further study to ascertain the potential impact of sediment disposal on recipient bodies, as RWH becomes increasingly implemented.

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Appendices A.

KENYATTA UNIVERISTY

Department of Environmental Planning and Management

HOUSE HOLD INTERVIEW QUESTIONNAIRE

INTRODUCTION

I am a Kenyatta University undergraduate student pursuing a Bachelor in Environmental Planning and Management carrying out a research on potential of roof catchment as a flood management strategy at Mavoko sub-county in Machakos County. Am kindly requesting for your time to answer some questions. The information you will provide shall solely be used for academic purpose.

Household Questionnaire

Bio Data Information

Date of Interview ____________________ name of the area________________

Respondent(s) Name________________________________ age______________________

Relationship of respondent to Household Head________________________

GPS coordinates: Longitude: (____^{0} DEG1 _____ "MIN1 _____ SEC1)

Latitude: (____^{0} DEG2 _____ "MIN2 _____ SEC2)

Altitude: Altitude MT. a.s.l MASL (__________)

Household type (*select only one*)

[__] Male headed and managed

[__] Female headed and managed

[__] Child headed (below 18 years) / Orphan.

1) **Background Information**
2) How long have you lived in this area?

Less than10 years [ ]
10-20 years [ ]
21- 30 years [ ]
31-40 years [ ]
More than 41 years [ ]

i) Why did you decide to settle in this area? _______________________________________

____

ii) What is the size of your plot? _______

iii) What is the mode of housing occupancy?

a) Owner occupier ( ) b) rental house ( ) c) company house ( )

d) Others (specify)__________________

3) To assess the causes of flooding Mavoko sub-county.

i. Do floods occur in this area? Yes ( ) No ( ).

ii. What is the frequency of flooding in this area a) more frequent ( ). b) less frequent ( )

iii. How long do the floods take to drain?

a) Days ( ) b) weeks ( ) c) months ( )

iv. What extent of the area is affected by floods?

a) Whole area ( ) b) part of the area ( ) specify which area___________________

v. What types of floods occur in this area?

a) Flash floods ( ) b)groundwater ( ) c)sewer flooding ( )

d) Others (specify)__________________

vi. What kind of rainfall causes floods in this area?

a) Prolonged heavy rains ( ) b) short heavy rains ( ) c) any rains ( )

vii. What do you think is the cause of flooding? (tick appropriately)

a)Rapid urbanization ( ) b)Too much rainfall ( ) c)Poor drainage systems ( )

d)Poor planning of the area ( ) e)Others (specify)________ ____

viii. In your opinion has the floods been increasing or decreasing overtime__________

____

4) To examine the consequences of flooding in Mavoko.

i. What are the impacts of the floods?

a) Social____

____

b) Economical____

____

c) Environmental____

____

d) Others____

ii. What sanitation disposal mechanisms do you use, how are they affected by floods and what is there reliability?

mechanism	Floods effects	Reliability
Municipal sewer		
Exhauster		
Septic tanks		
Pit latrines		
Others (specify)		

iii. Approximately how many households are replaced every time floods occur?____

iv. Is there any compensation/resettlement when floods occur? Yes ( ) No ( ).

5) To assess the potential of roof catchment to address flooding in Mavoko.

i. Water supply (please fill in the table).

Water sources	uses	quality	Cost per month	reliability
Piped ( )				
Borehole ( )				
Wells ( )				
Rivers ( )				
Springs( )				
Water kiosks ( )				
Roof catchment( )				
Others (specify)				

i. Do you know what roof catchment is? Yes ( ) No ( ). If yes elaborate__________

____

ii. Can your roof design support roof catchment? Yes ( ) No ( ) if no, why? ________

____

iii. Do you practice roof catchment? Yes ( ) no ( )

If yes what is its potential? ____

iv. What is the approximate plinth area of your house?

Between:

100m/sq-200m/sq ( )   200m/sq-300m/sq ( )

300m/sq-400m/sq ( )   Above 400m/sq ( )

v. What kind of roofing material have you used in your house? (tick appropriately)

Asbestos ( )   Iron sheets ( )   Tiles ( )   Green roof ( )

Others (specify) ________________________________

vi. Are you aware of the benefits of roof catchment? Yes ( ) No ( ). If yes which ones____

vii. What other methods have you employed to manage floods?

a) Drain trenches ( )   b) Dug wells/ bore wells ( )   c) Others (specify) ___

What is there potential? ____

viii. What challenges do you face in implementing the above methods? _____________

____

ix. Suggest other methods that can be used to manage floods____________________

____

6) The institutional capacity to support roof catchment as a flood management strategy.

i. Do you have any access of disaster management information? Yes ( ) No ( )

If yes from which source?

a) Institutional offices ( ) b)Television ( ) c)Radio ( ) d)Fellow neighbors ( )

e) Social networks ( )   f)Others (specify)________________________________

ii. Do you get any support from the authorities in managing floods? Yes ( ) no ( ). If yes, what kind of support?

a) Technical ( )   b) Financial ( )   c)Professional

d)Others(specify)______________

Describe the form of support____

____

iii. Do the relevant authorities involve the local community in flood management strategies? Yes ( ) No ( ) If yes how______________________________________

____

iv. In your opinion is there a gap in the existing authorities in regard to flood management?____

____

v. How can you rate effectiveness of relevant authorities in responding when floods occur?

Good ( ) fair ( ) bad ( )

Appendices B.

KENYATTA UNIVERISTY

Department of Environmental Planning and Management

INSTITUTIONAL INTERVIEW QUESTIONNAIRE

INTRODUCTION

I am a Kenyatta University undergraduate student pursuing a Bachelor in Environmental Planning and Management carrying out a research on potential of roof catchment as a flood management strategy at Mavoko sub-county in Machakos County. Am kindly requesting for your time to answer some questions. The information you will provide shall solely be used for academic purpose.

institutional Questionnaire

Date of interview_________________

1) Name of the institution____
2) Year of the establishment ___________________________________
3) Position of the respondent ___________________________________
4) Mandate of the institution ____

   ____

   ____

5) What are the causes of floods in this area? (tick appropriately)

   a) Urbanization ( ) b)Poor planning ( ) c)Poor drainage system ( )

   d) Too much rainfall ( ) e) Others______________

6) What are the impacts of floods in this area?

a) Social ____

   ____

b) Economical____

   ____

c) Political____

   ____

d) Environmental____

____

e) Others (specify)____

____

7) Do you think the institution has the capacity to support roof catchment? Yes ( ) No ( ). If yes, how____

____

8) Do you think the roof design of the Mavoko sub-county residences is favorable for roof catchment or a re-design is required____

____

9) What other methods have you put in place to manage floods?______________________

____

If any what is there potential? ____

____

10) What challenges do you face in implementing these methods?

a) Financial ( ) b)Technical ( ) c)Professional ( ) d)Social ( ) e)Others _________

11) Do you involve the local community in decision making regarding flood management?

Yes ( ) No ( )

If yes, how? ( )

What other measures do you think can be put in place to manage floods?

a)

b)

c)

Appendices C.

CHRISTINE MUSYAWA.

N36/2785/2010.

OBSERVATION GUIDE.

Date______________________ name of the area____________________

Theme 1. The causes of floods in Mavoko sub-county.

1) Topography of the area____
____

2) Vegetation cover of the area____
____

3) Land use activities in the area____
____

4) Soil type in this area____
____

5) The condition of drainages and adequacy_______________________________________
____

6) Increased pavement due to urbanization____
____

7) Planning of the area____
____

Theme 2. The consequences of floods in Mavoko sub-county.

8) Evident flood plains____
____

9) Evident gullies as a result of surface runoff _____________________________________
____

10) Evident vegetation destruction such as breakage/ bending of trees and vegetation covered by soil as a result of flooding____

11) Washed away building structured____

____

12) Abandoned/ damaged building and other structures________________________________

____

Theme 3. Potential of roof catchment

13) Type of the house__________________________

14) Roof design and roofing materials___________________________

15) Sources of water supply

a) Borehole ( ) b) Piped water ( ) c) Roof catchment ( ) d) Springs ( )

e) Rivers ( ) f) Wells ( )

g)Others____

16) Any practice of rainwater harvesting ____

____

17) Roof design and materials used____

____

18) Peoples attitude/ willingness to adopt roof catchment_______________________________

____

19) Available technologies for roof catchment____

____

Theme 4. The institutional capacity.

20) Number of institutions in this area?____

21) Number of trained personnel?____

22) By-laws governing roof catchment____

____

Appendices D.

CHRISTINE MUSYAWA.

N36/2785/2010.

FOCUS GROUP DISCUISION GUIDE.

1) What are the factors contributing to flooding of this area?
2) What are the impacts of floods?
3) What measures do you think should be put in place to control floods?
4) What is the potential of roof catchment?