ASSESSING THE POTENTIAL OF STORMWATER IN AUGMENTING DOMESTIC WATER SUPPLIES IN KAPSERET SUB-COUNTY, UASIN-GISHU COUNTY, KENYA

BY

GLADYS CHELAGAT BIWOTT

A THESIS SUBMITTED TO THE SCHOOL OF ENVIRONMENTAL SCIENCES AND NATURAL RESOURCES, DEPARTMENT OF ENVIRONMENTAL PLANNING, SUSTAINABILITY AND GEOINFORMATICS IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR DEGREE OF DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL PLANNING AND MANAGEMENT, UNIVERSITY OF ELDORET, KENYA

OCTOBER, 2023

DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been presented for a degree in any University. No part of this thesis may be reproduced without prior written permission of the author and/or University of Eldoret.

_________________________________ **Date** ______________________

Biwott Chelagat Gladys

SES/DPHIL/017/14

Declaration by Supervisors

This thesis has been submitted with our approval as University supervisors.

_________________________________ **Date** _________________

Dr. Andrew K. Kiplagat

University of Eldoret, Kenya

_______________________________ **Date** _________________

Dr. Job K. Ngetich

University of Eldoret, Kenya

______________________________ **Date** _________________

Prof. Eng. Emmanuel C. Kipkorir

Moi University, Kenya

DEDICATION

I dedicate this work to my husband, Masson, and children; Clifford, Kate, Kathleen and Kaylah. Thank you for the wonderful support, prayers and immense sacrifice throughout my study.

ABSTRACT

Water is essential for human survival and development. However, many rural communities continue to experience various domestic water supply challenges. The purpose of this study was to explore the potential of stormwater as an additional source of water for domestic use in Kapseret Sub-County (KSC), Uasin Gishu County. The specific objectives were to assess domestic water consumption, to examine the potential of stormwater in KSC, to establish determinants of stormwater utilization (SWU) and to identify challenges in stormwater management (SWM). The study targeted households in rural settlements within KSC where a total of 404 households drawn from a population of 59,746 households were interviewed. Sample size was determined using Yamane's sampling formula. Stratified random sampling was adopted. Both primary and secondary data sources were utilized. Qualitative and quantitative data from questionnaires, interviews, observation, photography, Remote Sensing imagery, Digital Elevation Models (DEM) and document analysis were used within the mixed approach design. To establish domestic water consumption, data from household questionnaires was collected and analyzed. Computation of mean was used to determine household and per capita domestic water consumption, while linear regression analysis was used to identify factors influencing household domestic water consumption. To estimate stormwater yield in Kapseret basin, rainfall, soil type, Land Use Land Cover (LULC) and slope data was utilized. Rainfall and temperature data was acquired from the Eldoret Airport and Kapsoya Meteorological stations. ArcGIS was used to process soil data, DEM, and LULC MAPS. Satellite imagery was downloaded from USGS website and processed using ArcGIS. Soil and Water Assessment Tool (SWAT) performed the maps overlay and estimated stormwater yield, and applied Multi-criterion analysis to map suitable sites for stormwater harvesting (SWH). Binary logical regression was utilized to identify factors influencing SWU. To determine the challenges of SWM, binary logistic regression and frequency analysis were utilized. The study established that daily household domestic water consumption was 149 liters and 168.8 liters in the dry and rainy seasons respectively, while per capita domestic water consumption was 41 liters and 48 liters in the dry and rainy seasons respectively. Factors that influenced household domestic water consumption include income, household size, distance to water source, main housing type, education level of household head and capacity of water tank. Secondly, stormwater yield for the year 2019 was estimated as 353.38mm. Suitable zones and four sites for SWH were also identified. Thirdly, determinants of SWU include access to stormwater, level of awareness, outdoor uses, and perception that stormwater is unclean. Finally, the challenges to sustainable SWM include unavailability of land, insufficient financial and technical capacity and support, and lack of education on benefits and strategies of SWM. This study concluded that water supply in KSC is inadequate in the dry season. In addition, the potential for stormwater to augment existing water sources is high but remains untapped. In addition, access to stormwater would increase stormwater utilization. Finally, there is a lack of supportive institutional framework for SWM in KSC. The study recommended that authorities need to enhance rural water supply to households and prioritize development of SWH infrastructure to harness stormwater. Finally, communities must be educated on end uses of stormwater and on SWM strategies and benefits.

Key words: water shortage, domestic water, stormwater utilization, access, potable

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

AMEC	International Association for Measurement and Evaluation of Communication
ASALs	Arid and Semi-Arid Lands
BMPs	Best Management Practices
CBOs	Community Based Organizations
CIDP	County Integrated Development Plan
DEM	Digital Elevation Model
EATEC	East Africa Tanning and Extraction Company
ELDOWAS	Eldoret Water and Sanitation Company
EPA	Environmental Protection Authority
EU	European Union
GIS	Geographic Information Systems
GOK	Government of Kenya
Ha	Hectares
HRU	Hydrologic Response Unit
HSMS	Household Stormwater Management System
IFDA	International Fund for Agricultural Development
IRWR	Internal Renewable Water Resources
ISWM	Integrated Stormwater Management
IWMA	Integrated Water Management Authority
IWRM	Integrated Water Resource Management
KSC	Kapseret Sub-County
LID	Low Impact Development
MDGs	Millennium Development Goals
MoALF	Ministry of Agriculture, Livestock and Fisheries

NASEM	National Academies of Sciences, Engineering, and Medicine
NRC	National Research Council
NWHSA	National Water Harvesting and Storage Authority
NSW	New South Wales
OECD	Organization for Economic Co-operation and Development
RS	Remote Sensing
SCS-CN	Soil Conservation Services- Curve Number
SDGs	Sustainable Development Goals
SEI	Stockholm Environment Institute
SWAT	Soil and Water Assessment Tool
SWM	Stormwater Management
SWH	Stormwater Harvesting
SWU	Stormwater Utilization
UG	Uasin Gishu
UGC	Uasin Gishu County
UN	United Nations
UNEP	United Nations Environmental Programme
UNICEF	United Nations International Children's Emergency Fund,
USDA	United States Department of Agriculture
WHO	World Health Organization
WRA	Water Resources Authority
WSP	Water Service Providers
WSUD	Water Sensitive Urban Design
WUAs	Water User Authorities
WWAP	World Water Assessment Programme

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

OPERATIONAL DEFINITION OF TERMS

Augmentation means to include additional sources hence increase supply or to supplement

Household domestic water consumption refers to the amount of water used in a domestic establishment for all routine tasks including flushing toilets, washing clothes and dishes, showering and bathing, drinking and food preparation.

Household refers to a person or group of persons who reside in the same homestead/compound but not necessarily in the same dwelling unit, and have same cooking arrangements.

Overexploitation is the long-term overuse of water resources resulting in a gradual decrease in water availability.

Per capita water consumption is the average amount of water each person uses on a daily basis in liters.

Stormwater is the water that flows on the earth surface resulting from heavy rain also referred to as runoff

Stormwater harvesting is the collection, accumulation, treatment or purification, and storing of stormwater for its eventual reuse.

Water scarcity is the long-term imbalance between water demand and water supply, caused by high average demand, low average water availability and/or problems with water supply

Water shortage is the acute lack of water for (social, economic, or environmental) needs, caused by lower water supply than demand

Water supply is the provision of water by public water provider, commercial organisations, community endeavors or by individuals

Water yield is the volume of harvested water over a certain period of time

ACKNOWLEDGEMENT

First, I wish to acknowledge Mr. Stephen Barno, the then Director of the Department of Water, Ministry of Environment, and the Kapseret Sub-County water officer, Mr. Charles Tonui for availing the information that I required. Secondly, I wish to acknowledge the support of my research assistants in data collection namely; Nicholas Sanet, Robert Chelal and Fibby Jelagat. Thank you. Finally, I cannot thank enough my supervisors, Prof. Eng. Emmanuel C. Kipkorir, Dr. Andrew Kiplagat and Dr. Job Ngetich for their exemplary guidance throughout this academic pursuit.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Water stress already affects every continent with physical water scarcity being a seasonal phenomenon in many instances (UNESCO/ UN-Water, 2020). As a matter of fact, global demand for water has been increasing at a rate of about 1% per year influenced by population growth, economic development and changing consumption patterns. At the same time, due to climate change, the wetter regions are becoming wetter and drier regions becoming drier (WWAP, 2018).

Today, over 2 billion people live in countries experiencing high water stress, and about 4 billion people experience severe water scarcity during at least one month of the year. Stress levels will continue to increase as demand for water grows and the effects of climate change intensify (UNESCO/UN-Water, 2020; Day & Sharma, 2020; WWAP, 2019; Pathak et al, 2019). Globally, 2.1 billion people lack safe drinking water, of whom four out of five live in rural areas (WHO/UNICEF, 2017) and this population is projected to increase to 4.8–5.7 billion by 2050 (WWAP, 2018). In 2020, about 25% lacked safely managed water in their homes (WHO/UNICEF, 2021).

It has been noted that rural Africa lags behind in provision of clean water (WHO/UNICEF, 2021). In spite of tremendous progress towards bridging the gap between water demand and supply, many people are still without access to improved and safely managed drinking water sources. In 2020, only 54% of people in Sub-Saharan Africa had access to safe drinking water (WHO/UNICEF, 2021), while over

336 million rural people lived without basic drinking water in Africa (Hope et al., 2020; WHO/UNICEF, 2017).

Kenya, on its part, is yet to attain 100% water security. The United Nations classified Kenya as a water-scarce country since it has less than 1000m^3 per capita of renewable freshwater supplies (GoK, 2006). Ondigo et al. (2018) observed that Kenya suffers from a chronic water crisis due to various causes among them droughts, forest degradation, floods, lack of proper water management strategies, water contamination and unprecedented population growth. About 80% of Kenya is made up of arid and semi-arid lands (ASALS) and only 20% is arable, hence exposing households to serious water shortages. Estimates indicate that only about 56% of Kenyans have access to safe water supply.

In Uasin Gishu County, only about 58% of the population has reliable access to potable water, while the rest experience water scarcity during the dry seasons (UGC, 2018; MoALF, 2017). The CIDP (2018) report documented that although the current domestic water demand in Eldoret and its environs stands at about 60,000 m^3 per day, the current total water production is only 36,000m^3 per day. Thus, water supply is insufficient to meet the demands of the increasing population throughout the year (UGC, 2018; MoALF, 2017).

Domestic water demand continues to rise with the growing population. A rising population, coupled with climate change and increasing water consuming sectors like institutions, agriculture and construction industry without corresponding investment in water resource development is exerting pressure on existing water sources (UGC, 2018; Goonetilleke et al., 2017; WWAP, 2012). This has led to increased abstraction of ground water, particularly through boreholes. WWAP (2012) noted that globally, the rate of groundwater abstraction is increasing at an alarming rate by 1% to 2% per year. Salehi (2022) observed that depletion of groundwater sources is an impending danger, and suggests utilization of surface water to augment water supplies.

Although Uasin Gishu County receives moderate to high rainfall annually, ranging between 624.9 mm to 1,560.4mm per annum, the rainfall is not evenly distributed throughout the year. The rainy season occurs between April and September, while the dry spell occurs between November and March (UGC, 2018). In Kapseret Sub-County, massive land fragmentation and deforestation have resulted in land use change from forest to farmland. An example is the former East Africa Tanning and Extraction Company (EATEC), which had tree plantations that used to occupy a large section of Kapseret Sub-County, but has since been privatized, cleared extensively and converted to farmlands, residential area and pavements among other land uses. Land sub-division in KSC has been very high, such that the sub-county has the lowest average household land owning size of 0.77 hectares (Ha) compared to the county average of 5ha (CIDP, 2018). Consequently, large volumes of stormwater are generated in the rainy season which can be harnessed for use in the dry season. Stormwater is increasingly acknowledged as a potential option for meeting the water demands (Day & Sharma, 2020; Pathak et al., 2019; Goonetilleke et al., 2017; Romano et al., 2014).

Stormwater harvesting and reuse is a relatively new source of water with water resource planners recognizing it as a resource, rather than a nuisance (Luthy et al, 2020). Although stormwater management can contribute in improving water security, stormwater is currently underutilized as source of water (Cousins, 2018). Stormwater harvesting has seldom been practiced in KSC. Although there are over 120 dams that were constructed by the colonial government in the county, these have to a large extent been abandoned particularly due to siltation (UGC, 2018). These apparent low levels of stormwater harvesting and utilization in KSC have not been researched on and consequently gave impetus to the researcher to undertake a study on the same.

1.2 Statement of the Problem

Kapseret Sub-County comprises of rural, peri-urban and urban settlements. Most of the urban households get water supplies from the Eldoret Water and Sanitation Company (ELDOWAS) water supply system which is mandated to supply water to the Eldoret Municipality. On the other hand, residents from rural and peri-urban settlements draw their water from shallow wells, rivers, streams, dams, springs, harvested rainwater and boreholes for domestic use. However, most of these sources are unreliable as they are seasonal and are prone to contamination from runoff during the wet seasons. Shallow wells, for example, are prone to drying up during dry seasons, forcing women and children to travel for longer distances to look for water for their families and that of their animals thereby wasting valuable time and energy that could have been used more beneficially. Evidently, access to clean, adequate and affordable water remains a developmental challenge due to the inadequacy of the existing water systems and effects of climate change UGC (2018). About 42% of the residents in UGC lack access to potable water. Moreover, the available sources of water now face challenges including reduced water tables due to the destruction of water catchment areas. Consequently, most water sources drying up in the dry season.

Population in Uasin Gishu has steadily grown over the years. The human population of UGC rose from 894,179 in 2009 to 1,163,186 in 2019. The annual growth rate in 2019 was estimated at 2.7%, which was higher than the national rate of 2.2% (KNBS, 2010: KNBS, 2019). This has increased the water demand significantly hence aggravating the existing water supply challenges. Additionally, the unprecedented deforestation and resultant land uses in KSC have led to reduced capacity for water infiltration and groundwater recharge with concomitant effects on increased stormwater generation. Ironically, seasonal water shortages in KSC are experienced perennially despite heavy rains being received in the rainy season that sometimes cause floods downstream, which have huge social, environmental and economic implications. This study seeks to examine the potential of harvested stormwater to provide water for domestic uses, hence mitigate households from seasonal water shortage in the future in KSC.

1.3 Objectives

1.3.1 General Objective

The purpose of this study was to explore the potential of stormwater in augmenting existing supplies for domestic use, with the aim of addressing seasonal water shortages in Kapseret Sub-County.

1.3.2 Specific Objectives

The study was guided by the following specific objectives:

i. To assess domestic water consumption in KSC.
ii. To examine the potential of stormwater harvesting in KSC.
iii. To establish determinants of stormwater utilization in KSC.
iv. To establish the challenges facing stormwater management in KSC.

1.4 Research Questions

The study sought to answer the following questions:

1. What are the domestic water consumption patterns in KSC?

   i. What is the daily household domestic water consumption in KSC?

   ii. What is the per capita domestic water consumption in KSC?

   iii. Which factors influence daily household domestic water consumption in KSC?

2. What is the potential of stormwater harvesting in KSC?

   i. What is the stormwater yield in Kapseret basin?

   ii. Are there suitable sites for stormwater harvesting in KSC?

3. Which factors influence stormwater utilization among households in KSC?

4. What are the challenges associated with stormwater management in KSC?

1.5 Justification of the Study

The study was undertaken in Kapseret Sub County because the area experiences intermittent floods in the rainy seasons, followed by water shortages in the dry season. As a result, many households experience water shortages in the dry season and lack a reliable water supply system. No research has been done to assess the domestic consumption patterns particularly in the rural areas of KSC. In addition, stormwater is an underutilized resource that could potentially be used as an additional source of water to augment the existing water sources in water scarce areas (Cousins, 2018; Luthy et al., 2020). Literature has shown that stormwater harvesting, on a broader scale, is more economical than other sources such as rainwater harvesting (Marsden, 2006). However, there has been little or no research on the level of stormwater utilization and potential of stormwater harvesting in Uasin Gishu County, and its capability to augment domestic water supplies towards meeting the rising domestic water demand. This research, therefore, explores the potential of stormwater management as a nature based solution towards addressing seasonal water shortage in Kapseret Sub County.

1.6 Significance of Study

The findings of this study provide valuable information for policy makers in the water sector that can assist in enhancement of water supply through sustainable water supply and demand management. Data on domestic water consumption patterns is handy to water resource planners and engineers in forecasting future water demand and thus inform future water development plans. This research also provides valuable information on the potential of stormwater as an additional source of water for households for various uses. In addition, suitable areas for stormwater harvesting are mapped and provide valuable information for water resource developers. In addition, the study brings to the fore the determinants of stormwater utilization and challenges of stormwater management respectively. Finally, the study contributes to building a body of literature which can be used by other researchers in the future as research findings shall be published.

1.7 Assumptions of the Study

Since there is no empirical data on stormwater yield in the area of study to be used in the SWAT model, the regionalization approach was utilized to calibrate the model. The approach is based on the assumption that basins with identical characteristics have similar hydrologic responses. The neighbouring basins of Sosiani, Nzoia and Kaptagat rivers provided the SWAT model calibration parameters.

1.8 Scope of the Study

The scope of study was confined within determined geographical and variable parameters.

1.8.1 Geographic Scope

The study was undertaken in Kapseret Sub-County, Uasin Gishu County, and covered rural part of Kapseret Sub-County and not areas experiencing urbanization.

1.8.2 Variable Scope

The research focused on stormwater runoff. It also addressed the sources and uses of domestic water, including all domestic routine purposes like cooking, drinking, cleaning utensils, cleaning houses, bathing, washing and toilet flushing.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This Chapter reviews literature and presents theoretical and conceptual frameworks. The chapter describes domestic water consumption, water supply in rural areas, water scarcity, stormwater, estimation of stormwater yield, siting suitable sites for stormwater harvesting, stormwater utilization, stormwater management, and legal and institutional frameworks. In addition, the theories underpinning this study including the Ecological Modernization Theory and the Boserupian Theory are also discussed.

2.2 Domestic Water Consumption

Domestic water refers to water used for all usual domestic purposes including consumption, bathing and food preparation (Abubakar, 2019; WHO, 2002). It exempts water used for non-human consumption like lawn irrigation, washing cars and watering animals. Pickard et al. (2017) defined domestic water demand as the amount of water used for human purpose and not for irrigation, livestock, aquaculture, industrial, mining and thermoelectric power water use. Assefa et al. (2019) agreed that domestic water consumption is a variable used to determine the current state of water consumption in routine household activities.

Water used for domestic consumption must be safe for human consumption. Potable sources include those from protected or improved sources. Improved drinking water refers to water sourced from a tap located within premises or yard/plot, a public stand pipe, a tube-well, a protected dug well or spring, and properly harvested rain water (UNICEF/WHO, 2015).

Apart from safety, domestic water must be available in sufficient quantities. According to National Academy of Sciences (1999), the quantity of water used in any activity is jointly determined by the supply of water available to support that activity and the demand for water in that activity. Both the supply and the demand for water are further determined by variables that tend to be location specific. Crouch et al. (2021) suggested that realistic estimates on water consumption can be achieved based on water use activities, while Reynaud et al. (2018) noted that household water consumption provides a measure of the pressure on the environment in terms of water abstraction from different water sources through household use.

Domestic water consumption varies from one household to another. Generally, domestic water consumption is high in developed countries. Assefa et al. (2019) defined per capita domestic water consumption on the other hand as the amount of water used per person per day for domestic needs. This varies from one household to another. The value adopted internationally for basic human water needs is about 50 liters per person per day (WHO/UNICEF, 2017; Gleick, 1996). Table 2.1 shows per capita water consumption in different regions.

Table 2. 1: Per capita domestic water demand in various regions

S/No	Region		Per capita water demand in liters	Reference
1.	Seven provincial towns in Cambodia		72	Basani et al. (2008)
2.	Madagascar		88	Larson et al. (2006)
3.	Salatiga city- Indonesia		130	Rietveld et al. (2000)
4.	Sri Lanka- Gampaha, Kalutara and		135	Nauges & Van Den Berg (2009)
5.	Rural China- Wei River Basin	Continuous Water Supply	71.3	Fan et al. (2013)
		Intermittent piped water	52.0	
		Public tap access	46.5	
		Average	56.2	
6.	Ngamiland District- Botswana		20.6 liters	Oageng & Mmopelwa (2014)
7.	Europe	Berlin	113	Stavenhagen et al. (2018)
		Copenhagen	104	
		Tallin and Zaragoza	96	
8.	Asia	Beijing	129.3	Lu et al. (2018)
9.	Kenya	Iten Town	44	Ngetich et al. (2018)
10.	Kenya	Kisumu City	32.9	Wagah et al. (2010)

Global water consumption has increased and continues to grow steadily at a rate of about 1% per year because of increasing population, economic development and shifting consumption patterns (UNESCO/UN-Water, 2020; WWAP, 2018). Baalousha & Ouda (2017) attributed the increasing global water demand to high population size, urbanization, and rising standards of living.

Fan et al. (2013) observed that it may be difficult to identify factors that influence domestic water consumption because of the complexities of water use patterns. Oageng & Mmopelwa (2014) noted that although many studies have been conducted to determine factors influencing water consumption, those done in rural areas, where water is obtained from open sources, are limited. However, various researchers have attempted to identify the factors that influence both household and per capita domestic consumption.

2.2.1 Factors that Influence Domestic Water Consumption

There are numerous factors that influence domestic water consumption which are discussed herein.

a) Household Income and Price of Water

Income positively correlates with household domestic water consumption (Oyerinde, & Jacobs, 2022; Navascues & Morales, 2018). Reynaud et al. (2018) observed that high living standards are sustained by higher incomes, leading to high rates of domestic water consumption. Hoyos & Artabe (2017) however noted that the relationship between income and domestic water consumption is inelastic, hence an increase in income has just a small effect on domestic water consumption as water is an essential commodity with low substitutability. Rahayu & Rini (2019) observed that families limit their household water uses depending on their propensity to pay for the water. Wang et al. (2021) on their part noted that wealthier homes consume more water because of a high standard of living. In addition, the price of water has a negative effect on domestic water consumption. That means that the lower the price of water, the higher the consumption (Lu et al., 2018; Ojeda, 2016; Romano et al., 2014; Fan et al., 2013).

b) Source of Water

The source of water also influences domestic water consumption. Hope et al. (2020) observed that rural water consumption varies as households choose between the various water sources including rainwater harvesting, dug wells, ponds, water kiosks with public taps, vended water, or private tap connections. Singh & Turkiya (2013) noted that households at close proximity to water sources were likely to use more water. Wagner et al. (2019) were in agreement, and identified factors affecting choice of water source as including income, price, accessibility irrespective of quality, and taste of water. However, Oageng & Mmopelwa (2014) reckoned that distance to the water source was not an important factor in determining per capita water demand in Botswana. Water supply patterns also influence domestic water demand, with households having intermittent water supply consuming less water compared to those with continuous supply (Ojeda et al., 2016; Fan et al., 2013). Nauges &Whittington (2010) observed that households with a private source of water tend to use more than those that depend on public sources. Wagner et al. (2019) consented that households prefer private water sources and least prefer surface water sources like rivers. Thomson et al. (2019), however, noted with concern that the presence of a protected water source does not guarantee its use, especially in the rainy season when households have access to rainwater and surface water sources. Wagner et al. (2019) agreed with this observation, noting that accessibility to water sources was a stronger determinant of choice of water source. They also observed reduction of groundwater use in the rainy season because of increased use of rain water and surface water and attributed this to proximity to water source.

c) Housing Type

Domestic water consumption is influenced by the housing type. Housing type is defined by the size, number and uses of rooms, and material of construction of the houses. Ojeda et al. (2016) noted that with an increase in the number of bathrooms in the household there was an increase in the water consumption at the house. Hoyos & Artabe (2017) noted that bigger houses consume more water in cleaning and gardening.

d) Household Size

Domestic household water used is influenced positively by the number of persons in the household (Fan et al, 2013; Rathnayaka et al., 2014; Ojeda et al., 2016, Aho et al., 2016; Wagner et al., 2019). However, studies have shown declining per capita use rates as the number of persons living in the household increases due to shared usage like cooking and cleaning (Fan et al., 2013; Mimi & Smith, 2000). On a larger scale, Wang et al. (2021) and Rahayu & Rini (2019) noted that population density caused variation in domestic water consumption among cities. Cities with high population densities have higher domestic water demand.

e) Technology and Conservation Attitudes

Household water-using technology, such as low-flow toilets, may also be an important determinant of per capita domestic water use, as are household appliances such as clothes and dishwashers. The use of water saving appliances significantly reduces water consumption (Lu et al., 2018; Martin et al., 2018; Rathnayaka et al., 2014; Fan et al., 2013).

Conservation attitudes and strategies are one approach towards managing domestic water demand. Crouch et al. (2021) observed that various conservation efforts lead to more efficient use of water. Sauri (2013) observed that in Europe, water conservation was used to significantly lower the water demand. Stavenhagen et al. (2018) further notes that awareness about the need to conserve water generally reduces domestic water consumption.

f) Water Use Category

Another factor that influences domestic water consumption is the domestic water use type. Crouch et al. (2021) defines a water use activity as a specific activity, either indoor or outdoors, for which water is used. Specific outdoor uses increase domestic water demand (Crouch et al., 2021; Reynaud et al., 2018). These include irrigated lawns and/or garden beds (Rathnayaka et al., 2014; Fan et al, 2013;), livestock (Fan et al., 2013), and swimming pools (Navascues and Morale, 2018; Rathnayaka et al., 2014). Aho et al. (2016) observed that the number of cars one washed at home influenced the household water demand. Crouch et al. (2021) observed that outdoor uses result from generally higher level needs like need for swimming pools and irrigated gardens, and influence household domestic water consumption significantly based on the local climate and building preferences. Because of the high water requirement of most outdoor uses, many water scarce regions are regulating allocation of water for outdoor water uses. Indoor uses include water activities for provision of basic needs including drinking, cooking, basic hygiene and sanitation.

g) Climate

Climate also influences domestic water consumption. In many cases, hot climates lead to an increase in domestic water consumption (Reynaud et al., 2018; Lu et al., 2018;

Rathnayaka et al., 2014). Hoyos & Artabe (2017) noted that when precipitation is lower, pressure for water uses is higher, hence a higher water demand in the dry season. Wang et al. (2021) further emphasized the role of high temperature in increasing domestic water consumption. They noted that the existence of urban heat accounts partly for the higher amount of domestic water consumed in urban areas that in adjacent rural settlements. In addition, they noted that towns with higher temperature record higher domestic water consumed compared to those with lower temperature.

h) Level of Education

Level of education influences domestic water consumption in various ways. Hoyos & Artabes (2017) noted than in Spain, level of education had a positive influence on domestic water demand. On the other hand, the level of awareness to water conservation could reduce water consumption when people consciously avoid wastage of water and adopt various conservation strategies. Koutiva et al. (2017) observed that highly educated people generally conserve water, since environmental behavior towards water conservation is highly correlated with higher education levels.

2.3 Water Supply in Rural Areas

More people in Africa currently live in rural settlements compared to the urban population. WWAP (2019) noted that people living in rural areas account for about 60% of the total population of Sub-Saharan Africa, and many of them remain in poverty. WHO/UNICEF (2021) further noted that 80% of people without basic water services live in rural areas, and that water supply lags behind particularly in rural areas. WHO/UNICEF (2021) and WHO (2021) concurred and noted that there is need to quadruple efforts towards water supply if SDG 6 is to be achieved by 2030.

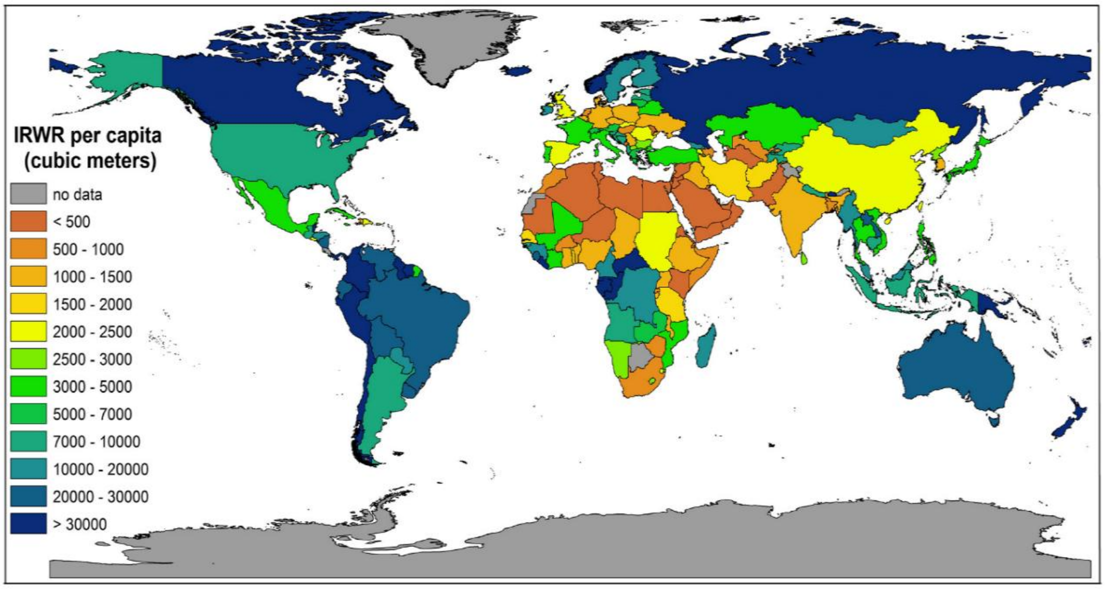
As a result, millions of poor people in rural areas, particularly women and children in low and middle-income countries, spend long hours fetching water from unsafely managed sources. When water sources run dry particularly in the dry season, they often face competition for the limited amounts of available water for domestic and productive uses, such as watering crops or animals (WWAP, 2017; Bates et al., 2008). Kimani et al. (2015) cited than in Makueni, people walk for more than 3 kilometers daily, spending more than one hour looking for water. The sources of domestic water include streams and rivers, boreholes, wells, dams, roof catchments and springs. Wagner et al. (2019) noted that in rural areas of Meru, the sources of water include shallow wells, boreholes, taps, rivers, springs, swamps and in the driest months, households buy water from water vendors. In Uasin Gishu County, only 42% had access to potable water in 2018. In the dry season, people look for water for relatively long distance of up to 2 kilometers from open or protected sources. The sources of water in UGC include dams, boreholes, shallow wells, springs and rivers (UGC, 2018). These sources are prone to seasonal fluctuations directly influenced by rainfall patterns, exposing households to seasonal water shortages.

The lack of access to safe drinking water in many rural areas can be rightfully attributed to water infrastructure that remains extremely sparse, so that millions of women, men and children are not covered by water and sanitation services. Water supply infrastructure in rural areas of developing countries like Kenya is barely developed, with residents accessing water from open sources. In addition, institutional capacity, including domestic resource mobilization and budget allocations has been insufficient to cater for maintenance needs of the installed water infrastructure (WHO/UNICEF, 2021; WWAP, 2019). Furthermore, Hope et al. (2020) averred that there is a disconnect in the approaches which address the socio-technical interface of rural water supply, and that the 'hardware' and 'software' components of functionality are often treated separately rather than as interrelated.

2.4 Water Stress

Water stress is a concern in many parts of developing countries today. Water stress refers to the lack of available safe water for consumers (Salehi, 2022). It is characterized by difficulty in accessing fresh water sources. (Crouch et al., 2021). Water scarcity and water shortage are elements of water insecurity and are one of the major global challenges today. Dandy et al. (2019) noted that existing water sources are currently under stress due to the ever rising water demand. As a response, dealing with water insecurity is one of the 2030 global Agendas for Sustainable Development. SDG 6 strives at achieving a water security in the world by 2030 (WHO, 2021; WWAP, 2017). Assefa et al. (2019) defined domestic water security as the ability of a population to safeguard sustainable access to adequate quantities of acceptable quality water for the basic household needs of drinking, sanitation, and hygiene. Global water security is yet to be achieved. Srinivasan et al. (2017) noted that the concept of water security has arisen in response to the multifaceted nature of the global water crisis.

Water stress is aggravated by the rising water demand. WWAP (2019) and Salehi (2022) observed that water scarcity on a per capita basis has been increasing and project that it will continue to increase due to population growth and climate change. In addition, distribution of water resources is a drawback in certain regions. Although the total Internal Renewable Water Resources (IRWR) for the world average 7,453 m^3 per person per year, these resources are distributed quite unevenly geographically (WWAP, 2019), as presented in Figure 2.1.



Source: FAO, IFAD and WFP (2014).

Fig 2. 1: Global Water Distribution

Consequently, two thirds of the world's population lived in areas that experience water scarcity for at least one month in a year while about 500 million people live in areas where water consumption exceeds the locally renewable water resources by a factor of two in 2017 (WWAP, 2017). In 2020, around four billion people experience severe physical water scarcity for at least one month per year, a situation that was exacerbated by the climate change (UNESCO/UN-Water, 2020).

The level of water insecurity in certain parts of the world is appalling. The World Health Organization (WHO) and UNICEF Joint Monitoring Programme estimated that in 2015, 1.1 billion people (17% of the global population) lacked access to water resources, where access is defined as the availability of at least 20 liters of water per person per day from an improved water source within a distance of 1 km. An improved water source is one that provides 'safe' water, such as a household connection or a bore hole. Additionally, WHO estimated that the total burden of disease due to inadequate water supply, and poor sanitation and hygiene, was 1.7

million deaths per year (UNICEF/WHO, 2015). WHO/UNICEF (2021) noted that Sub-Saharan Africa is experiencing the slowest rate of progress in water supply in the world, with 46% of people lacking access to clean drinking water. Already, parts of Northern and Southern Africa and the Middle East experience absolute water scarcity. As population grows and water resources remain more or less constant, many countries are projected to fall below 1000m^3 per person (WWAP, 2019). It is projected that water scarcity will worsen in the future, due to a variety of factors including climate change, rising populations, increasing human activity and urbanization (WHO/UNICEF,2021; Assefa et al., 2019; WWAP, 2017; Lim et al, 2011). WHO/UNICEF (2021) expressed concern that several years into the Sustainable Development Goals (SDGs), the world is not yet on track on SDG 6 on attaining water security.

Kenya is classified as a water scarce country with an annual renewable freshwater per capita of 647m^3 (Njora & Yılmaz, 2020; UNEP, 2008; GOK,2006), as can be seen in Figure 2.2. Falkenmark & Widstrand (1992) established benchmarks for water stress of between 1000m^3 and 1700m^3 per person, water scarcity of between 500m^3 and 1000m^3 per person, and absolute scarcity of less than 500m^3 per person. The United Nations recommends a minimum of 1,000m^3 per capita per year. The problem of water scarcity is already being felt in Kenya, particularly during the dry seasons. Njora & Yılmaz (2020) opined that the severe crisis in Kenya could be aggravated by multiple causes including drought, deforestation, floods, land pressure from population growth, water contamination, lack of proper water management measures, and ineffective water policies.

2.4.1 Addressing Water Scarcity

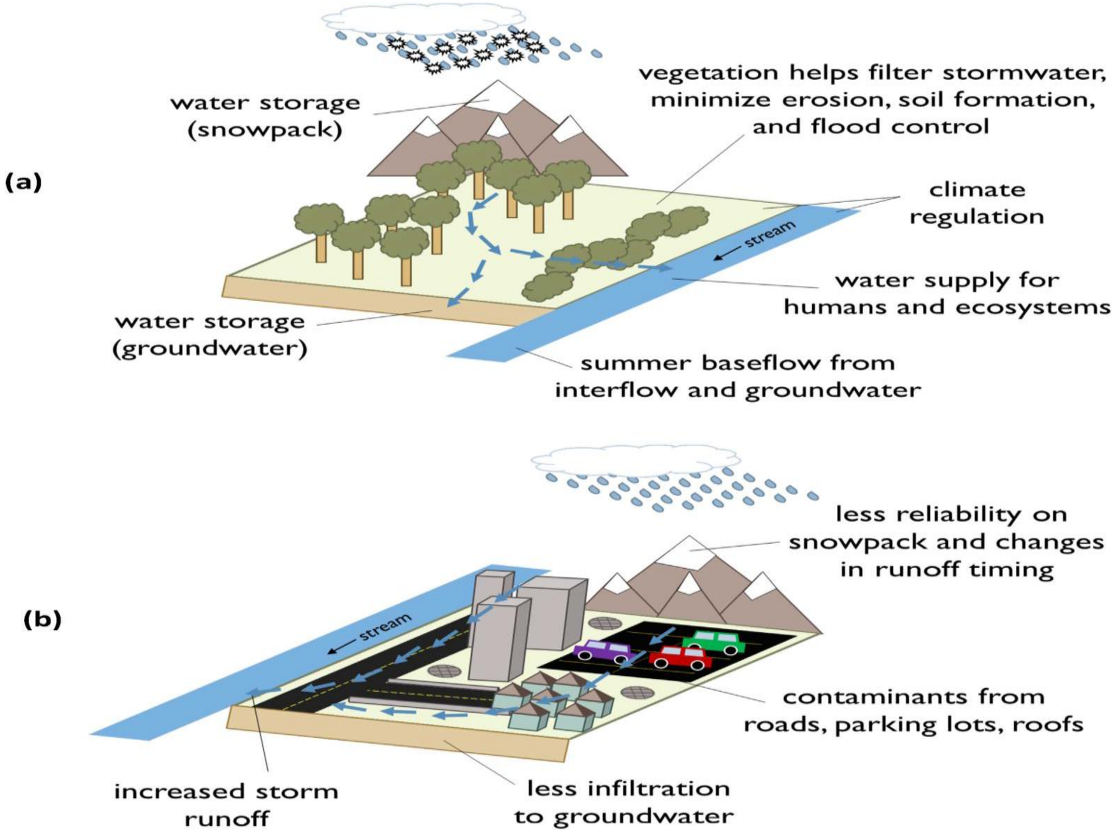
To address the existing water scarcity, there is need to proactively consider both water demand and supply management. Several strategies have been suggested towards this end. In an effort to balance domestic water demand and supply, Stavenhagen et al. (2018) observed that domestic water consumption can be significantly reduced through using water efficient devices, water restrictions, tariff policies and raising awareness about need for water conservation. Using examples from megacities in China, Lu et al. (2018) noted that expanding water sources through basin water transfer and desalination, subsidizing households to adopt water saving appliances and adopting a multi-tier pricing system would also help in dealing with water shortages.

Srinivasan et al. (2017) opined that human adaptation to environmental change in the modern world necessitates a more flexible and dynamic view of water security. Salehi (2022), Anwar (2019) and Pathak et al. (2019) agreed that because current freshwater availability is impacted by climate change, rapid urbanization, and an increase in population, alternative water resources need be explored. Cosgrove & Loucks (2015) suggested that in this era of growing water scarcity there is need to identify how to use our technical capacity and human ingenuity to reduce inefficiencies in the utilization of water resources. The new era of water management involves a search for untapped water sources, one of which is stormwater (UNESCO/UN-Water, 2020; Dandy et al., 2019; NASEM, 2016). Among all alternatives, stormwater has been found as among the most promising for reuse and recycling (Anwar, 2019; Cousins, 2018). Zhang et al. (2020) noted that stormwater can actually help alleviate water insecurity by providing water for domestic use.

2.5 Stormwater

Stormwater is generated when precipitation from rainfall does not infiltrate into the ground but flows off the land and impervious surfaces (Luthy et al., 2020; Dandy et al., 2019). Bassi et al. (2017) observed that stormwater runoff is water that is not absorbed by soil because the surface is saturated or sealed. They noted that the saturation point of surface areas depends on the soil type, landscape, evapotranspiration and biodiversity of the area. National Research Council (2012) observed that stormwater can be measured in a downstream river, stream, ditch, gutter, or pipe shortly after the precipitation has reached the ground.

The recent changes to natural conditions and processes are among the most radical of any human activity and are to blame for increasing stormwater runoff volumes. The rapid development of urban and suburban areas has limited the natural infiltration of water. Increase in impermeable areas has in turn raised the risk of flooding through generation of huge volumes of runoff. Changes in land use, land cover and climate intertwine to create changes in runoff coefficients and water stress (Batalini et al., 2019; Prudencio & Null, 2018; Ayeni et al., 2015). Figure 2.2 shows the role of development in increasing runoff generation.



(Source: Prudencio & Null 2018)

Fig 2. 2: Schematic presentation of effect of development on runoff

Leeuwen et al. (2019) observed that although stormwater could have negative impacts on human living spaces, infrastructure and natural environments, it has immense value as a water resource. Stormwater is a valuable resource and should be harnessed (Hager et al.,2021; Luthy et al., 2020; Wijesiri et al., 2020; Zhang et al., 2020: Leeuwen et al., 2019).

2.5.1 Stormwater Harvesting

Stormwater harvesting (SWH) is used in the literature to refer to the collection, storage, treatment and use of runoff from urban surfaces such as roads and drains that would otherwise drain to a water body (Akram et al., 2014; O'Connor et al., 2007). While rainwater involves collection of water from rooftops, SWH entails collection of runoff from seasonal streams, gullies, creeks and underground conveyances. SWH is one of the ways that man tries to avert water shortages (Gallo et al., 2020; Okedi & Armitage, 2019; Luthy et al., 2020; Kimani et al., 2015). Sivapalan (2015) observed that it is increasingly recognized that water systems are not only impacted on by humans, but human societies also adapt in response to changes in water systems at different time scales. Some countries have adapted to these changes by harvesting stormwater. Table 2.2 shows countries that have practiced stormwater harvesting across the world.

Table 2. 2: Examples of countries that have practiced stormwater harvesting around the world

S/No.	Continent	City/State	Source
1.	Africa	Cape Town, Republic of South Africa	Okedi & Armitage (2019)
		Kenya	Kimani et al. (2015)
2.	USA	California	Watereuse California (2019)
		Washington D.C	National Academies of Sciences(2016)
		Los Angeles	Gallo et al. (2020)
3.	Australia	Melbourne	Luthy et al. (2020)
		Adelide	Leeuwen et al. (2019)
4.	Asia	Singapore	Lim et al. (2011)

In Kenya, the practice of harvesting stormwater is carried out mainly in the more arid and semi-arid regions (ASALs). Typically, the harvested water is stored in tanks or dugout water pans which are ponds used for storing water that runs off fields and roads, or used directly for crop production. However, the adoption rate is generally low because of poor awareness of the technology by farmers and poor information transfer by agricultural extension officers to farmers. Another problem is sedimentation in dams (GOK, 2018). Kimani et al. (2015) noted that in Makueni, there was slow adoption of water harvesting technologies irrespective of their high potential to improve livelihoods. The available technologies include shallow wells, earth dams, water pans, and rock catchment structures.

2.5.2 Advantages of Stormwater Harvesting

SWH presents a variety of benefits including augmenting existing water sources, groundwater recharge, improving water quality and flood mitigation.

a) Water Supply

Harnessing stormwater provides an alternative source of water for domestic use. Stormwater utilization helps to reduce pressure on potable uses by providing water for non-potable uses (Hager et al., 2021; Gallo et al.,2020; Luthy et al., 2020; Okedi & Armitage, 2019; Leeuwen et al., 2019; Batalini et al., 2019; Hammes et al., 2018). National Academies of Sciences, Engineering, and Medicine, NASEM (2016) and Pathak et al. (2020) noted that utilization of stormwater also provides ways to augment and diversify local water supplies and reduce reliance on imported water supplies. Appropriate treatment technologies can be utilized to improve the quality of water so that it be used for potable uses (Payne et al., 2019; Luthy et al, 2019).

b) Aquifer Recharge

Stormwater harvesting plays a significant role in aquifer recharge. WWAP (2019) noted that stormwater reservoirs enhanced aquifer recharge leading to an increase in surface water availability, including during dry seasons. Kubbinga (2015) in his study confirmed that stormwater collection helped in groundwater recharge, which was evident in shallow wells that used to dry before becoming more productive even during the dry seasons. In addition to potentially being accessed directly for instance through wells, aquifers can also augment surface water availability via lateral groundwater flows into natural waterways. When managed from a watershed level, stormwater can be reconsidered as a potential resource for groundwater recharge (Day & Sharma 2020; Luthy et al., 2020).

c) Attenuating Flooding

Floods can be reduced through adoption of various stormwater management strategies. Stormwater harvesting helps to control the volume of water flowing into the drainage system hence minimize pluvial flooding (Metto et al., 2020; Okedi & Armitage, 2019; Payne et al., 2019; Luthy et al., 2020; Leeuwen et al., 2019; Qiao et al., 2018). Anim et al. (2019) noted that stormwater harvesting can be used to mitigate against excess stormwater volumes, hence control flows.

d) Improving Water Quality

Anthropogenic activities like agriculture and manufacturing contribute to pollution in the form of oils, grease, toxic contaminants and other chemicals, and leads to decreasing stormwater quality. The chemical effects of stormwater runoff are deleterious (Vojtek & Vojteková, 2016). However, SWH has clear benefits in reducing pollutant loads to water bodies like streams, rivers, lakes and the ocean (Zhang et al., 2020; Payne et al., 2019; Leeuwen et al., 2019; Kipyego & Ouma, 2018; Hammes et al., 2018; WWAP, 2018; Deletic et al., 2018). Downstream, reduced pollutant loads leads to healthier aquatic ecosystems (Payne et al., 2019).

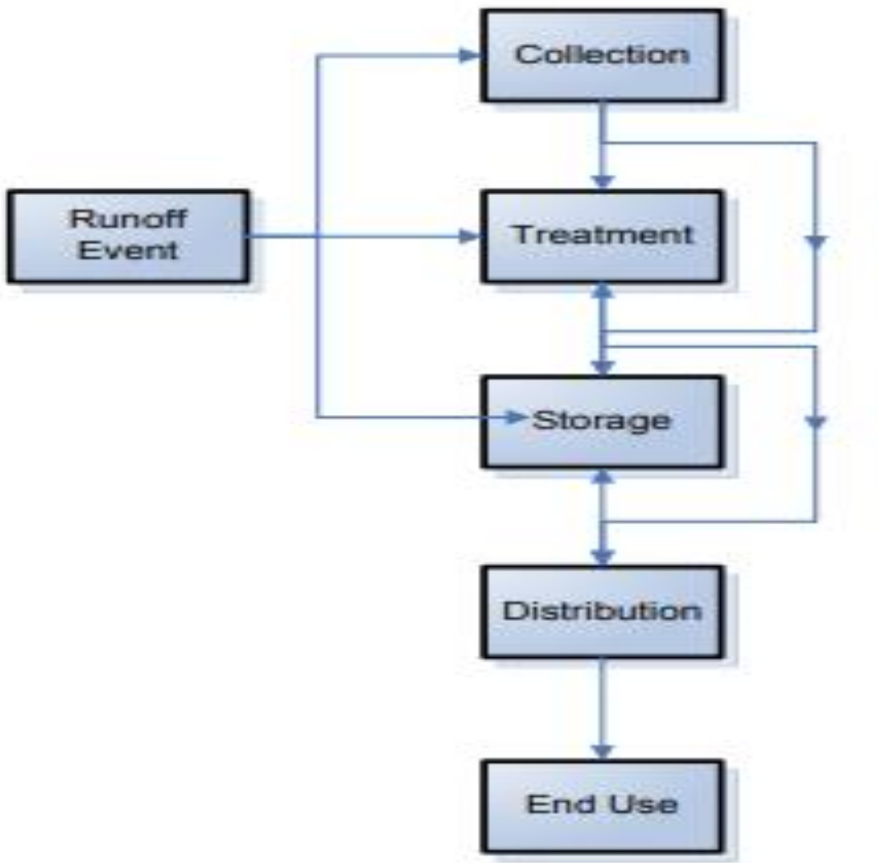
Natural and constructed wetlands can also help improve water quality as opposed to the conventional drainage systems which were generally focused on managing local flooding and largely ignored the need to preserve or improve water quality (Armitage et al., 2013; Burns et al., 2010; Woods-Ballard et al., 2007; AMEC et al., 2001).

2.5.3 Stormwater Harvesting Systems

A stormwater harvest and reuse system is a constructed system that captures and retains stormwater for beneficial use at a different time or place than when or where the stormwater was generated. A stormwater harvesting and use system potentially has four components as outlined by Philp et al. (2008).

i. Collection system which could include the catchment area and stormwater infrastructure such as curb, gutters, and storm sewers
ii. Storage unit (such as a cistern or pond)
iii. Treatment system: pre and post (that removes solids, pollutants and microorganisms, including any necessary control systems), if needed, and the
iv. Distribution system (such as pumps, pipes, and control systems).

These major components are shown in Figure 2.3.



(Source: Philp et al. 2008)

Fig 2. 3: A model stormwater harvesting and use system

The specific components of a stormwater harvesting and use system vary by the harvested stormwater source including rooftops, low density development, traffic and areas, and the beneficial use of stormwater such as irrigation, flushing, washing, bathing, cooling drinking.

2.5.4 Siting Suitable Stormwater Harvesting Sites

Reservoir siting involves identification of the most suitable sites for location of water harvesting infrastructure. There are three main techniques used in dam siting, including GIS/RS methods, Multicriteria Decision Making and Machine Learning Methods. Setiawan & Nandini (2022) critically evaluated the application of each method. Although GIS/RS methods have the ability to analyze and capture data with significant accuracy, all factors are weighed equally, which is not realistic. Multicriteria Decision Making on the other hand addresses the shortcoming of GIS/RS methods by weighing the influence of multiple factors differently, while still utilizing the GIS/RS geospatial techniques in siting. In addition, they are a cost effective approach (Wondimu & Jote, 2020; Buraihi et al., 2015). Zamarrón-Mieza et al. (2017) observed that the Multi-criteria Decision Analysis technique is a useful tool for comprehensive management of dams at all levels. Machine Learning Methods on the other hand is suitable when dealing with complex data.

Setiawan & Nandini (2022) noted that dam siting is usually site specific due to a regions' unique characteristics. As a result, factors to consider while identifying suitable sites are dependent on the purposes of the dam. Sayl et al. (2020) and Mbilinyi et al. (2007) observed that important factors to consider while siting a stormwater reservoir include topographical, geological, hydrological, socio-economic, environmental and water quality.

Wondimu & Jote (2020), Buraihi et al. (2015) and Critchley & Siegert (1991) observed that gently sloping areas are good sites for location of dams. Critchley & Siegert (1991) recommended slopes of not more than 5%. Land uses are also considered when selecting suitable sites for stormwater harvesting. Wondimu & Jote (2020) and Mbilinyi et al. (2007) noted that areas land uses such as bare land that generate high volumes of runoff are ranked highly for siting reservoirs. They noted that water harvesting dams should be located in areas with significant runoff as opposed to areas with little runoff such as in forested areas. Setiawan & Nandini (2022) concurred, noting that land use types and spatial extent of vegetation influences runoff velocity and yield. Soil type and proximity to roads are important factors to consider when selecting suitable dam sites. Wondimu & Jote (2020) and Mbilinyi et al. (2007) noted that sites with clay soils are best for location of dams because of inherent capacity of clay soils to hold harvested water. Wondimu & Jote (2020) and Sayl et al. (2020) further observed that stormwater harvesting dams should be located in close proximity to stream network so as to capture runoff. On socio-economic factors, Setiawan & Nandini (2022) concluded that dams should be situated away from roads and settlement because of conflict of interests amongst users, and because of safety considerations.

2.6 Estimation of Stormwater Yield

There are three major methods that are commonly used to estimate the quantity of stormwater; rational method, Soil Conservation Services- Curve Number (SCS-CN) method and the Soil and Water Assessment Tool (SWAT). In both rational and SCS-CN method, the quantity of stormwater is considered as function of intensity of rainfall, coefficient of runoff and area of catchment. (LMNO Eng., 2012). The total precipitation falling on any area is dispersed as percolation, evaporation, storage in ponds or reservoir and surface runoff. The runoff coefficient can be defined as a fraction, which is multiplied with the quantity of total rainfall to determine the quantity of rain water, which will reach the sewers. The runoff coefficient depends upon the porosity of soil cover, wetness and ground cover. The overall runoff coefficient for the catchment area can be worked out as follows:

Overall runoff coefficient, $C = [A1.C1 + A2.C2 + ... + An.Cn] / [A1 + A2 + ... + An]$

Where,

A1, A2, ... An are types of area with C1, C2, ...Cn as their coefficient of runoff, respectively.

Model source: Gomaa et al. (2012); NRCS, (1986).

2.6.1 Rational Method

Rational method is an important formula for determining the peak runoff rate where rainfall intensity is measured. The Rational equation is the simplest method to determine peak discharge from drainage basin runoff, and is commonly used for sizing sewer systems LMNO Eng., (2012). The formula is premised on the following: consideration of the entire drainage area as a single unit, estimation of flow at the most downstream point only, rainfall is uniformly distributed over the drainage area and is constant over time. The Rational Formula follows the assumptions that the predicted peak discharge has the same probability of occurrence (return period) as the used rainfall.

Storm peak water quantity can be estimated by rational method using the formula:

Storm peak water quantity, $Q = \frac{C.I.A}{360}$

Where,

Q = Quantity of stormwater, $m^{3/}sec$

C = Coefficient of runoff

I = intensity of rainfall (mm/hour) for the duration equal to time of concentration, and

A = Drainage area in hectares

Model source: LMNO Eng., (2012).

2.6.2 Soil Conservation Services- Curve Number (SCS-CN) Method

The SCS-CN formula is one of the moderately simple models and is widely used for flood estimation. It is a globally tested empirical model with clearly stated assumptions and few data requirements (Al-Ghobari et al., 2020; Ajmal et al., 2020; Xiao et al., 2011). The SCS-CN is a conceptual method for predicting direct runoff depth using storm rainfall amount, land use and soil hydrological properties of a catchment (SCS, 1985; NRCS, 1986).

A high curve number means high runoff and low infiltration, whereas a low curve number means low runoff and high infiltration (Al-Ghobari et al., 2020; Zhan & Huang, 2004).

In the Curve Number (CN) method, the runoff volume (Q) is dependent on several parameters, including the amount of rainfall (P), the potential maximum soil retention (S), and the initial abstraction (Ia). The maximum soil retention is related to the physical characteristics of the soil. The SCS determined that runoff does not begin immediately after rainfall starts. This delayed onset of runoff is a result of interception, infiltration, and surface storage of rainfall, and is termed the initial abstraction by the SCS (Xiao, et al., 2011).

Normally the SCS model computes direct runoff with the help of the following relationship:

Stormwater yield, computed as runoff depth in mm, Q can be estimated as:

$$\mathrm{Q} = \frac{[P - 0.2S]^2}{[P + 0.8S]}$$

Where

P, is rainfall depth in mm,

S, the potential maximum soil retention in inches = (1000/CN) – 10,

and CN = $\{\Sigma (Ci * Ai)\}/A$

Where,

CN = weighted curve number,

CN_i = curve number from 1 to any number i,

A_i = area with curve number CN_i.

S is representative of the capacity of the soil for infiltration, which is a function of both the physical characteristics of the soil, and of the available storage within the soil matrix.

Model source: Ajmal et al. (2020); NRCS (1986); SCS, (1985); Hand book of Hydrology (1972).

The NRCS curve number (CN) is related to soil type, soil infiltration capability and land use (Ajmal et al., 2020; United States Department of Agriculture, 1986). The lower the curve number, the more permeable the soil is (United States Department of Agriculture, 1986).

To account for different soils' ability to infiltrate, NRCS has divided soils into four hydrologic soil groups (HSGs), depending on the soil texture (Al Ghobari et al., 2020). Table 2.3 shows USDA-SCS Soil Classification

Table 2. 3: USDA-SCS Soil Classification

Hydrologic Soil Group	**Type of Soil**	**Runoff Potential**	**Final Infiltration Rate (mm/hr)**	**Remarks**
Group A	Deep, well-drained sands and gravels	Low	>7.5	High rate of water transmission
Group B	Moderately deep, well-drained with moderately fine to coarse textures	Moderate	3.8-7.5	Moderate rate of water transmission
Group C	Clay loams, shallow sandy loam, soils with moderately fine to fine textures	Moderately High	1.3-3.8	Low rate of water transmission
Group D	Clay soils that swell significantly when wet, heavy plastic and soils with a permanent high water table	High	<1.3	Very low rate of water transmission

(Source: NRCS, 1986)

The SCS-CN is advantageous over the rational approach. This is because it uses one software to perform all procedure steps. Only satellite imagery on land cover and land uses, soil maps and DEM are needed to calculate the runoff parameters (Al-Ghobari et al., 2020; Khalil, 2017). Classified land use/ land cover maps are overlaid with classified soil maps to come up with the CN, whose value ranges from 0 to 100. Lower numbers indicate low runoff potential while larger numbers are for increasing runoff potential. Weighted curve numbers should be used to eradicate errors while estimating runoff (Ajmal et al., 2020).

However, the SCS-CN has its shortcomings in that it does not factor in the influence of slope and temperature in the computation of runoff.

2.6.3 Soil and Water Assessment Tool (SWAT)

The Soil and Water Assessment Tool (SWAT) is a model of small watershed basin that simulates the quantity and quality of surface and ground water and foretells the environmental impacts of land use, land management practices and climate change. The flow of water in and out of the hydrological system, informs all the processes in the SWAT model. Daniel et al. (2011) & Parajuli et al. (2009) postulated that SWAT is a deterministic and continuous watershed model that operates on daily and hourly basis. SWAT model was developed to improve on the SCS-CN model by the Agricultural Research Service of the United States Department of Agriculture, and is one of the most widely used watershed-scale models (Parajuli et al., 2009). It can model changes in the hydrologic response of the catchment resulting from land use/ land cover (LULC), water quality, and erosion and surface runoff. In order to model a hydrological unit, entire catchment is divided into sub-catchments which are further divided in to hydrologic response units (HRU) based on land use, vegetation and soil characteristics. SWAT then estimates run off of each HRU separate and then the total runoff for the entire basin (Arnold, et al., 2013; Neitsch, et al., 2011). Parajuli et al. (2009) noted that the model requires input of DEM, land use, and soils, as well as time series of climate data such as daily precipitation and temperature. The hydrology component of the model calculates a soil-water balance at each time step based on daily amounts of precipitation, runoff, evapotranspiration, percolation, and base flow.

Arnold et al. (2013) noted that SWAT operates on a daily time step and is designed to predict the impact of land use and management on water, sediment, and agricultural chemical yields in un-gauged watersheds. The model is process based, computationally efficient, and capable of continuous simulation over long time periods. Because of the aforementioned benefits, SWAT model was selected for the study.

2.7 Stormwater Utilization

Lundy et al. (2018) defined stormwater use as the application of stormwater to meet a defined need. Dowsett (2014) suggested that stormwater can be beneficial for its recreational and aesthetic value, rather than as a water supply source. However, with the current global water crisis, stormwater is gaining acceptability as an alternative source of water for various domestic uses (Hager et al., 2021; Zhang et al. (2020); Mankad et al., 2019; Leeuwen et al., 2019; Luthy et al., 2020; Goulden et al., 2018; Massoud et al., 2018; Lundy et al., 2018). Wijesiri et al. (2019) observed that stormwater is currently being underutilized. The main determinants of stormwater utilization are worth examining.

2.7.1 Community Acceptance

Public acceptance is an important factor in water reuse. Mankad et al. (2019) and Massoud et al. (2018) noted that plans to capture stormwater for use should take into account the local people’s perception about stormwater. Public perception is in turn highly influenced by perceived health risk, religious prohibition, political issues, and the degree of human contact with recycled water. Public acceptance informs the end uses of stormwater (Mankad et al., 2019; Lundy et al., 2018). Luthy et al. (2020)

noted that if people have a negative perception to an alternative water source, then they are less likely to adopt it as a source of water.

Studies have identified the ‘yuck’ factor as a major constraint to water reuse as the water could be contaminated (Lopez-Ruiz et al., 2020). There is therefore need to observe high levels of standards through regulations to as to win public acceptance though appropriate treatment technologies that improve the quality of water significantly (Luthy et al., 2020; Lundy et al., 2018). Currently, however, one of the major obstacles to the widespread implementation of SWH is the availability of reliable and affordable treatment technologies (Philp et al., 2008; Hatt et al., 2004).

In residential developments with treated stormwater, there is a higher degree of satisfaction and acceptance among households (Mankad et al., 2019; Coombes et al., 2002). Mitchell et al. (2007) recommended that water should be treated to a quality that meets end-use requirements. In Cape Town, South Africa and Nairobi, Kenya, stormwater is generally considered highly polluted and therefore cannot be used for potable uses unless it is sufficiently treated (Robertson et al., 2019; Lusigi et al., 2017).

2.7.2 Awareness of Stormwater as a Source of Water

Qiao et al. (2018) noted that lack of knowledge among communities is an impediment to sustainable stormwater utilization. The level of knowledge on variety of the end uses influences the decision to utilize stormwater in households (Martini et al., 2015; Newburn et al., 2014).

General lack of knowledge on alternative water sources is highly correlated with lack of knowledge on reuse potential, and negatively impacts on the water source utilization (Rupiper & Lodge, 2019). Lack of knowledge on stormwater, for instance, contributed to low stormwater utilization levels in Latin American countries (Leeuwen et al., 2019). On the other hand, greater knowledge on water issues leads to conservation attitudes and support for alternative water sources (Luthy et al., 2020).

There is need for awareness creation on the various end uses that can be met by stormwater. Many end uses like garden irrigation do not require high quality standards, and stormwater could be used to reduce pressure on potable water. Proper public education and awareness can help engage water stakeholders in needed actions, particularly with regard to reducing water demands (WWAP, 2012)

Lopez-Ruiz et al. (2020) noted that a higher technical knowledge is related to a greater acceptance of water reuse, and that people who are well informed about likely to adopt water reuse. They also noted that people who are concerned about environmental conservation and protection are generally likely to accept water reuse.

2.7.3 Access to Harvested Stormwater

Like all other resources, proximity to stormwater influences its use. Lundy et al. (2018) observed that financial and economic investment need to be applied so as to promote access and utilization of stormwater. Strauch et al. (2021) further noted that in rural areas, development programs are not equitably implemented, hence there is unequal access to water.

Storage of harvested stormwater requires appropriate SWH infrastructure. The design of the storage component of a SWH system is a trade-off between maximizing volumetric reliability and minimizing the required storage size and associated costs (Mitchell et al., 2007). Ahmed & Yakimowich (2007) noted that SWH infrastructure is usually capital intensive beyond communities and households. Bassi et. al., (2017) agreed, and noted that funds are usually not available from the public sector to meet the increasing needs for capital and operation and maintenance costs of water management infrastructure. Cosgrove & Loucks (2015) averred that because investments made in water storage infrastructure and conveyance facilities represent huge stocks of physical capital, water infrastructure remains extremely sparse in rural areas. Consequently, millions of women, men and children are not covered by water and sanitation services.

Currently, water infrastructure is barely developed in rural areas of Kapseret Sub-County. WWAP (2019) noted that the lack of water management infrastructure in terms of both storage and supply delivery as well as for improved drinking water and sanitation services contributes to the high poverty levels in developing countries. Qiao et al. (2018) noted that this is a result of insufficient funding. UNEP (2012) documented that although water supply and hydropower infrastructure development is at an advanced stage in over 65% of countries, fewer countries report advanced implementation for irrigation, rainwater harvesting and investment in natural systems

2.8 Stormwater Management

Stormwater management is the effort to reduce runoff of rainwater or melted snow into streets, lawns and other sites and the improvement of water quality, according to the United States Environmental Protection Agency (EPA, 2009).

Berland et al. (2017) and Chang et al. (2018) noted that sustainable stormwater management should focus on capabilities of soil and vegetation to increase water infiltration, redistribution and storage, as opposed to the traditional stormwater management that focused on conveyance of stormwater runoff to wastewater systems or into surface water sources.

Sustainable stormwater management is sometimes referred to as Green Infrastructure (GI), Low Impact Development (LID) or Best Management Practices (BMPs). Christman et al. (2018) defined green stormwater infrastructure (GSI) as the suite of interventions, comprised of both natural and artificial materials, that utilize vegetation to slow or store surface water runoff, hence regulating the velocity and volume of stormwater. NAS (1999) noted that floodwater stored in reservoirs are important in aquifer recharge, and reiterated the role of vegetation in the water balance.

Green Infrastructure, also known as Low Impact Development, provides an ecologically sound and cost-effective stormwater management approach (Berland et al., 2017). They include green roofs, trees and tree boxes, rain gardens, vegetated swales, pocket wetlands, infiltration planters, porous and permeable pavements, reforestation and revegetation, and protection of riparian buffers and floodplains. They also include decentralized harvesting approaches such as rain barrels and cisterns that can be used to capture and re-use rainfall for watering plants or flushing toilets. These attract multiple environmental, social and economic benefits. (Chang et al., 2018; Shin & McCann, 2017; Berland et al, 2017; Congressional Research Service, 2016). Berland et al., (2017) noted the important role of trees in reducing runoff.

Green infrastructure also poses an opportunity to improve stormwater quality by keeping rainwater out of the sewer system, thus preventing sewer overflows and also reducing the amount of untreated runoff discharged to surface waters (Shin & McCann, 2017; NRC, 2012; U.S. Environmental Protection Agency, 2009). USEPA

(2007) noted that green infrastructure practices provide stormwater conveyance and treatment and also lower the cost of conventional stormwater infrastructure. Bassi et al. (2017) agreed that instead of draining runoff away, green infrastructure aims to increase surface infiltration and lower the amount of stormwater at the source. This would reduce the need for investments in gray infrastructure, given that runoff and its concentration of pollutants would be lower.

Studies have been carried out on benefits of sustainable stormwater management strategies. In Brazil, Batalini et al. (2019) observed that bioretention achieved an average runoff retention efficiency of 70%. This resulted in a reduction of water demand for potable uses by more than a half because the stored runoff was harvested hence available for non-potable uses. Similarly, in Eldoret town, Metto et al. (2020) observed that bioretention ponds reduced runoff flow rate and volume by 1.6% and 4.4% respectively, while infiltration trenches led to reduced runoff flow rate and volume by 25% and 19.6% respectively. Bioretention ponds and infiltration trenches combined reduced runoff volume and flow by 10.7% and 5.9% respectively, and were therefore recommended as an appropriate stormwater management strategy in Eldoret Town. Kipyego & Ouma (2018) observed that BMPs including dry and wet retention ponds, grassed swales and constructed wetlands reduced pollutant loads in Sosiani River by 40%. This agrees with the observations of Qiao et al. (2019) and Goulden et al., (2018) who noted that several countries are increasingly recognizing the importance of managing stormwater sustainably.

2.8.1 Challenges of Stormwater Management

Despite the benefits of stormwater management, there are low adoption rates of the various strategies in many countries including Kenya. The main challenges of stormwater management include limited SWH infrastructure and due to insufficient funding, lack of technical support, and lack of education on SWM. In addition, there is a weak institutional framework.

a) Lack of supportive institutional framework

Institutional challenges in stormwater management originate from ineffective organization of the agencies that manage or regulate stormwater quality and quantity. In the case of stormwater, many of these problems originate because stormwater is a combination of both flood control and water supply which are almost always controlled by different agencies. Water management institutions are part of the broader institutional framework of countries. The potency of this framework has worked to either encourage or hinder effective approaches to managing water resources and its related services (WWAP, 2012). Global water problems can be traced to a deficit of governance resulting from a lack of appropriate institutions at all levels, and the chronic dysfunctionality of existing institutional arrangements (Lenton et al., 2008). UNEP (2012) observed that the common constraints to the development of appropriate institutional arrangements relate to mandates, particularly cross-sector coordination, capacity building and participation. Bassi et al., (2017) noted that one major constraint in water resource management is lack of technical capacity, including the need for specialized skills which may not be available locally.

WWAP (2019) noted that the institutional capacity, including domestic resource mobilization has been insufficient. They suggested that good governance seeks to move away from hierarchical power structures while embracing concepts of accountability, transparency, legitimacy, public participation, justice and efficiency, principles which are in line with the Human Rights Based Approach. Water resource allocation mechanisms can be established to ensure that enough water is available and of suitable quality, to meet basic human needs as a guaranteed priority. Qiao et al., (2018) observed that challenges to sustainable stormwater management are mostly related to governance involving unclear leadership and lack of stakeholder participation. Harvey & Reed (2004) opined that in order for the different partnership models described to be successful it is essential that the different institutional stakeholders have sufficient capacity to fulfil their respective roles.

In order to avert the water crisis from worsening, Cosgrove & Loucks (2015) recommended that there is need to identify, establish and then set in motion systems of governance and regulation that lead to long-term sustainable development.

Institutions in charge of water governance must embrace stakeholder engagement. OECD (2015) defined this as a process by which stakeholders are involved in the water-related policy or project processes and activities to ensure effective water governance. At all stages, there should be well-understood processes available for involvement of internal and external stakeholders. This is an important consequence of the fact that risk assessment involves a number of trans-scientific assumptions and the involvement of stakeholders at all stages promotes transparency to the process and ultimately a greater acceptance of the ultimate risk management decision (NRC, 2012; Crump, 2003). On stakeholder engagement, WWAP (2019) noted that it is important that political, institutional and financial support be given to ‘bottom-up’ initiatives while AMEC et al. (2001) observed that stormwater management solutions and programs have to be tailored to each communities’ particular circumstances and needs. Migosi (2014) concluded that community participation in stormwater management, together with enforcement of legislation by the county will go a long way in abating floods.

WWAP (2012) noted that water management should transform from the traditional approaches to the Integrated Water Management Approach which leads to interconnection of water management with land management and sectors like agriculture, mining and energy, at the institutional level. This can be facilitated through formulation of appropriate national and county laws and enhance the probability of effective decision-making. For successful and effective water governance, it is importance to develop a properly aligned water policy (OECD, 2015). In addition, WWAP (2019) observed that weak institutional structures at the local level are often cited as the root cause of the inability to attract funding for investments. WHO (2009) advised that in the face of climate change, major changes in policy and planning are needed if future investments on water resources are to be impactful.

Although new structures for water management have been put in place in many countries, there is need for implementation of integrated approaches to water management. UNEP (2012) noted that the coordination between the organizations including government, civil society and the private sector needs to be strengthened, supported by the availability of expertise and resources to pursue effective integration in many nations. In Kenya, the various institutions in National and county governments in charge of water governance, need to work with communities in a bottom-up approach towards stormwater management.

b) Limited Financial and Technical Capacity

The high cost of infrastructure reduces uptake of the various stormwater management strategies (Gullo et al., 2020). Luthy et al. (2020) noted that for stormwater management infrastructure, unit costs are high when new infrastructure is being developed. For example, Leeuwen et al. (2019) attributed low levels of stormwater management in Latin America and the Caribbean countries to lack of monetary resources and development of stormwater infrastructure. Shin & McCann (2017) also noted that high cost of installing rain gardens and rain barrels was a major limitation to their adoption of these strategies in Missouri, Columbia.

In addition, aging stormwater infrastructure and regulatory requirements create fiscal and institutional demands that require new approaches and resources (Ahmed & Yakimowich, 2007). There is need to ensure necessary maintenance of existing infrastructure is conducted with sufficient frequency. Failure to properly maintain SWM infrastructure can lead to excessive sedimentation, clogged inlets and outlets, loss of vegetative plantings, soil compaction, and failure to properly infiltrate stormwater. This can lead to additional overflows and have a harmful effect on water quality, thus negating the original intent of the project. Shin & McCann (2017) noted that lack of requisite equipment is a constraint to SWM maintenance.

Land availability is another impediment to development of stormwater management projects like dams. Luthy et al. (2020) noted that space for large projects is scarce. Kimani et al. (2015) observed that lack of legal land ownership may hinder adoption of stormwater management technologies.

c) Lack of Sufficient Education about SWM

Shin & McCann (2017) observed that people who are knowledgeable about implementation of stormwater management practices like rain gardens are more likely to adopt the practices. Martini & Nelson (2014) agreed that the lack of information about how to install and use rain barrels were a barrier to adoption of rain barrels. Households with more knowledge of lawn management are more likely to adopt lawn management BMPs (Martini & Nelson 2014; Brehm et al., 2013). There is therefore need to educate households on why they need to conserve, maintain and restore the natural resources on their farms. ISCO (2004) noted that many people do not understand the cause and effect of what they do on their land and the potential downstream impacts. Education is essential and needs to be done on a routine basis as an ongoing program activity. Salehi et al., (2020) concurred that communities need awareness on actions towards stormwater management, and available infrastructure if they are to adopt the various stormwater management strategies

Environmental knowledge and attitudes are key factors affecting behavioral intentions to adopt stormwater management practices (Dietz et al., 2004). Knowledge-based factors such as knowledge about recommended stormwater management strategies and awareness of a watershed management plan or other planning efforts may increase adoption of such strategies in urbanizing watersheds (Bakacs et al., 2013; Swann, 2000).

Salehi et al., (2021) noted that in Australia, communities generally lacked knowledge on stormwater management strategies. Kimani et al. (2015) made a similar observation in Kenya. They suggested that local government inform communities on the benefits and strategies of stormwater management. Migosi (2014) while assessing flood abatement through effective stormwater management, noted challenges facing urban stormwater management revolve around inadequate planning, lack of stakeholder participation and low level of community awareness.

Households sometimes lack accurate information on the cost of SWH investments. The cost of stormwater harvesting is relatively low in comparison to other supply options like wastewater (Lundy et al., 2018). This lack of accurate information regarding costs can be a barrier to households adopting SWH, and undermines the 'driver' of reduced potable water demand. It is therefore important to provide upfront information on the local costs of installing and operating such a system (Leonard et al., 2014; USEPA, 2007).

2.9 Policy, Legal and Institutional Framework of Stormwater Management in Kenya

This section will detail the policy, legal and institutional frameworks for water and stormwater resource planning and management in Kenya, as these are critical if sustainable SWM is to be realized.

2.9.1 Policy Framework

An analysis of the legal and policy frameworks in many of the countries reveals that there are many policy and legislative gaps with regard to stormwater. In Kenya, stormwater is barely acknowledged and planned for as a water resource. The policies discussed in respect to water resource herein include SDGs, Agenda 21, Kenya's Vision 2030, Kenya's Water Policy and Water Rules.

a) Sustainable Development Goals (SDGs)

The 2030 Agenda for Sustainable Development Goals (2030 Agenda) was unanimously adopted by members of the United Nations General Assembly in 2015 to act as a blueprint for a better and sustainable future for all. SDG 6, on water and sanitation. The member states, including Kenya, confirmed the human right to water and committed to ensuring availability and sustainable management of water and sanitation to all by 2030. SDG 6 aims at guiding policy decisions of member states including international and local organizations, public and private sector towards universal access to clean water and sanitation. The SDG 6 reiterates the need to implement integrated management of water resources in all levels, and the right to access water by all, with special attention to women, children and people living with disabilities (UNDESA, 2021; United Nations, 2015). However, UN (2021) in the Sustainable Development Goals Report 2021 observed that 129 countries are not on track in achieving clean water and sanitation for all by 2030, and current efforts must be doubled if this was to be achieved.

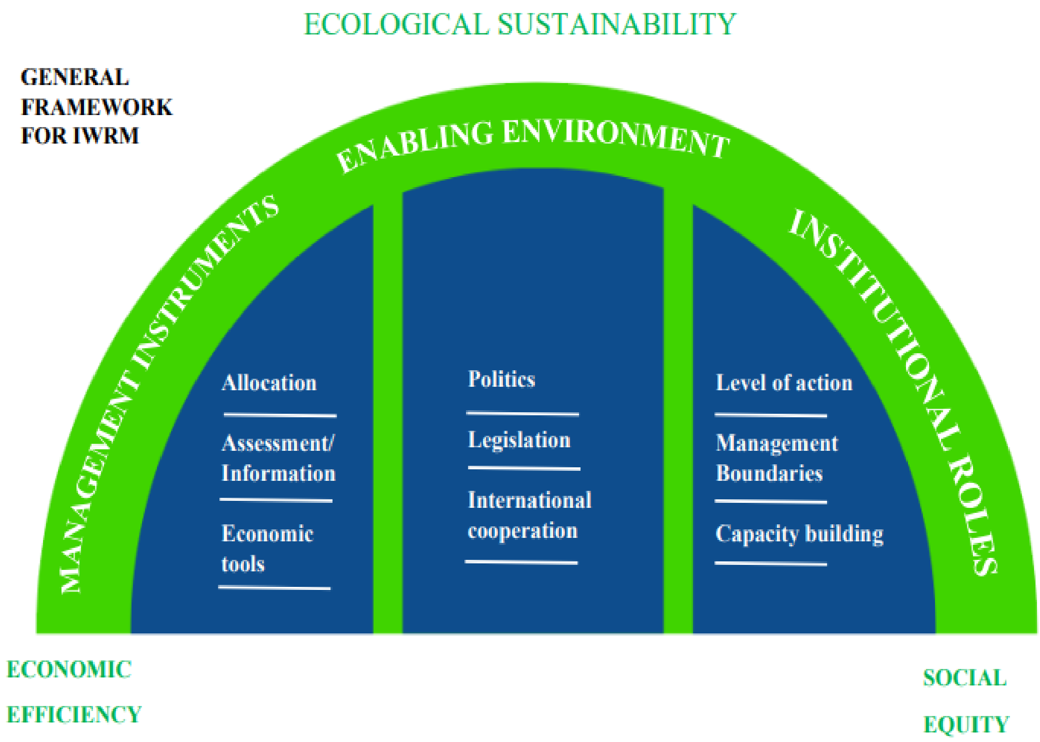
b) Agenda 21 and the Integrated Water Resource Management (IWRM) Approach

Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally in every area which human impacts on the environment. Chapter 18 of the Agenda 21 document deals exhaustively with water resource planning and management. It affirmed the right of all people, including the women, children and the poor to safe drinking water and sanitation. Agenda 21 stated that water is an economic good and is a finite resource and advocated for integrated approach to the development, management and use of water resources in member countries and implementation of water efficiency strategies, plans and programs at national and at regional levels, with national-level IWRM plans to be developed by 2005 (UNEP, 2012; UN, 1992).

IWRM is a process which draws its inspiration from the 1992 Dublin Principles. It is a systematic process for the sustainable development, allocation and monitoring of water-resource use in the context of social, economic and environmental objectives (Day, 2009; Falkenmark, 2003). U.S. Army Corps of Engineers (2002) described IWRM as a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations. Global Water Partnership (GWP) defined IWRM as a process which promotes coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP, 2000). UNEP (2021) further holistically described IWRM as an approach that helps to balance competing water demands from across society and the economy, without compromising the sustainability of vital ecosystems. This is achieved through coordinated policy and regulatory frameworks, management arrangements and financing. IWRM has integrated the Dublin Principles which include that water is a finite and vulnerable resource, that participatory approach should inform water management, that women are an important component in water resource management, and that water has an economic value (Grubb et al., 2019). The principles on vulnerability of the water resource and it having an economic value imply that water in any form though extremely valuable, must be conserved. This realization should consequently inspire development of infrastructure for water harvesting and reuse globally.

UNESA (2021) observed that IWRM is a cross-sectoral policy approach designed to replace the traditional, fragmented sectoral approach to water resources and management that has led to poor services and unsustainable resource use. IWRM is based on the understanding that water resources are an integral component of the ecosystem, a natural resource, and a social and economic good. UN-Water (2008) noted that the Integrated Water Resources Management (IWRM) approach has now been accepted internationally as the way forward for efficient, equitable and sustainable development and management of the world's limited water resources and for coping with conflicting demands. IRWM is guided by three principles including a strong enabling environment, a comprehensive and robust institutional framework and effective use of management and technical tools for water allocation and pollution control (Smith & Clausen, 2018). Although IRWM has been incorporated in water management in many countries including Kenya, full implementation is yet to be achieved. UNEP (2021) noted that the main challenges to full implementation of IWRM can be categorized into three, which include poor financing and lack of capacity, outdated and ineffective legal framework and institutions that are too weak to enforce legislation and implement planned programs. Kenya's implementation of IWRM was rated at 59% in 2020.

The IWRM approach has not been without criticism. Snivasan et al. (2017) noted that the IWRM relied on physical models only that relied on population dynamics and infrastructural development parameters only. Biswas (2008) on his part opined that the approach lacked a clear actionable framework. Day (2009) further observed that although IWRM was envisaged to reform management of water and land resources, it has the tendency to ignore community based water management, by neglecting stakeholders at local authorities. In addition, he observed that although IWRM is theoretically sound, it often remains impractical to implement because the concepts are too complex for agencies and practitioners to manage. In China, for instance, IWRM was instituted in a top-down approach which failed to address the socio-political circumstances in the country (Mao et al., 2020). However, these concerns could be as a result of limited understanding and poor implementation of IWRM. UNEP (2021) recommends that to realize the benefits of IWRM, countries must among other measures strengthen political good will, improve coordination and alignment of progressive water policies, increase financing and strengthen inclusive participation. The general IWRM framework is outlined in Figure 2.4.



(Source: GWP 2000)

Fig 2. 4: The IWRM Framework

c) Vision 2030

Vision 2030 is a long term plan launched in 2008 to guide development in Kenya, and is focused around the social, economic and political pillars. Water and sanitation is one of the six priority areas within the social pillar. To enhance water supply in rural areas, the government aimed at rehabilitating rural water schemes, drilling boreholes and constructing pans and dams in regions with insufficient surface water sources. Towards water harvesting and storage, the government planned to invest in water storage in every village (GOK, 2021). Today, however, the ASAL areas still experience water scarcity while other areas with ‘reliable’ rainfall like Kapseret experience seasonal water shortages particularly in the dry season. It is evident that the government plans and programs have not been fully implemented.

d) The Water Policy

The current water policy is the Sessional Paper No.1 of 1999 on National Policy on Water Resources Management and Development. The policy sought to address issues of water resource management, water and sewerage development, institutional framework and financing of the sector. However, with the numerous new laws and regulations being enacted, the policy is to a large extent irrelevant. Consequently, a new water policy is to be adopted once the Sessional Paper No.1 of 2021 on National Policy. The sessional paper proposes measures and actions that respond to the challenges facing the water sector. The policy seeks to reengineer the sector in consonance with SDGs, Water Act (2016) and Constitution of Kenya (2010).

2.9.2 Legal Framework

The laws that govern water resource development, planning and management in Kenya include the Constitution of Kenya, 2010 and the Water Act (2016).

a) Constitution of Kenya, 2010

In Kenya, the Water Act (2016) was enacted by the Kenyan Parliament to incorporate IWRM in water resource management. The act states that access to clean and safe water in adequate quantities is an economic and social right of all Kenyan citizens. The equalization fund was set to ensure provision of basic services like water. The responsibility for water supply and sanitation service has been assigned to the 47 counties to carry out public works and services including SWM systems and water and sanitation services. In addition, county governments are tasked to implement government policies on natural resource and environmental conservation including soil, water and forestry (Constitution of Kenya, 2010).

b) The Water Act (2016)

The Water Act enacted in 2016 aims at aligning the water sector with the Constitution of Kenya, 2010's primary objective of devolution. The Act recognizes that every citizen has a right to clean and safe water in adequate quantities and reasonable standards of sanitation. The national government, through the Cabinet Secretary of the Ministry of Water is mandated with the responsibility of supporting county governments to perform their respective duties of water provision mainly through public works and funding. The Act saw the establishment of Water Service Providers to oversee the management and distribution of water to various users, and National Water Harvesting and Storage Authority to harvest surface water (Water Act (2016)).

Mwihaki (2018) noted that although the legal framework on water resource management in Kenya had evolved over time to accommodate decentralization, water supply was still insufficient particularly in rural areas and among the urban poor.

c) Water Rules

With regard to stormwater management, the Water Rules, 2012 guides licensees, who are Water Service Boards established under the Water Act (2016) to collaborate with local authorities so as to stormwater from entering sewerage systems. This is aimed at easing pressure in the sewerage systems. In addition, they are to develop and promote water storage. This is by developing water reservoirs like dams for provision of reliable water supply.

2.9.3 Institutional Framework

Hope et al. (2020) note that institutional design is central to the economic performance and social outcomes of water services. Institutional design affects the management of operational risks and information flows, asset ownership and management, service delivery models, monitoring and regulation, and financial sustainability. The contextual nature of these issues is influenced by climatic, environmental, and cultural factors.

UNEP (2012) noted that institutional reforms have been undertaken in many countries and that a central philosophy of an integrated approach to water resources management is that water should be managed at the lowest appropriate level. This means decentralizing decision making, usually with increasing input and role for various stakeholders.

a) Water Resources Authority

In Kenya, the Water Resources Authority was established under the Water Act (2016), with the general mandate of regulating the management and use of water resources. In consultation with the Cabinet Secretary of the Ministry of Water, the WRA is mandated to designate basin areas. A basin area is a defined area from which rain water flows into a watercourse. A basin water resources committee is then established for each respective basin area. Its responsibilities, among others include to advise the WRA and county governments concerning; conservation, use and apportionment of water resources and protection of water resources and increasing the availability of water.

b) The National Water Harvesting and Storage Authority (NWHSA)

The National Water Harvesting and Storage Authority (NWHSA) was established in Kenya following the enactment of the Water Act, 2016. The NWHSA is a parastatal under the Ministry of Water, Sanitation and Irrigation, and is mandated with the task of developing a water harvesting policy and enforcing water harvesting strategies, among other roles. However, its role in managing rainwater as an additional source of water which can help communities to cushion themselves from seasonal water shortages has not been successful.

c) Water Services Regulatory Board

The Water Services Regulatory Board was established under section 70 of the Water Act (2016). It is mandated to protect the interest and rights of water users, for instance by recommending water and sewerage tariffs. The board also accredits Water Service Providers.

d) Water Service Providers (WSP)

These are licensed by the Water Services Regulatory Board with the duty to operate water works and provide water services in conjunction with county governments in their jurisdiction. ELDOWAS is the WSP under whose jurisdiction Uasin Gishu County falls. Water Service Providers should be responsible for efficient and economical provision of water services so as to fulfill the fundamental right to water. However, the scope of WSP seems to have been limited to urban areas only, and many rural areas are marginalized with regard to water supply in Kenya. Mwihaki (2018) noted that there is need for a holistic approach to water governance that incorporates social, legal, economic, institutional and administrative concerns. In addition, there is need to foster government and local citizens' relations that will enhance water services provision as envisaged in the Constitution 2010.

2.10 Theoretical Framework

Two theories supporting sustainable water resource management have been reviewed in this section including the Boserupian Theory and the Ecological Modernization Theory.

2.10.1 The Boserupian Theory

UNEP (2012) observed that the growing need to address water resources emanates from profound failures in water management over many years, because local management is not equipped to adapt and respond adequately. In the Kenyan context, and Kapseret Sub County in particular, water shortage occurs due to lack of sustainable water management, and a proactive reaction to the growing population. The environment and population discourse has been under discussion since the days of Rev. Robert Thomas Malthus. Malthus explained that overpopulation was the source of all ills in society, and that population needed to be controlled. Ester Boserup (1910-1999), an agricultural economist, however, criticized the Malthusian theory and advanced the environmental possibilism approach which holds the belief that humans can overcome environmental forces by advancing technology. In her document 'Boserup's land-intensification hypothesis', she posits that population increase eventually necessitates technological advancement. She theorized that population was the cause rather than result of agricultural change, and that the major change was intensification of land use. For instance, she noted that with population rise, there grew the need for land intensification. With further population increase, technological advancement took the form of land intensification for instance through mechanization and use of fertilizers (Boserup, 1965). Other changes included improvement in agricultural technology and in land tenure systems. With regard to water, Malthus viewed water as a resource, thus associated with scarcity. Boserup on the other hand rejected this assumption because of she believed in the possibilities of technological development (Zisopoulou et al., 2022). Boserup argued that the existing technology level constraints the current supply of any resource and that modern technologies could unlock a more efficient and plentiful water supply. Saiz-Rubio & Rovira-Más

(2020) agreed that with modern technology in the agricultural sector, water efficiency can be improved and crop yields increased. Boserup identified six ‘structures’ as being relevant to the development of her theory Environment (E), Population (P), Technology (E), Occupational structure (O), Family structure (F) and Culture (C). She studied the nexus of three or more of these structures under various scenarios (Boserup, 1965). In Kenya today, as a result of the gradually growing population in many parts, pressure on water resources is increasing. As a result, water demand has exceeded water supply. However, technological advancement can allow expansion of water sources, for instance by harvesting rain and stormwater, and conservation of water resources. However, as Boserup rightly noted, technological adoption depends on the occupational structure of households (O). In vicinities where households are willing and able to invest in stormwater management systems, this theory provides a perfect framework for development of water resources. Stormwater management is most sustainable when households understand the benefits and willingly accept to work as individuals or in groups to manage stormwater.

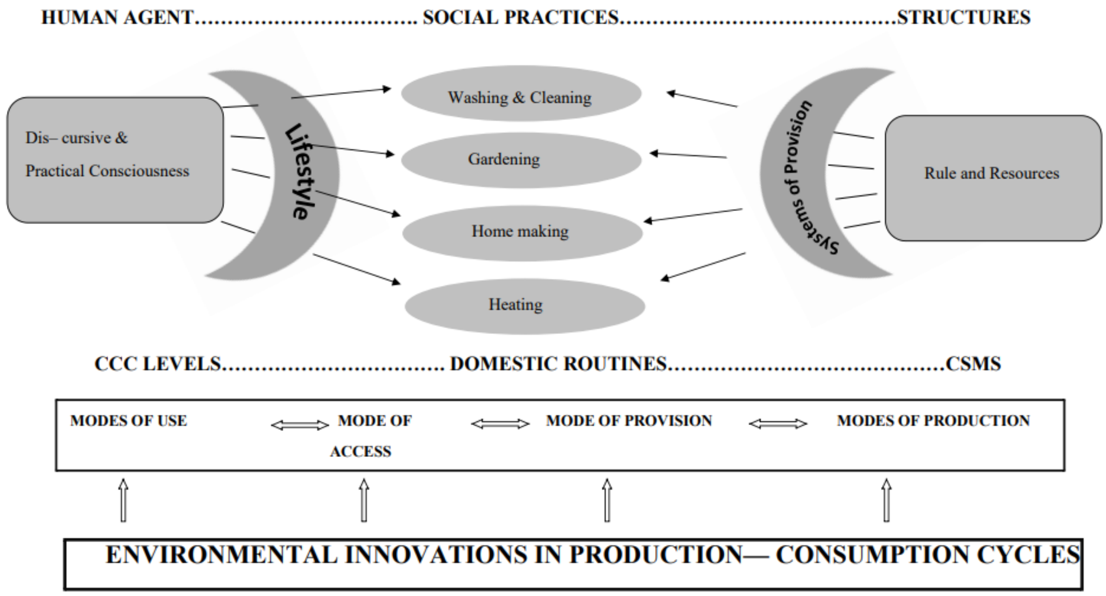
For effective management of water resources, technology, and the provider of the particular technology are equally important. In the case of water resource development in Kenya, the role of national and county governments cannot be overstated due to the fact that water development projects are capital intensive and require technical support Cosgrove & Loucks (2015). Although Boserup did not delve into importance of institutional structures, she discussed the roles of family structure and culture. Culture influences people’s way of doing things (UNEP, 2012). It affects their perceptions and attitudes to a large extent. Although many rural residents are low and medium income earners and may lack the capacity to adopt appropriate SWM technologies, if their attitude towards water conservation is changed, either by necessity or education, then such communities can easily embrace stormwater harvesting and use. Unless communities participate actively in generating solutions to their own problems, the poor are likely to be trapped in the vicious cycle of poverty (World Bank, 1993). However, with institutional support that focuses on bottom-up approaches, communities can be empowered to participate in SWM. This can be in form of education and awareness creation, funding for SWH technologies including green infrastructure and formulation and implementation of laws that focus on stormwater management. Overall, the Boserupian theory is relevant in this study as the roles of technology and supportive institutional frameworks in harnessing of stormwater cannot be overemphasized.

2.10.2 Ecological Modernization Theory

Ecological Modernization (EM) Theory emerged in the early 1980s as a theoretical approach to describing the relationship between economics and the environment. It is described as a technology-based approach oriented to inform environmental policy (Mol, 2002). One basic assumption of ecological modernization relates to environmental re-adaptation of economic growth and industrial development. The relationship between economy and ecology can be symbiotic. Productive use of natural resources and environmental media including air, water, soil and ecosystems, can be a source of future growth and development in the same way as labor productivity and capital productivity.

On its applicability, Spaargaren (2000) noted that the EM Theory has become one of the leading perspectives in environmental sociology. This theory is often associated with eco-efficient innovation, particularly the introduction of environmentally friendly technologies that increase resource productivity. It focuses on the role of the government in accelerating technical progress. As a theory of social change, it reflects on the process of institutionalization of environmental concerns through the need to refine the existing models. Spaargaren posited that ecological concerns must be taken into consideration in the restructuring of production and consumption. Mol (2002) observed that environmental concerns are a response to globalization processes and dynamics that are mostly detrimental to the environment. Huber (2004) further observed that science and technology are agents of modernization of production and consumption and that advanced technologies are key propellers of change. He implored on the use to technology to improve access to water, regulate water use, and enhance ecofriendly production of water.

This theory resonates well with the need for stormwater management as an ecofriendly approach to manage water demand by expanding water sources as opposed to other approaches like drilling boreholes. In addition, technological advances in BMPs and LIDs are sustainable local solutions to the global phenomenon of increased runoff volumes. This is thus the proponent theory in the study. Figure 2.5 presents a conceptual presentation of the EM Theory.



(Source: Mol 2002)

Fig 2.5: The Ecological Modernization Theory

The EM Theory has however suffered criticism. Mol (2002) criticized the EM theory as was originally coined, that it did not pay attention to the actual process of consumption itself and that consumers were depicted as passive agents. Thus, the theory seemed to ignore the user, yet the user significantly influences the production and consumption patterns. However, modification to the theory has seen improvements to incorporate the role of societal factors including scientific, economic, institutional, legal, political and cultural in water governance (Huber, 2004).

Moreover, Fisher & Freudenburg (2001) noted that the EM theory seems to have limited global efficacy, applying primarily to its countries of origin including Germany and the Netherlands, and has little to say about the developing world. In Ghana, for example, EM was not successful as the approach was weak and did not lead to sustainability in water resource management. This was manifested in water scarcity aggravated by water degradation and climate variability, despite adoption of the model in Ghana. To overcome this, countries must adopt the model with special consideration on the existing socio-economic and environmental context. Atampugre et al. (2016) recommended that ecosystem-friendly indigenous approaches needed to be integrated with contemporary management systems for the long term goal of sustainability.

Though having shortcomings, the fundamentals of EM Theory were a precursor to the sustainable development debate and contributed to the development and adoption of the adaptive and progressive Integrated Water Resource Management (IWRM) Approach.

2.11 The Conceptual Framework

The conceptual framework developed shows the inter-relationship between dependent, independent and intervening variables. The dependent variables in the study include domestic water consumption, stormwater potential, stormwater utilization and stormwater management. Traditional approaches of water management have not been effective in promoting water security. As a result, there are perennial shortages of water particularly in the dry seasons, while the wet seasons are characterized by floods. Water shortage occurs particularly in the dry season because water sources are often inadequate, and water supply cannot meet water demand.

Analysis of domestic water consumption was crucial in this study. Factors that influence domestic water consumption include main housing type, water use types, distance to main water source, education level of household head, income and family size.

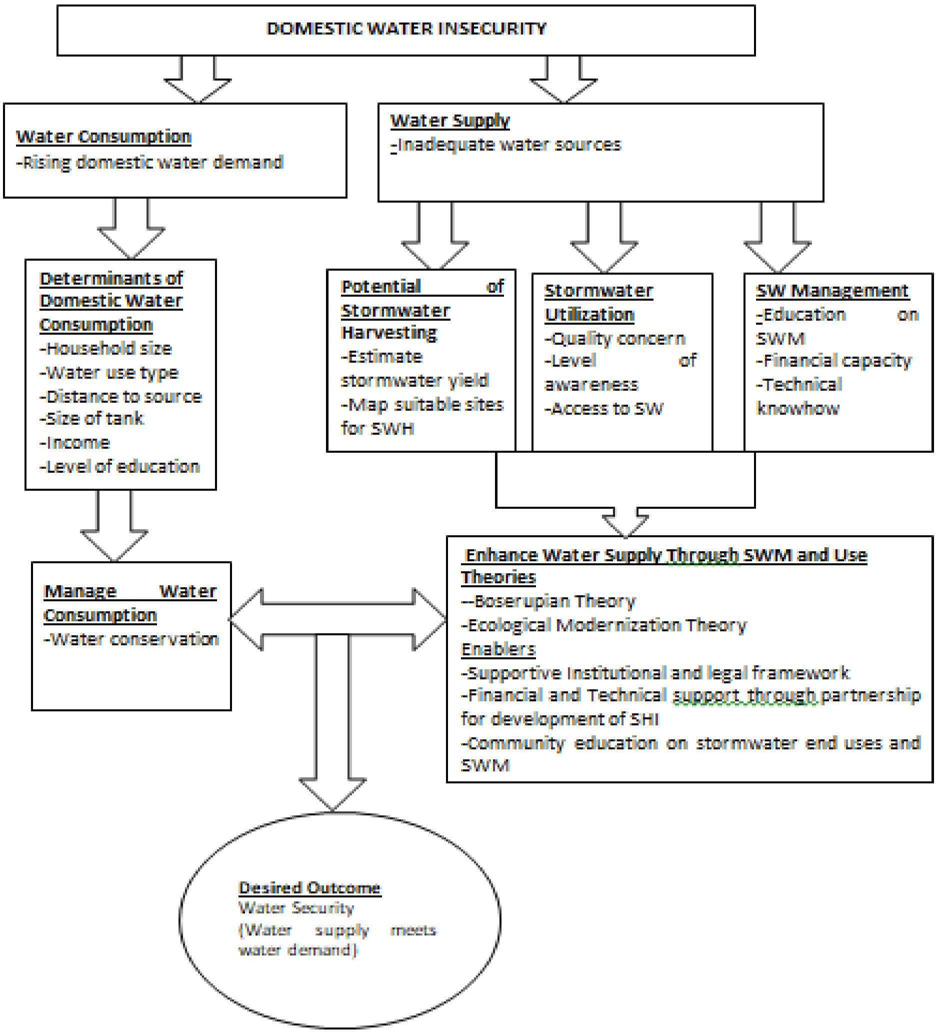
Efforts towards attaining water security must include strategies to reduce water demand and increase water supply. One way to increase water supply as proposed in the study is to expand water sources through stormwater harvesting. The study explored the potential of stormwater harvesting as an alternative source of domestic water. Rainfall amounts, soil type, slope and land use/land cover were used to estimate the stormwater yield. In addition, suitable sites for stormwater harvesting were mapped. Stormwater utilization is an important component of water reuse. The determinants of stormwater utilization include access to harvested stormwater, outdoor water uses, awareness that stormwater is a source of water and quality concerns. The challenges to stormwater management were also investigated. They include inadequate financing for various SWM strategies, lack of technical support for SWM and lack of education on SWM benefits and strategies for communities. These challenges can be overcome through provision of:

i. Adequate financing for sustainable stormwater management. Stormwater infrastructure is usually capital intensive, right from stormwater collection, storage, treatment and distribution. Sources of funds could include multinational agencies, national governments through WUAs, county governments through ward projects, NGOs and CBOs.
ii. Supportive institutional and policy framework. The national and regional laws and regulations should provide an enabling environment for a sustainable SWM process. This should include laws on land uses, water abstractions and uses. Government should provide staff to provide training and technical support on SWH to communities through well formulated policies at both national and county governments.

iii. Community Education. Water users should be engaged if any project is to succeed. Communities should be educated on the benefits of stormwater management as a solution to seasonal water shortages. They should also be educated on the various end uses of stormwater and conservation practices so as to effectively manage their demand for water.

The study was guided by two theories; the Boserupian Theory and Ecological Modernization Theory. A major point of convergence of these theories inclined to environmental possibilism is the possible use of technology for posterity.

Whilst expanding water sources hence availing as more water as possible, water consumption needs to be minimized. This can be done by adopting water conservation. Communities need to be educated on the various water conservation strategies. The desired end is a water-secure environment as envisaged in Vision 2030, where water demand is met by water supply. Figure 2.6 depicts the conceptual framework developed for this study.



(Source: Author, 2022)

Fig 2. 6: The Conceptual Framework

2.12 Knowledge Gap

This study sought to address specific gaps that were identified with respect to stormwater utilization and domestic water supply. Wagner et al. (2019) studied water demand in rural areas in Meru County. They identified factors influencing households' choice of water source. Although they modelled water demand, they did not assess the water demand of rural households in dry and rainy seasons. However, they did not delve into the factors influencing water consumption. Thomson et al. (2019) studied the relationship between rainwater and groundwater use in rural

Kenya. They however did not quantify domestic water consumption in the study area, neither did they establish factors that influence amount of water used.

Many studies on stormwater management and use have aimed at exploring the usefulness of stormwater in agriculture. Examples include the studies by Ngigi (2003) who assessed the level of adoption and the impacts of stormwater ponds on farm income. Ahmed (2007) evaluated rainwater harvesting techniques in Yatta District, Kenya, to investigate factors affecting adoption of rainwater harvesting techniques in Yatta district for agricultural purposes. These studies did not explore utilization of stormwater for domestic purposes. In addition, no study in KSC has either attempted to estimate the stormwater yield or identified suitable sites for stormwater harvesting. The study by Lusigi et al. (2017) focused on the quality of stormwater in Nairobi. However, they did not estimate the quantity neither did they assess level of usage of stormwater. With respect to stormwater utilization, very little or no study was found that addressed factors influencing stormwater utilization. Rather, studies have been carried out particularly on water reuse of municipal wastewater.

On stormwater management, Metto et al. (2020) studied the impact of bioretention ponds and infiltration trenches to stormwater flow and volume in Eldoret Town. Similarly, Kipyego & Ouma (2018) studied the impact of selected BMPs in reducing pollutant loads, runoff flow and volume into Sosiani River. The BMPs included dry and wet retention ponds, grassed swales and constructed wetlands. However, the extent of adoption of various stormwater management strategies was not determined, neither were the challenges to adoption of LID and BMPs established.

This study sought to address the outlined gaps by:

i. Determining domestic water consumption in both the dry and rainy seasons and explaining cause for variation. In addition, factors affecting household and per capita domestic water consumption were determined and a mathematical model developed to estimate per capita domestic water consumption.
ii. Estimating stormwater yield in rural areas, hence expose its untapped potential in providing additional water that can be utilized for domestic and other uses in the dry season. In addition, using the multi-criteria analysis approach, suitable zones and sites for location of stormwater harvesting infrastructure in KSC were identified.
iii. Establishing the level of access and utilization of stormwater, and establish factors influencing stormwater utilization.
iv. Establishing the level of stormwater management and presenting the challenges to sustainable stormwater utilization and management.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This Chapter presents research procedures that guided this study. These include the study area description, research design, data requirement, target population and sampling techniques, data collection instruments, data analysis and presentation, data validity, data reliability, and ethical issues in research.

3.2 Research Design

Creswell (2009) noted that research designs include the plans and procedures for research that cover the decision from wide-ranging assumptions to meticulous methods of data collection and analysis. Sileyew (2019) noted that a research design is intended to provide an appropriate framework for a study. There are three main research designs namely quantitative, qualitative and mixed method designs. This study adopted the mixed method design that incorporates both quantitative and qualitative data management. While the positivism theoretical perspective focuses on observation and measurement and is achieved through quantitative data analysis, interpretivism on the other hand mainly dwells on qualitative data analysis (Junjie & Yingxin, 2022).The mixed method approach, also referred to us multimethodology approach incorporates both positivism and interpretivism perspectives.

3.2.1 Quantitative Data

Quantitative data included household responses from questionnaires age, income and level of education, sources of water, distance to water source, domestic uses of water, amount of water used for various water uses, and reliability of water sources access and use of stormwater, and stormwater management. In addition, rainfall, soil type, LULC and slope data were collected and analyzed quantitatively.

3.2.2 Qualitative Data

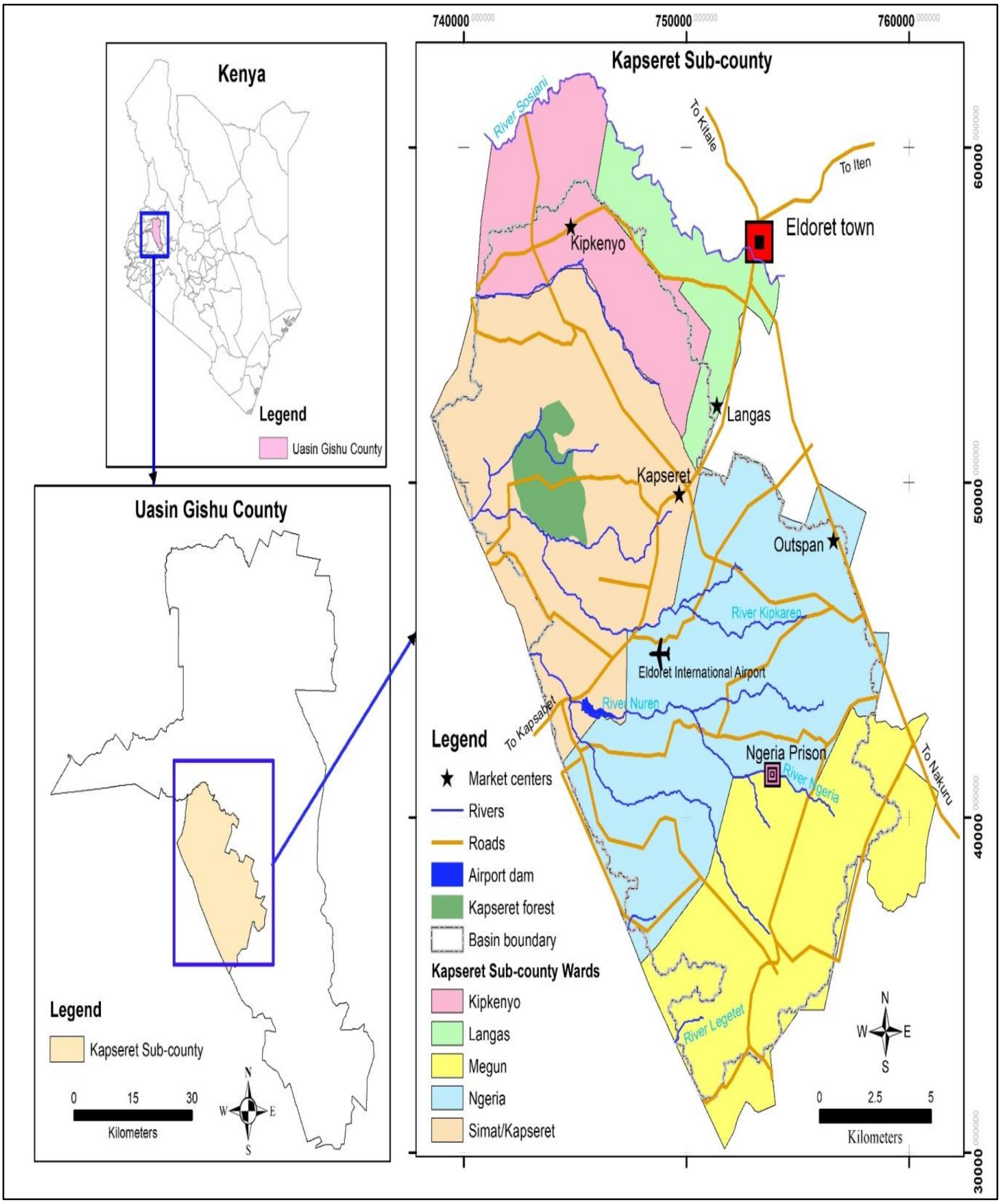
Qualitative data was acquired from the interview with key respondent. In addition, certain responses from questionnaires distributed in homes were open ended and elicited varied responses that were analyzed qualitatively. The responses were categorized into themes. Furthermore, information from field observations on water supply issues, water use behaviors, and stormwater utilization and management formed part of the qualitative data. The data was analyzed qualitatively by categorizing responses into themes.

3.3 Study Area Description

The study was undertaken in Kapseret Sub-County (KSC), Uasin Gishu County. The area was selected for this study because households experience seasonal water shortages despite the area receiving ‘sufficient’ rainfall annually. In addition, there has been unprecedented land use change in the study area that has resulted in increased runoff volumes.

3.3.1 Physical Location

Kapseret Sub-County is one of the 6 administrative units in Uasin Gishu County and consists of five wards namely Kapseret/Simat, Langas, Kipkenyo, Ngeria and Megun. The headquarters of Kapseret Sub-County is Kapseret center. It is located to the South West of Eldoret Town, along Eldoret-Kisumu road and it is about 10 km from Eldoret Central Business District. Figure 0.1 shows the location of Kapseret Sub-County, Uasin Gishu, Kenya.



(Source: UGC 2018)

Fig 3. 1: Location of Kapseret Sub-County and Basin, Uasin Gishu, Kenya

3.3.2 Size and Population

The sub-county has an area of 299.3 km^2 and an average population density of 663 persons per km^2 (KNBS, 2019). It is notably the smallest in size, yet the most densely populated sub-county in UGC. In 2019, it had a population of 198,499 persons and 59, 746 households. Given the national intercensal growth rate of 2.2% from the 2019 census, population of KSC in 2022 is projected at 211,890 persons.

3.3.3 Climate

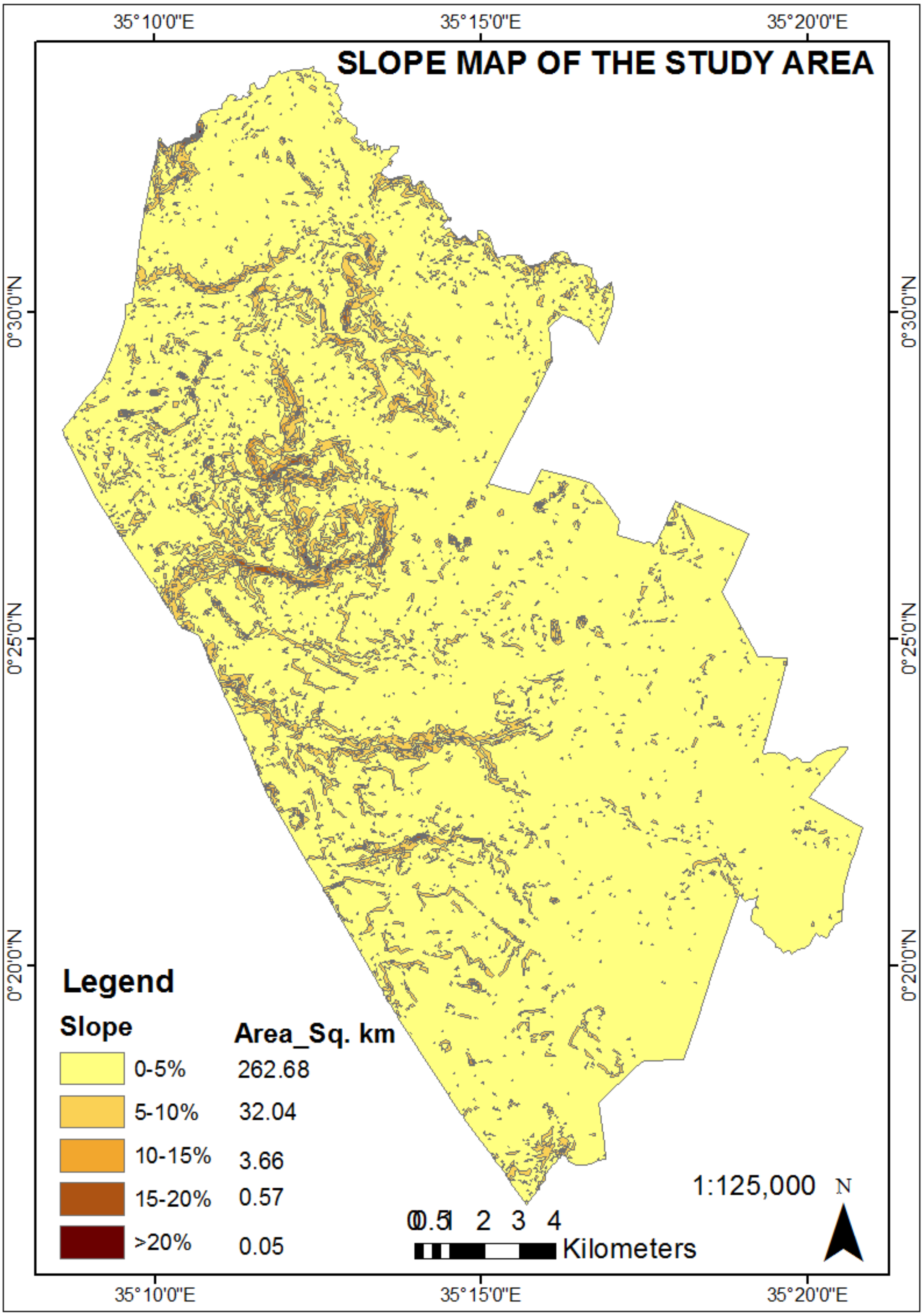
UGC has a relatively cool climate with mean annual temperatures across the county being predominantly below 21°C, a factor attributed to its location on a plateau that rises gently from 1500m above sea level to 2,700 m above sea level. Rainfall in the county is relatively high with the northern and central parts receiving between 1000 and 1250mm of rainfall annually, the southern parts receiving 1250-1500mm annually and the western tip receiving above 1500mm. The rainy season lasts from March to September followed by a dry spell lasting from November to February (UGC, 2018).

3.3.4 Soils

Soils in the county are red loam soils, red clay soils, brown clay soils and brown loam soils (MoALF, 2017). The two soil types in KSC are orthic ferrasols and humic nitosols.

3.3.5 Slope of the Study Area

There is evidence of slope in KSC. The largest area (262.68 km^2) has a gentle slope of <5%, 3.66 km^2 has a slope of 10-15% while only 0.6 km^2 has a slope of >15%. Figure 3.2 shows the degree of slope in KSC.



(Source: Author, 2023)

Fig 3. 2: Degree of slope in Kapseret Sub-County

3.3.6 Drainage

The DEM revealed a stream network exhibiting a dendritic pattern in Kapseret basin. There are numerous ephemeral streams and four main rivers, Kipkaren, Elegirini, Ngara and Sosiani. There are five main dams in KSC; Ngeria, Strawback, Kimuri, Eldoret Airport and St. Georges.

3.4 Target Population and Sampling Procedure

The target population is the people living in Kapseret Sub County, and the unit of analysis is the household. The number of households in Kapseret sub-County from the 2019 census was 59,746, with a total population of 198,499 persons.

3.4.1 Sample Size

The sample size was determined using Yamane's formula as adopted from Yamane (1967).

$$n = \frac{N}{1 + Ne^2}$$

Where

n= sample size, N = population size, and e = Margin of error (MoE), e = 0.05

Sample size$= \frac{59{,}746}{1+59{,}746*0.05^2}$

Thus, the sample size from a population of 59,746 households at 95% significance level was 399.993 which is approximately 400 households. Yamane's sampling formula is a simplified but widely accepted formula for determining sample size (Singh & Masuku, 2014).

3.4.2 Sampling Techniques

Stratified random sampling was applied to identify respondents drawn from each of the 4 rural wards namely Simat, Kapseret, Ngeria and Megun. Langas/ Pioneer is entirely an urban settlement. The sample size was proportional to the population size. Each ward was a stratum, from which respondents were selected randomly to give equal chances of selection. Villages were listed from each ward, after which 4 villages in Kipkenyo, 7 in Kapseret/ Simat, 6 from Ngeria and 3 from Megun were picked randomly, based on number of households in each ward. From each selected village, the first household was picked randomly followed by every fourth household, until the required sample size was achieved. Out of the 400 respondents, 83 were selected from Kipkenyo ward, 137 from Kapseret/Simat ward, 122 from Ngeria Ward and 62 from Megun ward in proportion to population size. Table 3.1 shows the population size in 2019 and corresponding required sample size from each ward.

Table 3. 1: Population in Kapseret Sub-County Wards and sample sizes

S/No	Ward	Number of Households-2019	Sample Size Required	Sample Size Collected	No Of Villages
1	Kipkenyo	4108	82	83	4
2	Kapseret/Simat	6778	136	137	7
3	Ngeria	6009	120	122	6
4	Megun	3080	62	62	3
	TOTAL	19975	400	404	20

3.5 Data Needs

This section details the data requirements for each objective and how the data was acquired.

To determine per capita and household domestic water consumption, data on socio-economic characteristics of households including age, income and level of education was acquired by interviewing households. Other information from the interviews included sources of water, distance to water source, domestic uses of water, amount of water used for various water uses, and reliability of water sources.

To estimate stormwater yield in Kapseret basin, rainfall, soil type, Land Use Land Cover (LULC) and slope data were required. Rainfall and temperature data was acquired from the Eldoret Airport and Kapsoya Meteorological stations and downloaded from World Weather for Water Data Service (W3S) website. This included daily rainfall and temperature data for 2019 and annual rainfall data for the past 35 years. Soil data was downloaded from FAO and also acquired from Kenya Soil Survey and processed by ArcGIS. DEM was generated for the study area using ArcGIS. LULC map was downloaded from USGS website at 30m resolution and processed using ArcGIS. To identify suitable sites for stormwater harvesting, data on slope and stream network was collated from DEM, while details of proximity to institutions, road and airport network was collated from LULC. DEM of 30m was downloaded from USGS website, which was used to process stream network, slope and contours. The LULC map downloaded from USGS website was used to process maps on roads, airport and institutions.

To determine factors influencing stormwater utilization households were interviewed on their uses of water, accessibility to stormwater, perception on quality of stormwater, reliability of other water sources, awareness that stormwater is a source of water and uses of stormwater.

To determine the challenges of stormwater management, data was required on level of household's engagement on SWM, level of education on SWM, technical and financial capacity to engage in SWM. In addition, data from key informant included budgetary allocation towards stormwater management, policy framework for stormwater management within UGC, and sufficiency of personnel and equipment for stormwater management.

3.6 Data Collection Procedures

Both primary and secondary data was collected.

3.6.1 Primary Data

Primary data was collected using the following instruments.

a) Survey

Questionnaires were used to carry out a cross-sectional survey across KSC. This study used both closed and open ended questionnaire which was used to collect data on household characteristics, uses of water, sources of water, distance to water source, water shortage, water consumed for various water uses, access to stormwater, stormwater utilization and stormwater management. Although the questionnaires yielded more quantitative data, useful qualitative data was also captured.

b) Interview with Key Respondent

A structured interview schedule with both closed and open ended questions was prepared. A key respondent was interviewed from the directorate of water in the

Ministry of Water, Environment, Natural Resources, Tourism and Wildlife Management, Uasin Gishu County. The interview captured information on the water supply situation in Uasin Gishu, budgetary allocation for water supply and stormwater development, legal framework, status and challenges of stormwater management, and anticipation of the UGC with respect to water provision and stormwater management.

c) Observation and Photography

An observation schedule was utilized to collect information on water consumption and supply, stormwater, stormwater harvesting and stormwater management. This was done by completing an observation schedule and taking photographs.

3.6.2 Secondary Data

Secondary data was collected using the following instruments.

a) Geospatial Tools

GIS and RS techniques were used to acquire LULC imagery and DEM for KSC. Soil maps were downloaded from FAO and Kenya Soil Survey. The DEM was downloaded from https://earthexplorer.usgs.gov/ with a resolution of 30m, and DEM of the study area extracted and used to generate stream network, slope map and contours. In addition, Landsat 8 satellite imagery were obtained from the US Geological Survey website and used to generate land use and land cover maps. The Kapseret Sub-County shape file obtained from Independent Electoral and Boundaries Commission (IEBC) was used for sub setting the landsat imagery to the desired location.

b) Records

In this study, the sources of documentary data used included rainfall and temperature data which was acquired from Eldoret Airport and Kapsoya Meteorological Stations and complimented with that downloaded from MS3 website that is compatible with SWAT. In addition, laws and policy governing water resource management were reviewed.

3.7 Methods of Data Analysis and Presentation

Data was analyzed separately for each objective.

3.7.1 Domestic Water Consumption

Household domestic water consumption for dry and rainy seasons was determined from household responses in the rural settlements of Kapseret Sub-County. The total amount of water used in a household from the individual domestic water uses was determined. Households provided data on how much water they used in both dry and rainy seasons for each activity in liters. Quantitative data from questionnaires was analyzed using the SPSS software to determine the household domestic water consumption for rural settlements in liters, for both dry and rainy seasons. Given the household size and household water consumption, per capita domestic water consumption for each household was computed.

In addition, using SPSS, linear regression was used to identify the factors influencing per capita water consumption in dry and rainy seasons.

3.7.2 Assessing the Potential of Stormwater

To determine the potential of stormwater in augmenting existing water sources, the stormwater yield in 2019 was estimated, and suitable sites for stormwater harvesting identified. The following data was analyzed;

a) LULC Map

Image pre-processing on LULC imagery was done using ArcGIS. The satellite image for 3rd August 2019 was geometrically corrected using high resolution google earth image of 2019 as reference and projected to coordinate system of World Geodetic System, 1984, Universal Transverse Mercator, Zone, 36 North (WGS_1984_UTM_Zone_36N) since it is the universal coordinate system which was also used for the shape file of the study area. Resampling of the satellite image was not necessary since all the five bands (2, 3, 4, 5, and 6) used were to common pixel size of 30m. In order to limit the image to the study area only, the shape-file of the sub-county was used to clip the image.

For classification, a total of eight classes were used in this study including trees, shrub, grass, cropland, built, bare, water and swamp. A supervised maximum likelihood classification (MLC) was subsequently applied to each image; such an algorithm has generally been proven to yield superior results from remotely sensed data if each class has a Gaussian distribution (Bolstad and Lillesand 1991). The maximum likelihood decision rule is based on the probability that a pixel belongs to a particular class. The basic equation assumes that these probabilities are equal for all classes, and that the input bands have normal distribution.

Accuracy assessment was then performed. Classification accuracy refers to the comparison of two datasets; one based on the analysis of remotely sensed data, and the other is based on reference information (Congalton, 1991).

Twenty (20) points per LULC class were randomly generated making a total of 160 accuracy assessment points for the entire basin. The extracted accuracy assessment points LULC were then compared to the corresponding Google earth image of 3rd August 2019.

The specific LULC accuracy is presented in Table 3.2.

Table 3. 2: LULC accuracy assessment

		Actual LULC type								
	LULC	Bare	Built	Grass	Crop	Shrub	Swamp	Trees	Water	Total
LULC type from classified map	Bare	18	1	0	1	0	0	0	0	20
	Built	2	17	0	0	0	0	1	0	20
	Grass	0	1	17	0	1	1	0	0	20
	Crop	0	0	1	19	0	0	0	0	20
	Shrub	0	0	1	0	17	0	1	1	20
	Swamp	0	0	1	0	0	18	0	1	20
	Trees	0	1	0	0	1	0	18	0	20
	Water	0	0	0	0	1	1	0	18	20
	Total	20	20	20	20	20	20	20	20	160
	Accuracy (%)	90.0	85.0	85.0	95.0	85.0	90.0	90.0	90.0	

$$\text{Overall accuracy} = \frac{\text{Total No. of correctly classified pixels (diagonal)} * 100}{\text{Total No. of Reference pixels}}$$

$$= \left(\frac{18+17+17+19+17+18+18+18+18}{160}\right) * 100$$

Overal accuracy=88.75%

b) Soil Type

Soils data from The Soil Survey of Kenya and Food and Agricultural Organization (FAO) is available in shape file and was clipped for the study area using the basin as the boundary. The soil map was processed using ArcGIS, and presented as a soil map.

c) Rainfall Data

Rainfall data was obtained from the Eldoret Meteorological Department. A data set was also sourced from https://www.uoguelph.ca/watershed/w3s/. This was downloaded in a format compatible with SWAT. In addition, seasonal rainfall variability analyzed using monthly and annual averages, and presented in a line graph.

d) Digital Elevation Model (DEM)

The Kapseret basin boundary was generated from DEM using the "Watershed Delineator" in SWAT. Other spatial data generated include the slope map, streams network, outlets and the watersheds, also referred to as sub-basins.

e) Estimating Stormwater Yield

Processing was done using SWAT 2012 model. First, the model was calibrated. Model calibration is an important process, and helps to increase robustness of the model in simulation (Karki et al, 2020). Wallace et al. (2018) noted that watershed size at which SWAT is calibrated has little effect, but the watersheds must have similar physiographic features. Since the study area lacked available stream flow measurements, data from neighboring basins of Sosiani River, Nzoia River and Kaptagat River were used to calibrate the model. The specific study basin model parameters for the calibration were sourced from Kibii et al., (2021), Odira et al.,

(2010) and Mainya (2017). The calibration in the study catchment was assisted by the ArcSWAT manual calibration helper.

For parameters with more than one value, means were obtained and used. The summary is presented in Table 3.3.

Table 3. 3:Calibrated parameter values

Parameter	Parameter value	Source	Watershed
CN	Agriculture – 85 Forest – 75.45 Shrub – 80.12 Water bodies – 92 Grassland – 84.1	Mainya (2017)	Sosiani River
ESCO	0.95	Odira et al. (2010)	Nzoia River
GWQMN	0	Odira et al. (2010)	Nzoia River
REVAPMN	0	Odira et al. (2010)	Nzoia River
GWREVAP	0.02	Odira et al. (2010)	Nzoia River
GWREVAP	0.05	Kibii et al. (2021)	Kaptagat River
Alpha_BF.gw	0.048	Kibii et al. (2021)	Kaptagat River
GWQMN	1000	Kibii et al. (2021)	Kaptagat River

After model calibration, SWAT model was run to estimate stormwater yield in KSC in 2019. The inputs into SWAT model included soil map, slope map, LULC map, DEM and daily climate parameters particularly rainfall and temperature. Surface runoff was estimated on monthly basis.

f) Identifying Suitable Sites for Stormwater Harvesting

To identify suitable sites for stormwater harvesting, the DEM of KSC was first added into ArcMap and projected to WGS_1984_UTM_Zone_36N using Raster projection tool. The shape file of the study area was then overlaid on the DEM in order to clip it to the extent of the study area using Data Management Tool, Raster, Raster Processing, Clip tool in ArcMap. The contours were then generated in ArcMap using Arc Toolbox's spatial analyst tool. The contour interval was set to 10 meters. The contour shape file was then projected from geographic coordinates system to UTM using Data Management Tool, Projection and Transformation.

Secondly, criteria classification and ranking was done. Criteria classification enables standardization of the factors, hence allows uniform consideration when performing overlay analysis. Ranking was done to segregate the classes based on their considered importance to selection of suitable stormwater harvesting sites. Five ranks were considered ranging from a scale of 1 representing the least preferred to 5, representing the most preferred. This was done for each criterion based on the expert assessment and recommendations as shown in Table 3.4.

Table 3. 4: Criteria Classification and Ranking

Criterion	High rank	Low rank	Reason
Slope	Well drained, gentle sloping	Steep and flat land	Gentle slope is cost effective and less prone to landslide (Wondimu & Jote, 2020; Buraihi et al., 2015; Critchley & Siegert, 1991)
Proximity to streams	Near	Far	The shorter the distance to streams, the better (Wondimu & Jote, 2020; Sayl et al, 2020, Buraihi et al., 2015)
Road network	Far	Near	May lead to conflict of interest with road users and development (Setiawan & Nandini, 2022)
Airport proximity	Far	Near	The dam might attract water fowl posing risks to aeroplanes (Setiawan & Nandini, 2022)
Institutions	Far	Near	Economic considerations in the event of relocation and safety concerns (Setiawan & Nandini, 2022)
LULC	Wetlands and low soil erosion areas	Forest	Land use types and vegetation coverage influence generation of runoff volume and velocity. Areas with high runoff potential are more suitable sites for water harvesting. (Setiawan & Nandini, 2022; Wondimu & Jote, 2020; Buraihi et al., 2015)

Finally, weighting overlay was performed in ArcGIS. Based on their importance, criteria were allocated weights adding up to 100%. Slope and proximity to stream network were considered the weightiest factors, while proximity to airport was the least weighty factor. This is shown in Table 3.5.

Table 3. 5: Assigned criterion weights.

Criterion	Weight (%)
Slope	30
Proximity to river	30
LULC	15
Road network	10
Institutions	10
Airport proximity	5
Total	100

The overlay inputs were all the criteria layers with identical geospatial characteristics of 702 columns, 917 rows, pixel size of 30 meters and spatial extent of 59039.4346329, 738576.044595, 759636.044595 and 31529.4346329 at the top, left, right and bottom respectively. The Weighted Overlay tool in ArcGIS will then overlay the criterion layers using the common measurement scale, 1-5, and the different allocated weights based on the importance to generate the dam suitability map.

The generalized methodology used in data processing and analysis included overlaying of base maps including DEM, LULC, rivers, roads, airport, institutions, contours and slope. Using multicriteria analysis, suitable dam sites were identified and their capacities established. This is presented in Figure 3.3.

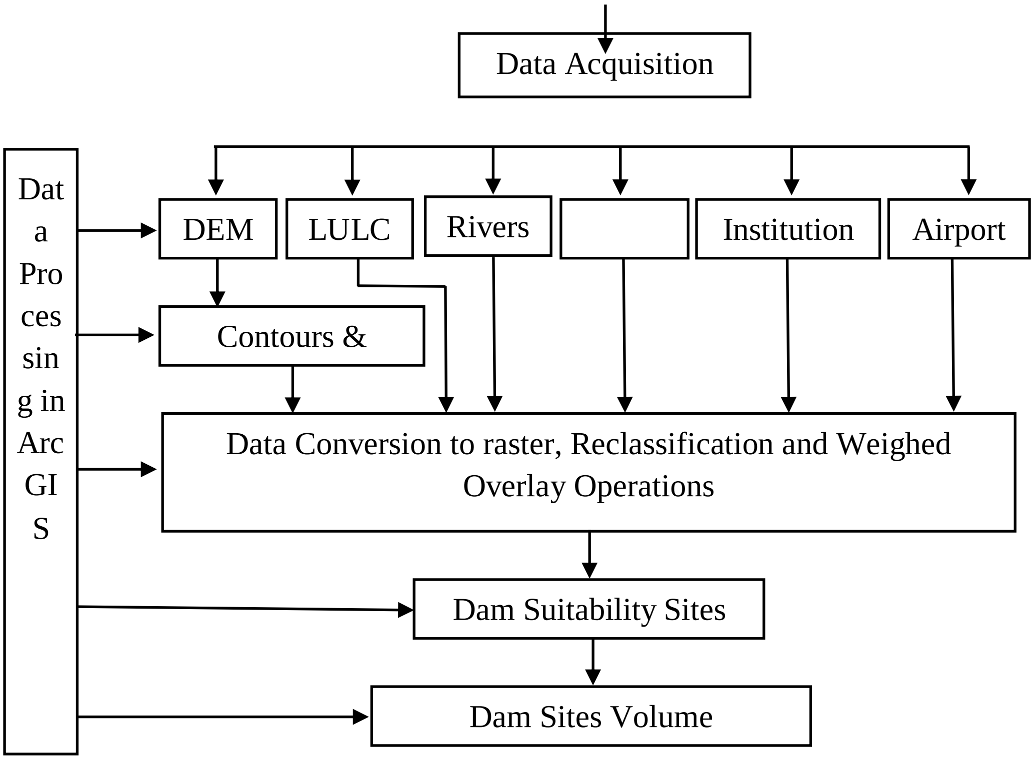


Fig 3. 3: Process chart showing activities involved in reservoir siting

3.7.3 Determinants of Stormwater Utilization

Binary logistic regression was performed on responses from households to determine the factors that influence utilization of stormwater, since stormwater utilization generated yes or no responses. This is presented in a regression equation.

Probability of Stormwater use = exponent(W)/1+exponent(W),

Where W = C + X_1*(AccessSW) + X_2*(Awareness) + X_3*(SWUnclean) + X_4*(OutdoorUses)---Equation 1

Where,

C is a constant

X_1, X_2, …are the coefficients in numerical values for each factor, and

(AccesstoSW) is access to harvested stormwater, (SWUnclean) is perception that stormwater is unclean, (Awareness) is awareness that stormwater is a source of water and (OutdoorUses) is domestic outdoor uses.

3.7.4 Challenges of Stormwater Management

Variables are analyzed using SPSS software to summarize the challenges of stormwater management as identified by households. In addition, the response from key respondent was incorporated. These are presented as tables and graphs.

3.8 Validity and Reliability

Louangrath & Sutanapong (2018) defined reliability as consistency in the result of the measurement and validity as the precision of the proposed scale, by having the instrument testing what it is required to test. Face validity was enhanced in the study by having each question addressing a specific issue, and segmenting the instrument according to objectives.

Construct validity was established by having an experienced team of experts and researchers to scrutinize the instruments of data collection to ensure that the tool is able to measure accurately the phenomenon being studied.

Criterion related validity was established by ensuring that all variables are included as informed by literature review. The entire process enabled the data collection instruments to be devoid of ambiguity, errors and omissions. Reliability on the other hand was enhanced by undertaking a pilot study to pre-test the data collection tool. Cronbach's alpha coefficient was then determined for the responses from pilot study using SPSS software, to test the internal consistency of data collection tool. Moser & Kalton (1985) noted that if $r>0.5$, then internal consistency of the tool is satisfactory.

A coefficient, r of 0.616 was achieved form the pilot study. Thus, it was concluded that the questionnaires were sufficiently consistent. Following further deliberations, a few changes were made on the tool to improve the original data collection tool.

3.9 Ethical Considerations

The researcher obtained a research permit from the National Commission for Science, Technology and Innovation (NACOSTI), so as to embark on data collection. In addition, permission was sought from the County of Uasin Gishu before collecting data from households and from the key informant (See Appendices VII and V111). The researcher sought informed consent from respondents and maintained privacy and confidentiality. The researcher avoided plagiarism by citing appropriately. Finally, the researcher observed honesty in collection and analysis of data and presentation of findings.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter presents results of analyzed data collected for the study within rural areas in Kapseret Sub County, Uasin Gishu, within the context of the following objectives; to determine per capita domestic water consumption in KSC: to estimate stormwater yield and map suitable areas for stormwater harvesting in KSC; to establish determinants of stormwater utilization in Kapseret Sub County; and to establish challenges facing stormwater management in KSC.

4.2 Per Capita Domestic Water Consumption.

To determine the per capita domestic water consumption, the following variables were considered in analysis; socio-economic characteristics of the households, domestic water uses, domestic water sources, methods of fetching, storing and purifying water, distance to main water source, safety of water sources and water shortage in the dry season. These were used to determine household domestic water consumption, and thereafter the per capita domestic water consumption was determined. In addition, this information was used to identify the factors that household domestic water consumption.

4.2.1 Socio-economic Characteristics Households

To describe the socio-economic characteristics of households in the study area, the variables that were analyzed include home ownership type, main housing type, income, level of education, household size and land size.

a) Home Ownership Type

A vast majority of households owned the homes they live in (92.8%), while 5.4% rented the houses. Only 1.7% of the residents were workers or caretakers in farms. Table 4.1 shows the home ownership types in KSC.

Table 4.1: Home ownership types in rural areas of KSC

S/No.	Home ownership type	Frequency	Percentage
1.	Owned	375	92.8
2.	Rented	22	5.5
3.	Caretaker/Farm worker	7	1.7
4.	Total	404	100.0

b) Housing Type

The majority of residents (50.3%) lived in temporary houses made of mud or polythene while 38.6% lived in permanent structures. Permanent houses include those made using construction stones, blocks and bricks. Only 11.1% live in semi-permanent houses made of iron sheets or wood as shown in Table 4.2.

Table 4.2: Main housing type in rural areas of KSC

S/No.	Main housing type	Frequency	Percentage
1.	Permanent	156	38.6
2.	Semi-permanent	45	11.1
3.	Temporary	203	50.3
4.	Total	404	100.0

An assessment of construction materials of the houses for the floors, walls and roofs was done. The construction materials varied from one house to another.

i. Main Construction Material for Floor

Majority of the houses (46.5%) in the study area had plastered floors, while 37.9% had mud floors. Only 15.3% had tiled floors with only 1 house (0.2%) having a wooden floor. Table 4.3 shows the main construction materials for floors.

Table 4.3: Main construction material for floors in rural areas of KSC

S/No.	Main construction material for floor	Frequency	Percentage
1.	Concrete/plaster	188	46.5
2.	Mud/earth	153	37.9
3.	Tiles	62	15.3
4.	Wood	1	0.3
5.	Total	404	100.0

ii. Main Construction Material for Wall

The houses in the study area were made from a variety of materials for the walls including construction stones, blocks, bricks, iron sheets, mud, polythene and wood. Majority of the houses (50%) had mud walls, 21% are made of blocks/construction stones, 17.6% were made of bricks while 10.4% are made of iron sheets. Only 0.7% and 0.2% of the houses had wooden and polythene walls respectively. This can be seen in Table 4.4.

Table 4.4: Main wall construction material for houses in rural areas of KSC

S/No.	Main construction material for wall	Frequency	Percentage
1.	Blocks/stones	85	21
2.	Bricks	71	17.6
3.	Iron sheets	42	10.4
4.	Mud/earth	202	50.0
5.	Polythene	1	0.3
6.	Wood	3	0.7
	Total	404	100.0

ii. Main Construction Material for Roof

Most of the houses (96.8%) of the houses were roofed using iron sheets while 1.5% of the houses were roofed using grass and tiles each. Another 1.5% were grass thatched while only 0.2% had a polythene roof. This is shown in Table 4.5.

Table 4.5: Main roofing materials in rural areas of KSC

S/No.	Main roofing material	Frequency	Percentage
1.	Grass	6	1.5
2.	Iron sheets	391	96.8
3.	Polythene	1	0.2
4.	Tiles	6	1.5
5.	Total	404	100.0

c) Level of Education

Majority of the household heads (45%) had attained upto secondary education, 5.4% had no schooling, 19.8% had not gone beyond primary school, 19.6% had graduated from college, 9.9% had university degree and only 0.2% had post graduate qualification, as shown in Table 4.6.

Table 4.6: Level of education of household heads

S/No.	Highest level of education of household head	Frequency	Percentage
1.	Unschooled	22	5.4
2.	Primary	80	19.8
3.	Secondary	182	45.0
4.	College	79	19.6
5.	Graduate	40	9.9
6.	Post graduate	1	0.2
	Total	404	100.0

d) Income

The average income for household head was 21,470.30. However, this income ranges from 0 shillings to 200,000 shillings. A small percentage of the household heads (6.4%), had no income at all, while majority of the household heads (64.6%) had an income of ksh1-ksh 20,000. 15.6% earned between ksh 20001 and ksh 40000, while 6.4% earned between ksh 40001 and ksh 60000. Only 6.9% earned more than ksh 60000 in a month as shown in Figure 4.1.

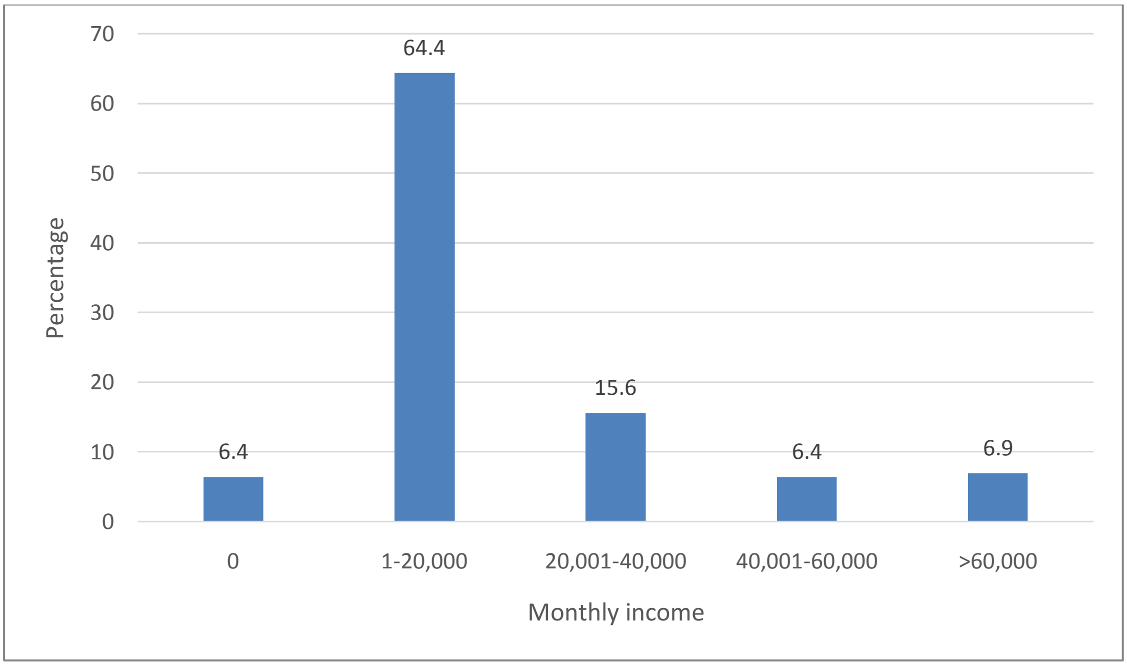


Fig 4.1: Income categories of household heads in KSC

e) Household Size

The average household size in KSC was found to be 4.05 persons. The smallest family had one member while the largest family had 11 members. That means that on average, a household in the study area had a moderately sized family of 4 members.

f) Household Land Size and Land Uses

The average land size in KSC was 3.03 acres, ranging from 0 to 84 acres. This means that the average acreage for a household in the study area within the sample was about 3 acres. However, some had no land, particularly those living in rented houses, others owned plots of 0.1 acre or 0.25 acre, while others owned large farms, up to 84 acres. The land was put under various uses including cultivation, grazing, settlement, roads and woodlots. The largest portion of land (40%) was under cultivation, 22% was used for grazing, while 18% was under woodlots. 11% of the land was bare, 7% was under settlement, while 2% of the land was covered by water bodies. With regard to prevalence of land uses, majority of households (77.7%) engaged in cultivation, 50.3% of the households maintained grazing fields, while 15.8% maintained woodlots. Only 9.7% and 0.25% of the households had bare land water bodies respectively. Table 4.7 shows the acreage under the various land use categories and prevalence of land uses among households.

Table 4.7: Average acreage and prevalence of various land uses among households

S/No.	Land use	Average Acreage in Acres	Percentage Acreage	Percentage of households with particular land use
1.	Cultivation	2.2	40	77.7
2.	Grazing land	1.2	22	50.3
3.	Settlement	0.4	7	100.0
4.	Woodlots	1.0	18	15.8
5.	Bare land	0.6	11	9.7
6.	Water bodies	0.1	2	0.25

4.2.2 Domestic Water Sources

There are multiple water sources in Kapseret Sub-County including shallow wells, harvested rain water, river, stream, borehole, metered piped water, unmetered piped water, dams and springs. Some households had access to multiple sources of water, especially in the rainy season where they would additionally use rain water. Majority of the households (92.8%) had access to a shallow well, while dams and springs were accessible to. This is presented in Figure 4.2.

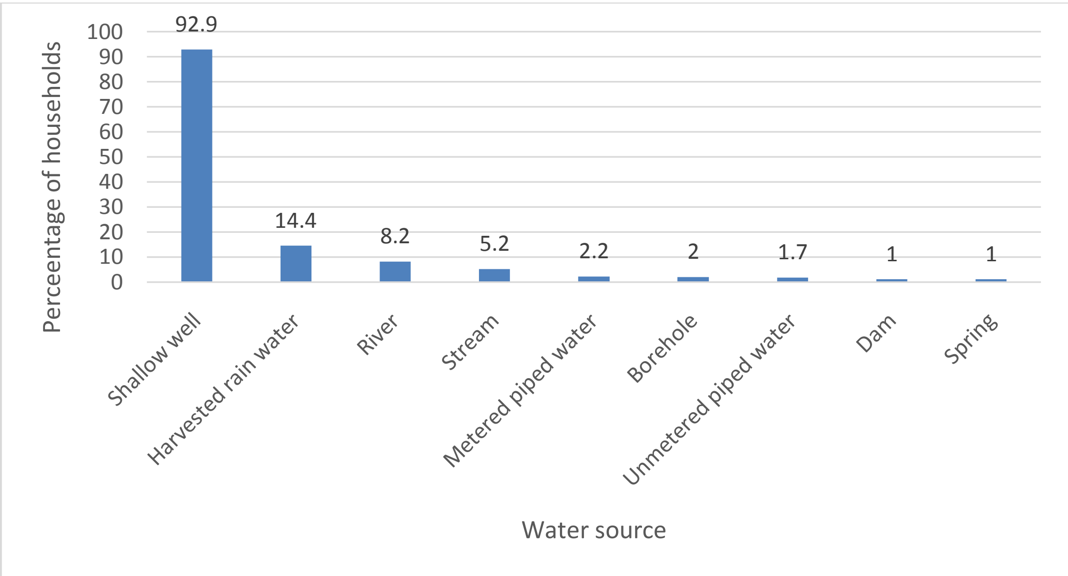


Fig 4.2: Water sources accessible to households in KSC

a) Main Water Source in the Dry Season

The main source of water for a majority of households in the dry season was shallow well, which accounted for 82.4% of the respondents. Rivers were a source of water for 10.6% of the households, while metered and unmetered piped water supply 2% and 1.5% of the households respectively. Dams were a source of water for only 1% of the households. A small percentage of households accessed their water from borehole, harvested rain water and springs, each accounting for 0.5%. This can be seen in Table 4.8.

Table 4.8: Main source of water for domestic use in the dry season

S/No.	Main source of water in the dry season	Frequency	Percentage
1.	Shallow well	334	82.7
2.	River	43	10.6
3.	Metered piped water	8	2.0
4.	Unmetered piped water	6	1.5
5.	Dam	4	1.0
6.	Stream	3	0.7
7.	Borehole	2	0.5
8.	Harvested rain water	2	0.5
9.	Spring	2	0.5
	Total	404	100.0

b) Main Water Source in the Rainy Season

Majority of the households (74%) use water from shallow wells in the rainy season. 16.3% harvest and use rain water, 4.5% use water from the river, 1.7% access their water from the stream, 1.5% use metered piped water, 1% use unmetered piped water, 0.5% accessed water from boreholes while 0.2% access water from dams and springs each. The main water sources in the rainy season in KSC are indicated in Table 4.9.

Table 4.9: Main source of water in the rainy season

S/No.	Main source of water in the rainy season	Frequency	Percentage
1	Shallow well	299	74.0
2	Harvested rain water	66	16.3
3	River	18	4.5
4	Stream	7	1.7
5	Metered piped water	6	1.5
6	Unmetered piped water	4	1.0
7	Borehole	2	0.5
8	Dam	1	0.2
9	Spring	1	0.2
	Total	404	100

4.2.3 Safety of Domestic Water Sources

The use of water from protected or unprotected sources varied in the dry and rainy seasons. Protected sources include boreholes, metered piped water, rainwater collected in tanks, protected springs and covered shallow wells. Unprotected sources, on the other hand include dams, rivers, streams, unprotected springs and uncovered wells. In the rainy season, 36.6% of households used water from unprotected water sources including shallow wells, rain water collected in open containers, rivers, stream, dams and unprotected springs, as shown in Table 4.10.

Table 4.10: Level of access to protected water sources in the rainy seasons

S/No.	Main Water Source in the rainy Season	Is water source protected		Total
		No	Yes	
1.	Shallow well	98	201	299
2.	Harvested rain water	24	42	66
3.	River	18	0	18
4.	Stream	7	0	7
5.	Metered piped water	0	6	6
6.	Borehole	0	2	2
7.	Unmetered piped water	1	3	4
8.	Dam	0	1	1
9.	Spring	0	1	1
	Total	148	256	404
	Percentage	36.6	63.4	100

In the dry season, 41.1% of the households accessed water from unprotected sources including dams, shallow well, unprotected spring, unmetered tap and rivers. The level of access to protected water sources in the dry season is presented in Table 4.11.

Table 4.11: Level of access to protected water sources in the dry season

S/No.	Main Water Source in the Dry Season	Is water source protected		Total
		No	Yes	
1.	Borehole	0	2	2
2.	Dam/pan	4	0	4
3.	Harvested rain water	0	2	2
4.	Metered piped water	0	8	8
5.	River	43	0	43
6.	Shallow well	109	225	334
7.	Spring	1	1	2
8.	Unmetered piped water	6	0	6
	Total	166	238	404
	Percentage	41.1	58.9	100

Below are examples of protected and unprotected water sources in various parts of Kapseret sub-county.

i) Shallow wells

Protected shallow wells are those with a concrete cover constructed to cover them. An example is shown in Plate 4.1.

(Source: Author, 2022)

Plate 4.1: A protected shallow well in Lemook, KSC

An unprotected shallow well is an open, or not properly covered well, which is prone to contamination from runoff, effluents and objects that could fall into the well. An example is shown in Plate 4.2.

(Source: Author, 2022)

Plate 4.2: An unprotected shallow well in Simat, KSC.

i) Springs

A spring is an outlet of groundwater onto the surface. A spring could be unprotected, as can be seen in Plate 4.3.

(Source: Author, 2022)

Plate 4.3: An unprotected spring at Ngara Falls, KSC.

In other instances, springs could be protected so that residents fetch water directly from the spring as opposed to fetching water from a pool. An example of a protected spring is presented in Plate 4.4.

(Source: Author, 2022)

Plate 4.4: A protected spring in Kipkenyo, KSC.

ii) Rivers

During extreme dry weather conditions when shallow wells dry up, households fetch water from the rivers. In Plate 4.5, women can be seen cleaning clothes near the river while donkeys are used to transport water to homes. In addition, cattle drink water from the same source.

(Source: Author, 2022)

Plate 4.5: Various water uses along Kipkaren River, KSC.

4.2.4 Methods of Water Purification

To purify their drinking water, most households either boil or treat, or apply both strategies at home. Many households (89.6%), boil their drinking water while 20.2% apply chemicals on the water. Only 1.2% have access to treated water from ELDOWAS, while 2% buy bottled water, as shown in Figure 4.3.

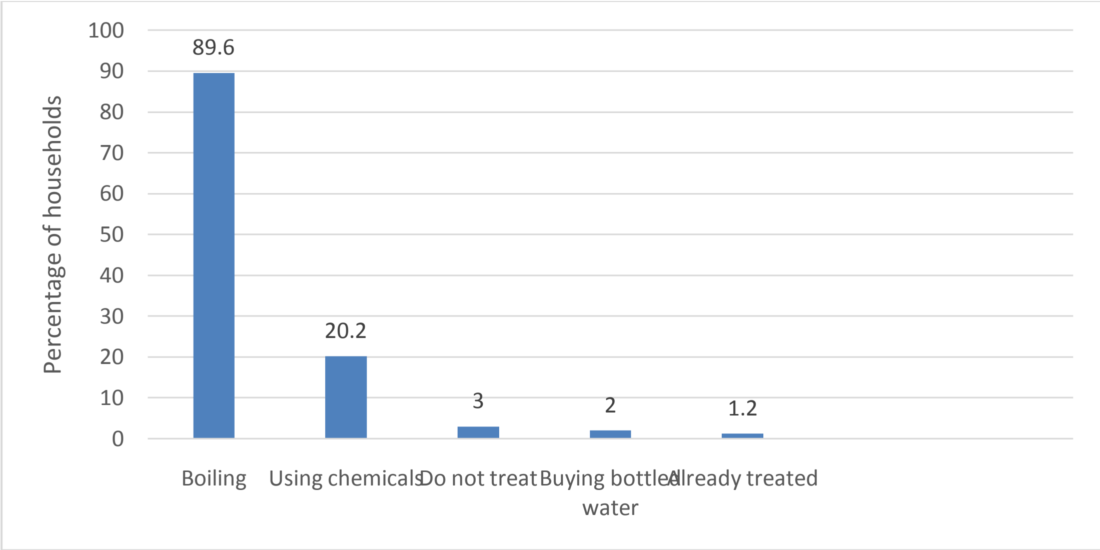


Fig 4.3: Household water purification options

4.2.5 Distance to Main Water Source

Distance from the main water source varied in the dry and rainy seasons. The average distance to the main water source increased from an average of 22 meters in the rainy season to an average of 216 in the dry season. The longest distance in the dry season is 2000m compared to 200m in the rainy season. This is because of seasonal water shortage. During the dry season, almost half of the population (44.8%) experience water shortage. This can be seen in Figure 4.4.

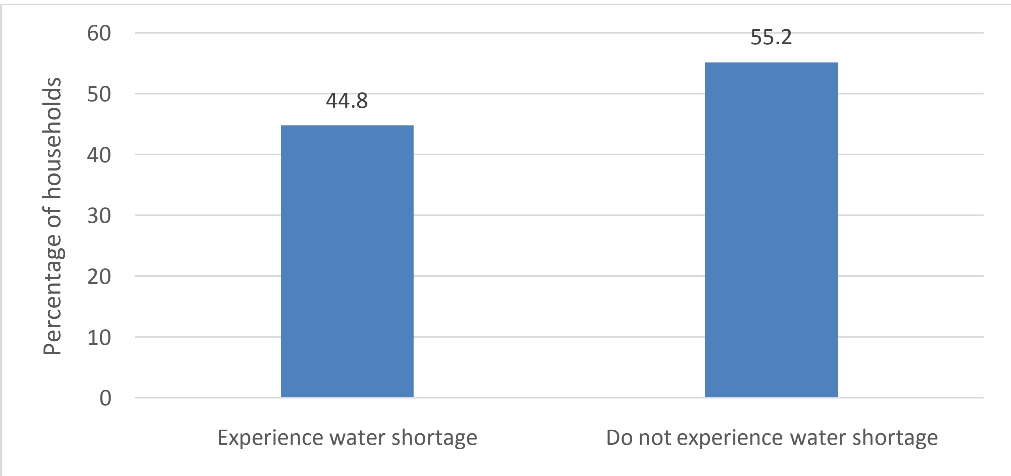


Fig 4.4: Percentage of households that experience water shortage in the dry season

As a result of the water shortage experienced in the dry season, households conserved water in various ways. Water reuse was practiced by 41.3% of the respondents while 37.9% avoided cleaning the floors of their houses daily. Another 29% cleaned clothes occasionally, 28.9% used minimum amount of water possible for various activities, 24.8% watered animals at the water point, for instance river, while 29.7% washed clothes at the water point. This can be seen in Figure 4.5.

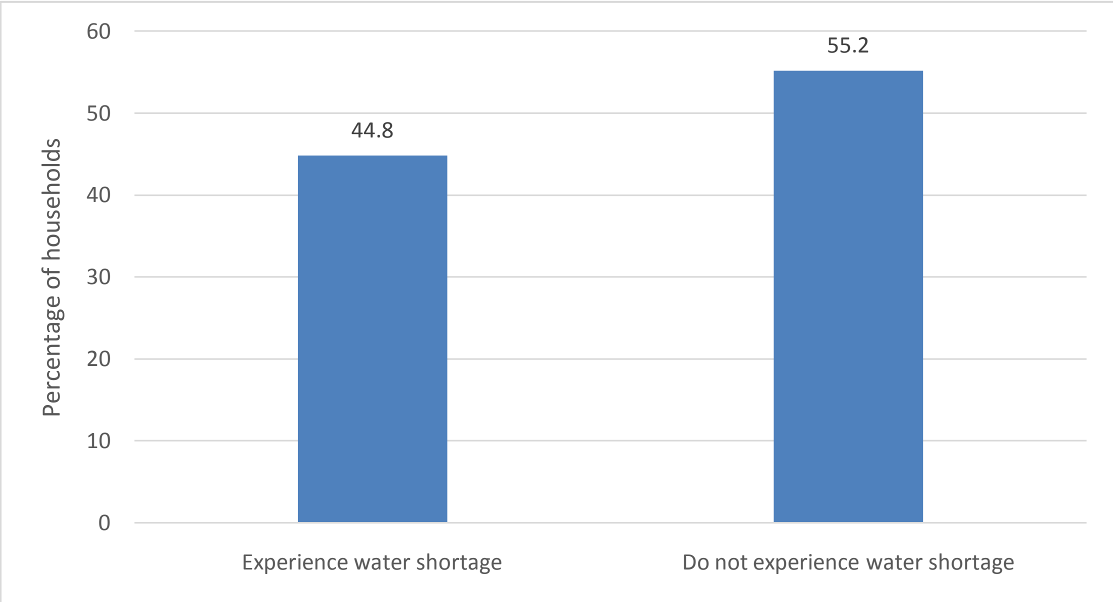


Fig 4.5: Water conservation strategies in KSC

4.2.6 Domestic Water Collection and Storage

Water is fetched in various ways in KSC. Majority of the households (63.6%) fetch water from shallow wells manually using a rope and container from the water source, while 27.5% pump water to a tank using electricity. Only 3.9% fetch water using a pulley and 2% use a hand pump, and 3% have piped water, as presented in Figure 4.6.

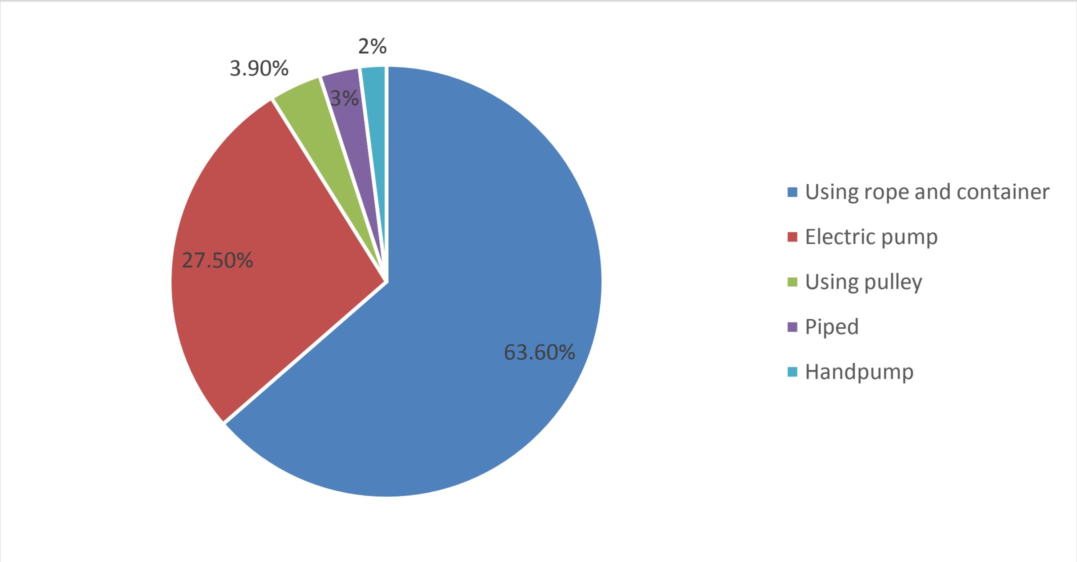


Fig 4.6: Methods of fetching water in KSC

Majority of the households (71.3%) fetch and store water in 10 or 20 liter jerricans, while only 28.7% store their water in tanks as shown in Table 4.12.

Table 4.12: Domestic water storage facilities

S/No.	Type of storage	Frequency	Percentage
1.	10/20 liter jerricans	288	71.3
2.	Tank/s	116	28.7

There are two main types of tanks in the study area including plastic and concrete tanks. The plastic tanks could be elevated or placed on the ground. Some households had more than one tanks. 28.7% of the households had elevated plastic tanks while 2.2% had plastic tanks placed on the ground. Only 1% of the households had concrete tanks. Table 4.13 shows the type of tanks in KSC.

Table 4.13: Type of tanks in the study area

S/No.	Type of tank	Frequency	Percentage
1.	Elevated plastic tank	108	26.7
2.	Plastic tank on the ground	9	2.2
3.	Concrete tank	4	1.0

The average capacity of tanks was 3184.70 liters, ranging from a minimum capacity of 100 liters to a maximum capacity of 10000 liters. Some families had multiple tanks to cushion their families from acute water shortages in the dry season. There was a positive moderate correlation, r=0.487 between tank ownership and monthly income level, and a correlation of r=0.523 between tank ownership and main housing type. This is presented in Table 4.14.

Table 4.14: Correlation between tank ownership, income and housing type

Variable		Ownership of a tank	Monthly income	Main housing type
Ownership of a tank	Pearson Correlation	1	0.487	0.523
Monthly income	Pearson Correlation	0.487	1	0.475
Main housing type	Pearson Correlation	0.523	0.475	

N=404

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

4.2.7 Household Water Uses

It was established that domestic water uses in rural areas of KSC varied and included drinking, cooking, bathing, toilet flashing, cleaning house, cleaning utensils, irrigating potted plants and lawns, washing of bicycles, motorcycles and cars, and watering animals including poultry, sheep, goats, pigs, cattle. The uses varied across the dry and rainy seasons.

a) Drinking and Cooking Uses

All households used water for cooking and drinking in their homes. A comparison was made for this water use in the dry and rainy seasons. The result indicates that for cooking and drinking, households used an average of 25.5 liters in the dry season and 29.7 liters in the rainy season. This is presented in Table 4.15.

Table 4.15: Average amount of water used for cooking and drinking in a household in a day

Season	Average amount of water used per household in liters	N	Percentage
Dry season	25.5	404	100
Rainy season	29.7	404	100

b) Cleaning of Utensils

Majority of the respondents, (99.8%) used water to clean utensils in their homes. The amount of water used for cleaning utensils varied with seasons. In the dry season, households used an average of 26.3 liters compared to 29.4 liters in the rainy season. This is shown in Table 4.16.

Table 4.16: Average amount of water used to clean utensils in a household in a day

Season	Average amount of water used per household in liters	N	Percentage
Dry season	26.3	403	99.8
Rainy season	29.4	403	99.8

c) Bathing

All households (100%), use water for personal hygiene in the rainy season. However, in the dry season, 0.5% of the respondents did not use water for bathing. In addition, it was observed that the amount of water used in the dry season for bathing was lower in the dry season compared to the amount used in the rainy season. The average amount of water used for personal hygiene in the dry and rainy seasons was 48.7 liters and 52.9 liters respectively. This can be seen in Table 0.17.

Table 4.17: Average amount of water used for bathing in a household in a day

Season	Average amount of water used per household in liters	N	Percentage
Dry season	48.7	402	99.5
Rainy season	52.9	404	100

d) House Cleaning

More households used water to clean their houses in the rainy season (84.9%) compared to those in the dry season (84.2%). The amount of water used for this purpose was higher in the rainy season (16.4 liters) compared to 13.8 liters used in the dry season. This can be seen in Table 4.18.

Table 4.18: Average amount of water used for house cleaning in a household in a day

Season	Average amount of water used per household in liters	N	Percentage
Dry season	13.8	340	84.2
Rainy season	16.4	343	84.9

e) Laundry

All households used domestic water to clean their clothes. However, frequency of cleaning laundry varied from one household to another across seasons. In the dry season, 47.8% of the households cleaned laundry daily using an average of 38.4 liters compared to 52.2% who cleaned their laundry occasionally, using an average of 26.8 liters. In the rainy season, 55.2% of the households clean their laundry daily using an average of 41.8 liters while 44.8% cleaned their laundry occasionally using an average of 32 liters. The findings are as presented in Table 0.19.

Table 4.19: Average amount of water used for laundry in a household in a day

Season	Average amount of water used per household in liters	N	Percentage
Dry season- daily laundry	38.4	193	47.8
Rainy Season-daily laundry	41.8	223	55.2
Dry season-occasional laundry	26.8	211	52.2
Rainy season-occasional laundry	32.0	181	44.8
Dry season(Average)	32.7	404	100.0
Rainy season(Average)	37.5	404	100.0

f) Flushing toilets

Only 12.6% of the population used water to flush toilets in the dry season compared to 14.4% in the rainy season. The amount of water used to flush toilets was higher in the rainy season (5.6 liters), compared to 4.5 liters used in the dry season. This is shown in Table 4.20.

Table 4. 20: Average amount of water used for flushing toilets in a household in a day

Season	Average amount of water used per household in liters	N	Percentage
Dry season	4.5	50	12.4
Rainy season	5.6	57	14.1

g) Outdoor uses

These are household water uses outside the domestic category. They include lawn irrigation and irrigation of potted plants, watering poultry and animals, and cleaning cars and bikes.

i) Potted plants and lawn irrigation

A few households use water for watering potted plants and lawn irrigation. This was represented by 9.2% in the dry season and 4% in the rainy season. In addition, more water was used in irrigating lawns and potted plants in the dry season (13.4 liters), compared to an average of 4.1 liters in the rainy season. This is shown in Table 4.21.

Table 4. 21: Average amount of water used for potted plants and lawn irrigation in a household in a day

Season	Average amount of water used per household in liters	N	Percentage
Dry season	13.4	37	9.2
Rainy season	4.1	16	4.0

ii) Watering animals

The number of animals and birds kept varied from one household to another. This directly influenced the amount of water used by these domestic animals. On average, a household had 7 chicken, 4 cows and/or donkeys and 5 sheep and/or goats. The amount of water used per household for watering animals increased significantly in the dry season compared to the rainy season. Majority of the respondents (64.9%) kept cows, 43.8% kept sheep and/or goats while 43.3% kept poultry. In the dry season, household used an average of 2.4 liters for poultry, 64.1 liters for cattle and 9.6 liters for sheep. In the rainy season, the average amount is generally lower, with poultry consuming 2.5 liters, 52.1 liters for cattle and 9.2 liters for sheep. The findings are presented in Table 4.22.

Table 4. 22: Average amount of water used for watering animals in a household in a day

Season	Animal	Average number of animals kept	Mean in liters	Number of households	Percentage
Dry season	Poultry	7.3	2.4	175	43.3
Rainy season	Poultry	7.3	2.5	175	43.3
Dry season	Cows and donkeys	4.0	64.1	262	64.9
Rainy season	Cows and donkeys	4.0	52.1	262	64.9
Dry season	Sheep and goats	5.1	9.6	177	43.8
Rainy season	Sheep and goats	5.1	9.2	177	43.8

4.2.8 Household Domestic Water Consumption

The household domestic water consumption pattern was determined as an aggregate of water used in individual domestic water uses. This includes cooking and drinking, cleaning utensils, bathing, cleaning house, laundry, and flushing toilets. Other non-domestic home uses included lawn irrigation and potted plants, and watering animals including poultry, sheep and goats, pigs, cattle and donkeys. This was done for both the dry and rainy seasons. Amount of water used in various activities varied with seasons. Amount of water used for cooking and drinking, cleaning utensils, bathing, house cleaning, laundry, flushing toilets, poultry and washing cars or motorbikes was lower in the dry season compared to the rainy seasons. On the other hand, the average amount of water used for watering cattle and sheep and irrigating lawns and potted plants was significantly higher in the dry season. These water uses can be categorized as indoor or outdoor, with indoor uses involving water use types that are specifically meet human needs. Indoor water uses include for cooking and drinking, cleaning utensils, bathing, house cleaning, laundry and flushing toilets. On the other hand, outdoor uses include activities such as watering animals, washing bicycles, motorbikes, cars, irrigating lawns and potted plants. The average household domestic water consumption was found to be 149 liters and 168.8 liters in the dry and rainy seasons respectively. This is can be seen in Table 4.23.

Table 4. 23: Average amount of water consumed for the various activities in a household in a day

Category of Water Uses	S/No.	Water Use Activity	Quantity Consumed in Liters-Dry Season	Quantity Consumed in Liters-Rainy Season
A. Domestic	1.	Cooking and drinking	25.5	29.7
	2.	Cleaning utensils	26.3	29.3
	3.	Bathing	48.5	52.7
	4.	House cleaning	11.6	14
	5.	Laundry-Average	32.6	37.5
	6.	Flushable toilets	4.5	5.6
		TOTAL	**149**	**168.8**
B. Other Uses	1.	Poultry	2.5	2.4
	2.	Cattle/donkey	64.1	52.1
	3.	Sheep/goats/pigs	9.6	9.2
	4.	Washing cars/motorbikes	2.2	2.6
	5.	Potted plants/lawn irrigation	13.4	4.1
		TOTAL	**91.8**	**70.4**

4.2.9 Determining Per Capita Domestic Water Consumption

Per capita domestic water consumption was determined for each of the 404 households given the household size. The average per capita water consumption in the dry and rainy seasons was computed as 41 liters and 48 liters respectively. This is shown in Table 4.24.

Table 4.24: Per capita water consumption

Category of Water Uses	S/No.	Water Use Activity	Water Consumption in Liters-Dry Season	Water Consumption in Liters-Rainy Season
A. Domestic	1.	Cooking and	7	8
	2.	Cleaning utensils	8	9
	3.	Bathing	13	14
	4.	House cleaning	3	4
	5.	Laundry-Average	9	11
	6.	Flushable toilets	1	2
		TOTAL	**41**	**48**
B. Other Uses	1.	Poultry	1	1
	2.	Cattle/donkey	20	15
	3.	Sheep/goats/pigs	3	3
	4.	Washing cars/motorbikes	1	1
	5.	Potted plants/lawn irrigation	5	1
		TOTAL	**30**	**21**

4.2.10 Factors Influencing Household Domestic Water Consumption

Linear regression was used to identify independent factors that influence household domestic water consumption and per capita domestic water consumption. In linear regression, a significance level of <0.05 implies that an independent variable influences a dependent variable.

Informed by literature review, the independent variables that were assessed included; main housing type (temporary, semi-permanent or permanent), home ownership type (owned, rented or other), land size, household size, level of education of household head, household income, distance to water source, water source, and outdoor water uses.

Linear regression function was performed to identify the factors that influence household domestic water consumption in dry and rainy seasons. The following factors were found to influence household domestic water consumption in the rainy season; main housing type, household size, level of education of household head, income of household head, distance to water source and capacity of water tank. This is because they had a significance of <0.05. Table 4.25 presents results from linear regression associating household domestic water consumption with several independent variables in the rainy season.

Table 4.25: Factors influencing household domestic water consumption in the rainy season

Coefficients					
	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	145.287	23.253		6.248	.000
Main housing type	-38.509	8.038	.360	4.791	.000
Household size	8.398	2.707	.223	3.102	.002
Education Level	17.425	5.014	.267	3.476	.001
Income of household head	.081	.016	.404	5.024	.000
Capacity of tank in liters	.008	.002	.360	4.528	.000

The R^2 for the model is 0.621 with a standard error of 15.85. this implies that the predictor variables in the model account for 62.1% of the household domestic water consumption in the rainy season, as shown in summary Table 4.26.

Table 4.26: Linear regression model summary for domestic water consumption in the rainy season

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.791	.625	.621	15.85820

In the dry season, the following factors with a significance of <0.05 were found to influence household domestic water consumption; main housing type, household size, income and distance to main water source. Table 4.27 presents results from linear regression associating household domestic water consumption with an array of independent variables in the dry season.

Table 4.27: Factors influencing household domestic water consumption in the dry season

Coefficients					
Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	138.351	28.192		4.907	.000
Main housing type	-41.720	12.756	.186	3.271	.001
Household size	12.798	4.391	.162	2.915	.004
Distance to main water source	-.013	.003	-.300	-5.093	.000
Income of household head	.394	.029	.787	13.375	.000

The model has an R^2 of 0.647. This implies that the predictor variables in the model account for 64.7% of the household domestic water consumption in KSC in the dry season. The model summary is presented in Table 4.28.

Table 4.28: Regression model summary for domestic water consumption in dry seasons and selected independent variables.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.812[a]	.659	.647	26.44564

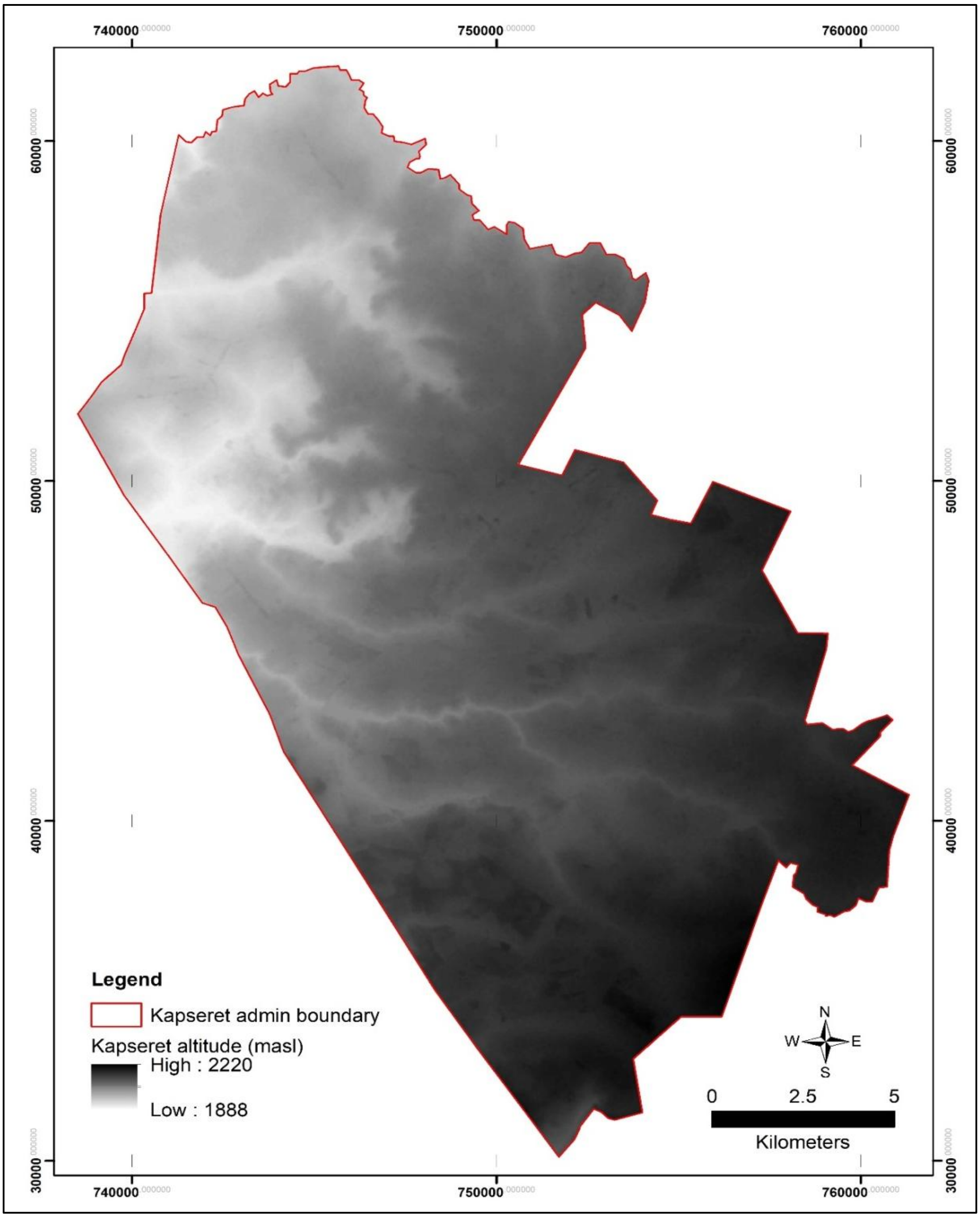
4.3 Assessing the Potential of Stormwater

To determine stormwater yield in KSC, the following was data was used in SWAT;

i. DEM and slope of KSC.
ii. Climate parameters- rainfall and temperature data of KSC.
iii. LULC map of KSC
iv. Soil map of KSC

4.3.1 Digital Elevation Model (DEM)

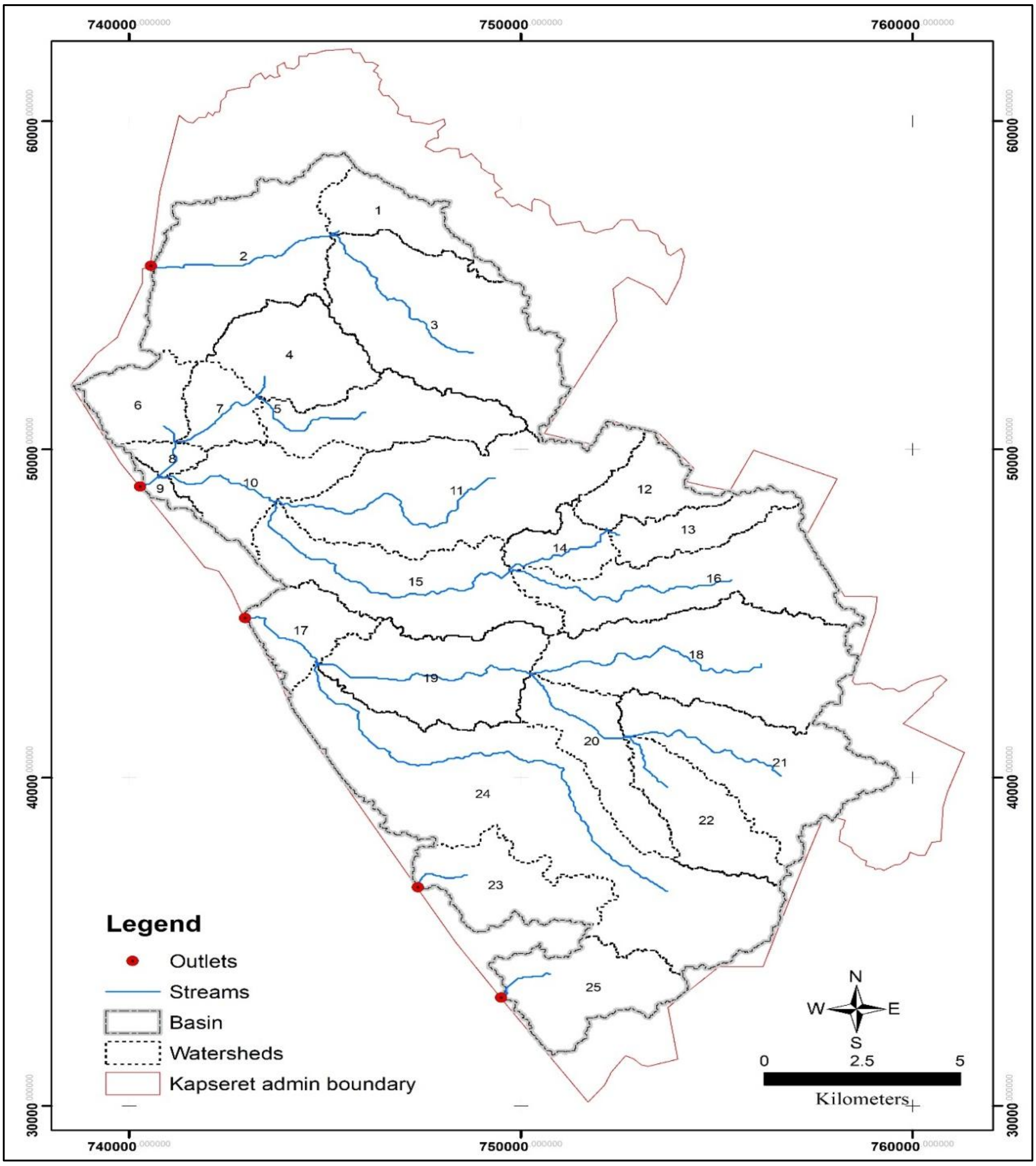
From a larger catchment area, the basin within the study area was identified, and basin boundary generated from DEM. This is presented in Figure 4.7.



(Source: Author, 2022)

Fig 4. 7: DEM of Kapseret Sub-County

From the DEM, a total of 25 watersheds were delineated from SWAT. Figure 4.8 is a presentation of the administrative and basin boundaries, stream network, 25 watersheds and 5 outlets.



(Source: Author, 2022)

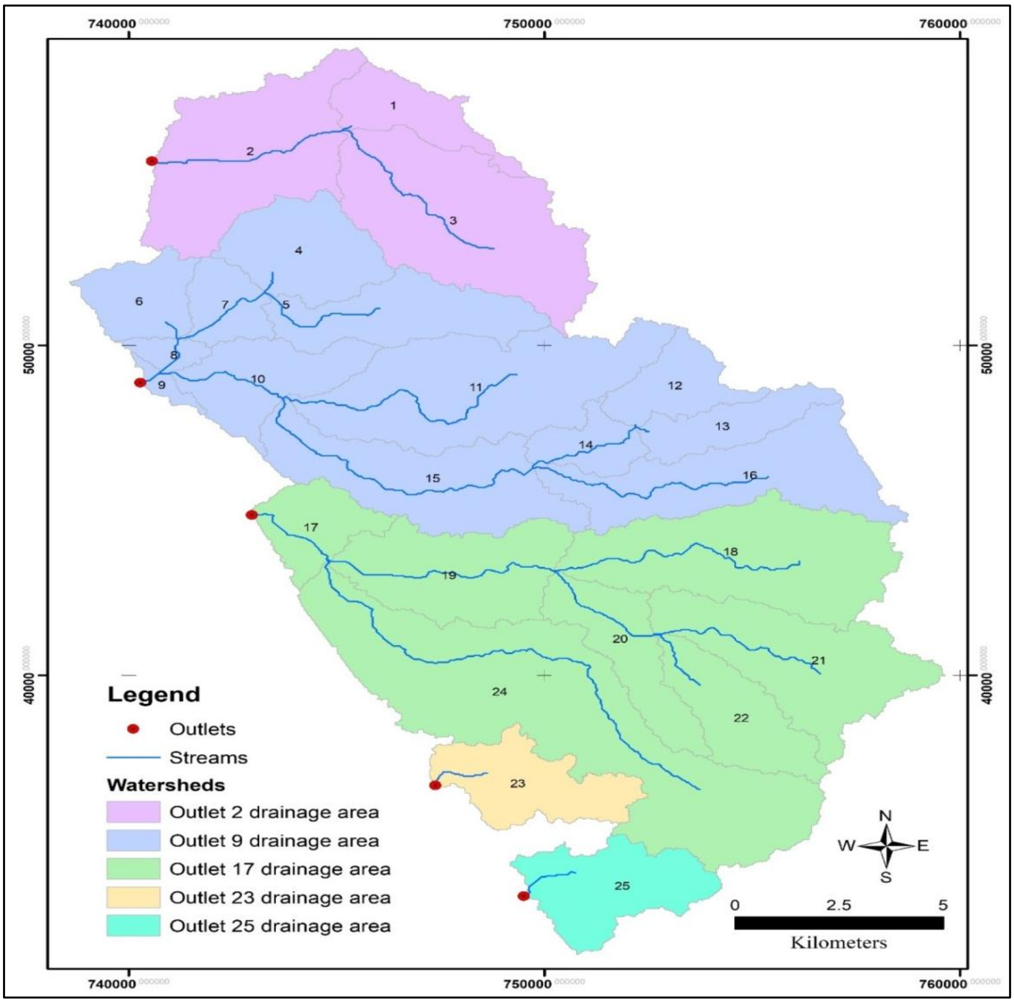
Fig 4. 8: Kapseret Sub-County administrative boundary, boundaries of basin, watersheds (sub-basins), stream network and the outlets

The size of each sub-basin was determined, and the outlets, highlighted in blue, were mapped. Outlets are the points from which stormwater exit the basin. The entire basin occupies an area of 283.818 km^2. Table 4.29 indicates the size of each sub-basin.

Table 4.29: List of extracted sub-basins and outlets

Sub-basin No.	Sub-basin ID	Area in sq.km
1	100001	5.8704
2	100001	18.5934
3	100002	21.9061
4	100004	9.5140
5	100005	10.0369
6	100006	5.6660
7	100007	4.1836
8	100008	1.5175
9	100010	0.9252
10	100009	8.4281
11	100011	21.6922
12	100013	5.3674
13	100014	5.2952
14	100015	3.9003
15	100012	15.6297
16	100016	15.4956
17	100017	5.7335
18	100020	20.4646
19	100018	13.2165
20	100021	8.2123
21	100022	15.8113
22	100023	8.4937
23	100024	8.9226
24	100019	39.1170
25	100025	9.8249
TOTAL		283.818

The five outlets from 5 sub-catchments located in sub-basins 2, 3, 17,23 and 25 are assigned identification codes (IDs) used in SWAT model. The IDs are 100003, 100010, 100017, 100024 and 100025. The 5 sub-catchments, each draining through a specified outlet, are shown in Figure 4.9.



(Source: Author, 2022)

Fig 4.9: The sub-catchments in Kapseret basin

The area under each sub-catchment was determined. The largest sub-catchment drains through outlet ID 100017 covering about 111km^2, while the smallest sub-catchment drains through outlet ID 100024 and covers 8.9km^2, as shown in Table 4.30.

Table 4.30: Areas drained by each of the 5 outlets

Sub basin ID	Outlet ID	Sub-basins drained	Area drained (km^2)
2	100003	1,2 and 3	46.3699
9	100010	4,5,6,7,8,9,10,11,12,13,14,15 and 16	107.6517
17	100017	17,18,19,20,21,22 and 24	111.0489
23	100024	23	8.9226
25	100025	25	9.8249

4.3.2 Rainfall Data

Rainfall amount in the study area is moderately high. The rainfall amount in 2019 was 1659.3 mm, and the mean for 10 years (2010-2019) was 1526mm (Appendix IX). The mean for 35 years was 1312.4mm (Appendix VIII). From the data, it is apparent that the rain is not evenly distributed throughout the year, but is concentrated between the months of April and September as can be seen in the line graph below. Figure 4.10 is a line graph shows monthly rainfall variation in 2019 and 10-year average from 2010-2019.

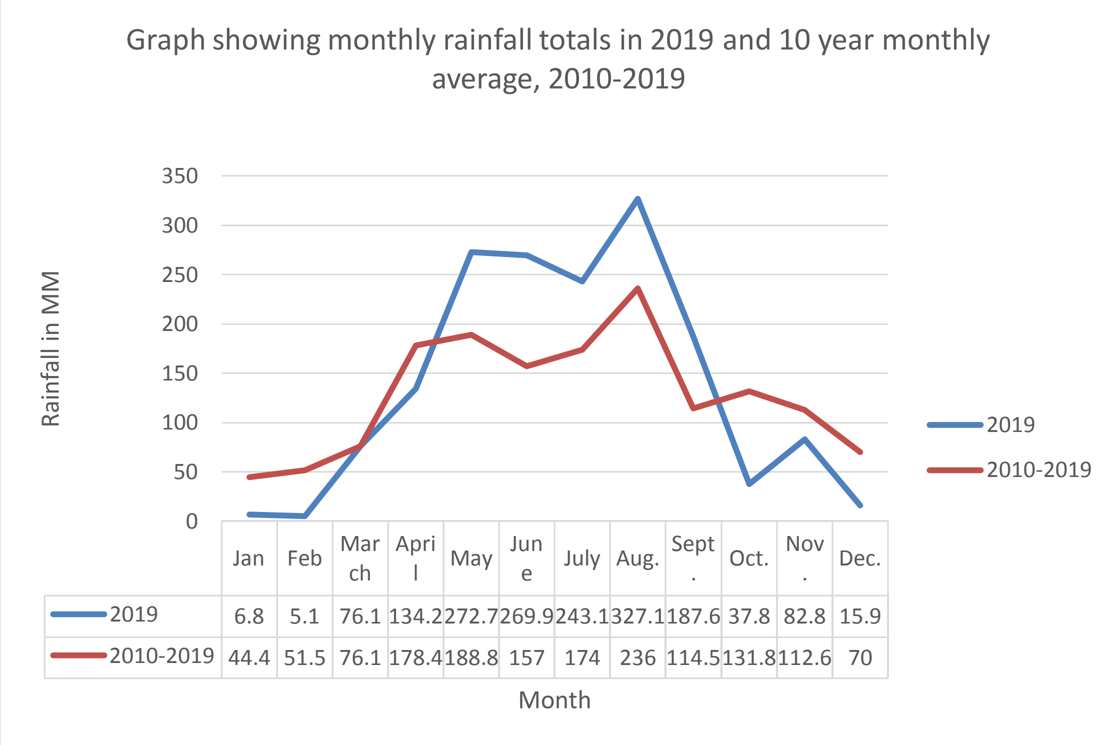
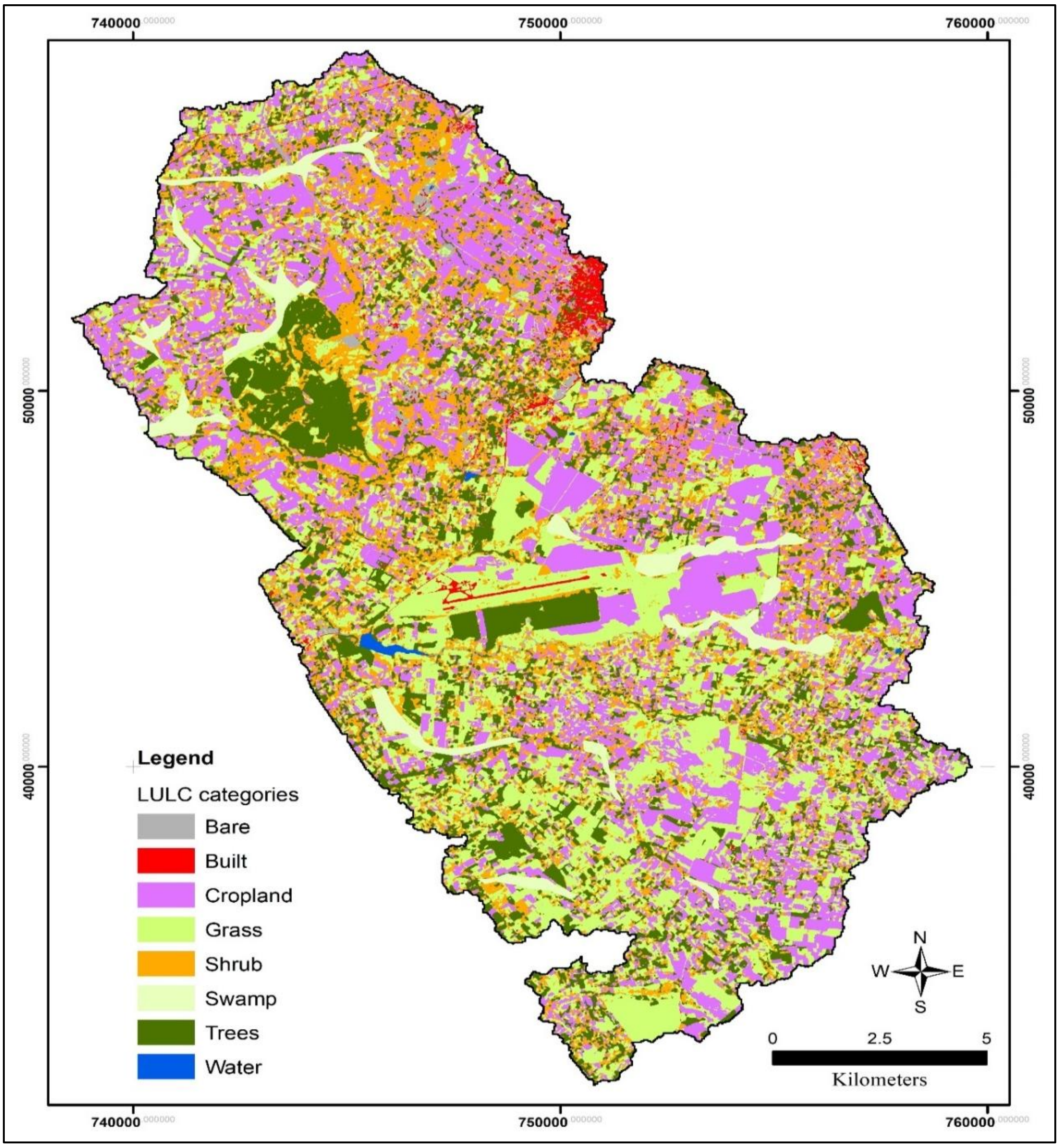


Fig 4.10: Monthly rainfall amount in KSC in 2019 and 10 year average, 2010-2019

4.3.3 LULC

A LULC downloaded satellite data imagery was captured on 3rd August 2019. Satellite imagery processing and analysis was then done using ArcGIS. Using the basin boundary, a true color image was generated and supervised classification conducted. A total of 8 training signatures were developed which correspond to each identified LULC including trees, shrub, grass, cropland, built, bare, water and swamp. This is presented in Figure 4.11.



(Source: Author, 2022)

Fig 4.11: LULC classified map of Kapseret Sub-County

The LULC classification resulted in classes with different sizes. Cropland occupies the largest area (82.8 km^2) while water bodies occupy the smallest area at 0.141 km^2. Figure 4.12 is a presentation of the area under each LULC in km^2.

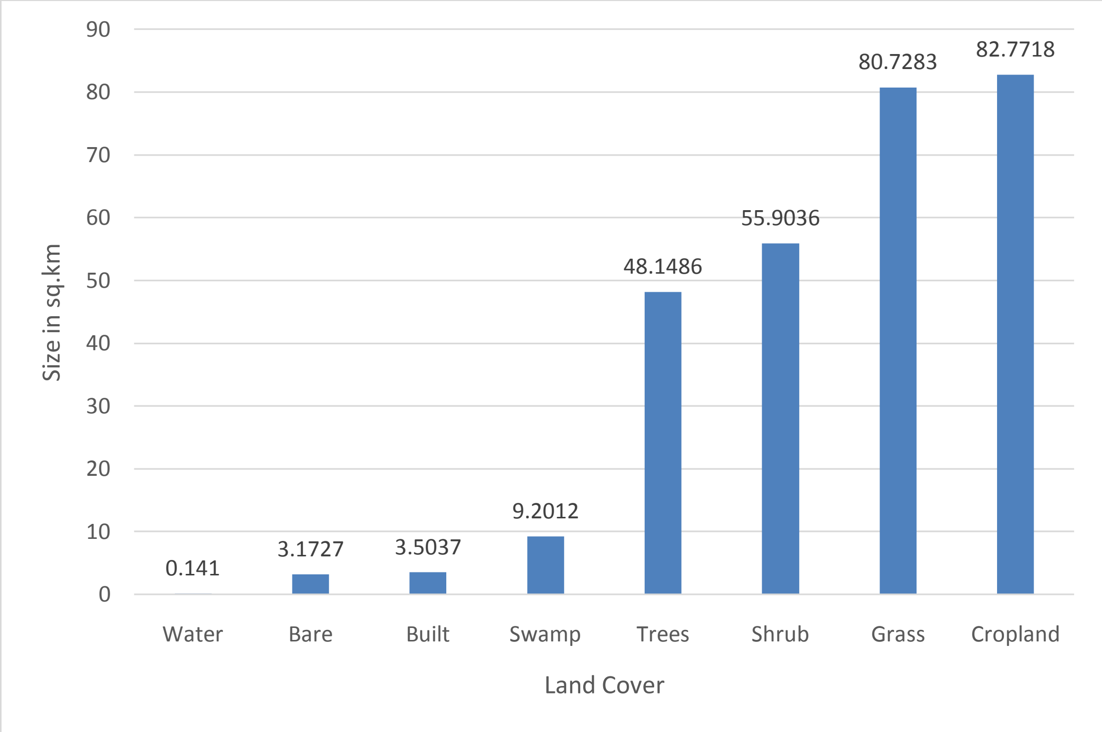
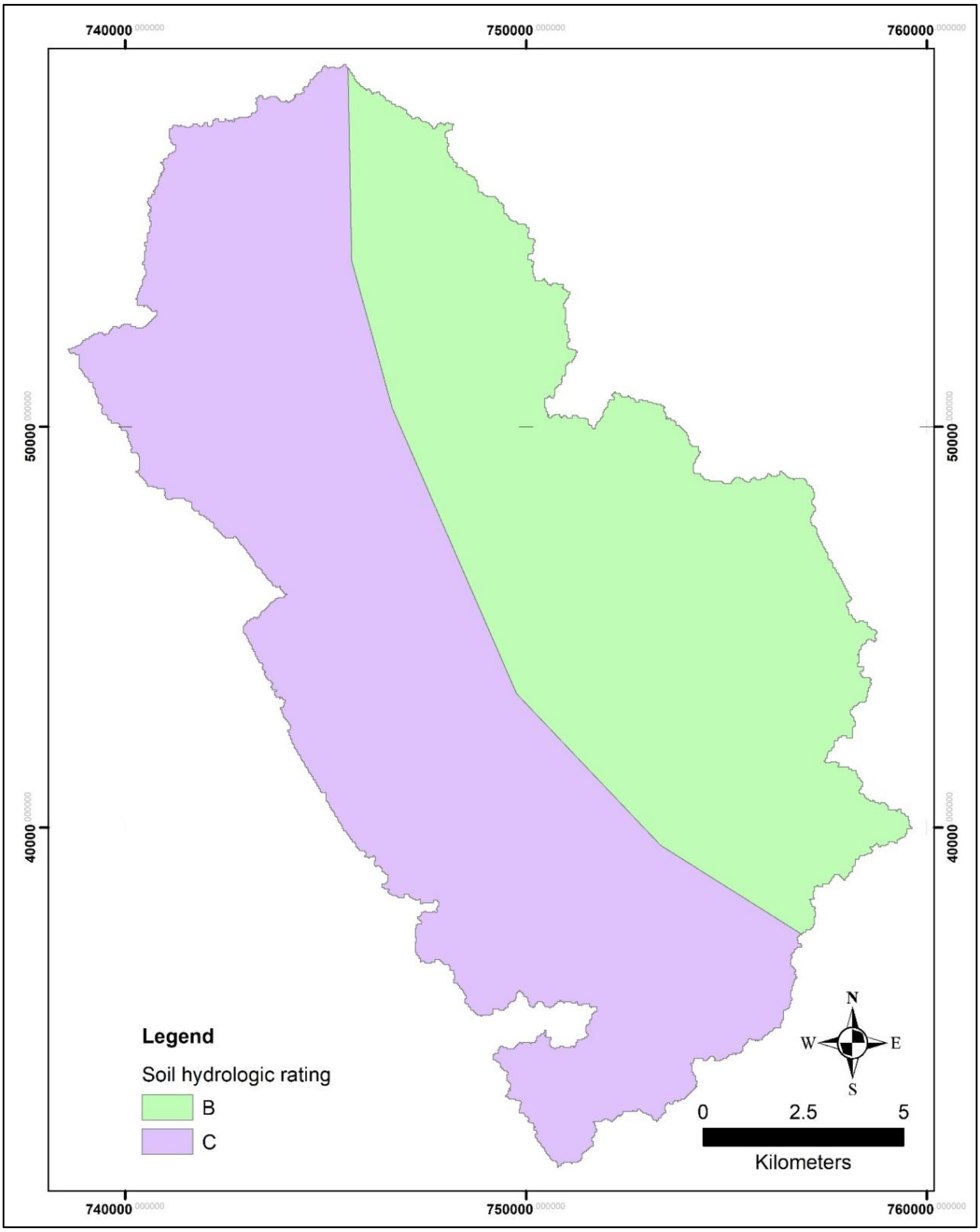


Fig 4.12: Area under the various land use categories

4.3.4 Soil

Two soil types were identified in the study area; humic latosols and orthic ferralsols. Orthic ferrasols are found on the north eastern located on the south-eastern side of KSC while humic nitosols are located on the south eastern part of KSC. Their distribution is shown in Figure 4.13.



(Source: Author, 2022)

Fig 4.13: Soil map of Kapseret Sub-County

Orthic ferrasols occupied 160.26km^2, a larger portion of KSC, while humic nitosols occupied 122.55km^2. Orthic ferralsols are well drained soils, mainly composed of sandy clay and were placed in Hydrologic Soil Group B. On the other hand, humic nitosols composed mainly of silty clay was placed in Hydrologic Soil Group C due to its lower infiltration capacity, as shown in Table 4.31.

Table 4.31: Area under each soil type and their hydrologic rating

S/No.	Soil Type	Hydrologic rating	Area (km^2)
1.	Orthic ferrasols	B	123.55
2.	Humic nitosols	C	160.26

Based on the land uses, slope and soil type, curve numbers (CNs) were generated. Area under cropland generated a CN of 85, trees 71.7, shrub 75.3, grassland 79 and swamp 79. Area under built, bare land and water bodies did not meet the model threshold for generation of CN since they covered very a small surface. Table 4.32 presents a summary CNs of various land covers.

Table 4.32: CNs from various land uses

S/No.	LULC	Area in Sq. Km	CN
1.	Cropland	82.77	85.07
2.	Trees	48.15	71.74
3.	Shrub	55.90	75.33
4.	Grassland	80.73	79.11
5.	Swamp	9.2	79.0

The weighed CN was computed then from the individual sub-water sheds;

$$CN = \frac{CN1 * Area\ 1 + CN2 * Area\ 2 + \cdots .. CNi * Areai}{Total\ Area}$$

The weighted CN for the basin was determined to be 78.31 which is relatively high.

4.3.5 Estimating Stormwater Yield

To estimate stormwater yield, input parameters to the SWAT model included daily rainfall amount, slope, LULC and soil type. Runoff for each of the 5 sub-catchments was estimated, hence that of the entire Kapseret basin was determined. The runoff, Q_1, $Q_2 \ldots Q_5$, for each sub-basin in liters was computed as:

$QI,_{2..5}$= (Surface area in km^2*1000*1000)* (Surface runoff in mm/1000) *1000.

The total runoff, Q, for the Kapseret basin was computed as summation of all sub-basins' runoff.

$Q=Q_1 + Q_2 + Q_3 +Q_4 + Q_5$

Based on CN, slope, LULC and soil type, sub-basin 2 had the highest surface runoff estimated at 411.77 mm, though covering the smallest area. Sub-basin 17 had the least runoff (348.91mm). Sub-basins 9 and 17 generated the largest volume of runoff, accounting for 39.87 billion liters and 37.56 billion liters respectively. Sub-basin 2 generated 19.09 liters, while sub-basins 23 and 25 generated 3.30 billion liters and 3.77 billion liters respectively. The total runoff generated in KSC in 2019 was 365.02mm, equivalent to 103.60 billion liters. This is shown in Table 4.33.

Table 4. 33: Volume of runoff generated at the outlets

Sub-basin ID	Outlet ID	Area drained (sq.km)	Surface Runoff (mm)	Runoff in billion liters
2	100003	46.3699	411.77	19.09373
9	100010	107.6517	348.91	37.56075
17	100017	111.0489	359.07	39.87433
23	100024	8.9226	369.79	3.299488
25	100025	9.8249	383.7	3.769814
TOTAL		283.818	365.02	103.5981

Monthly analysis of runoff was done. Runoff volume was high in August (80.3mm), June (64.5mm), May (64mm), September (52.2mm) and July (45mm). Runoff was lowest in January, February and December, with <1mm. This is shown in Figure 4.14.

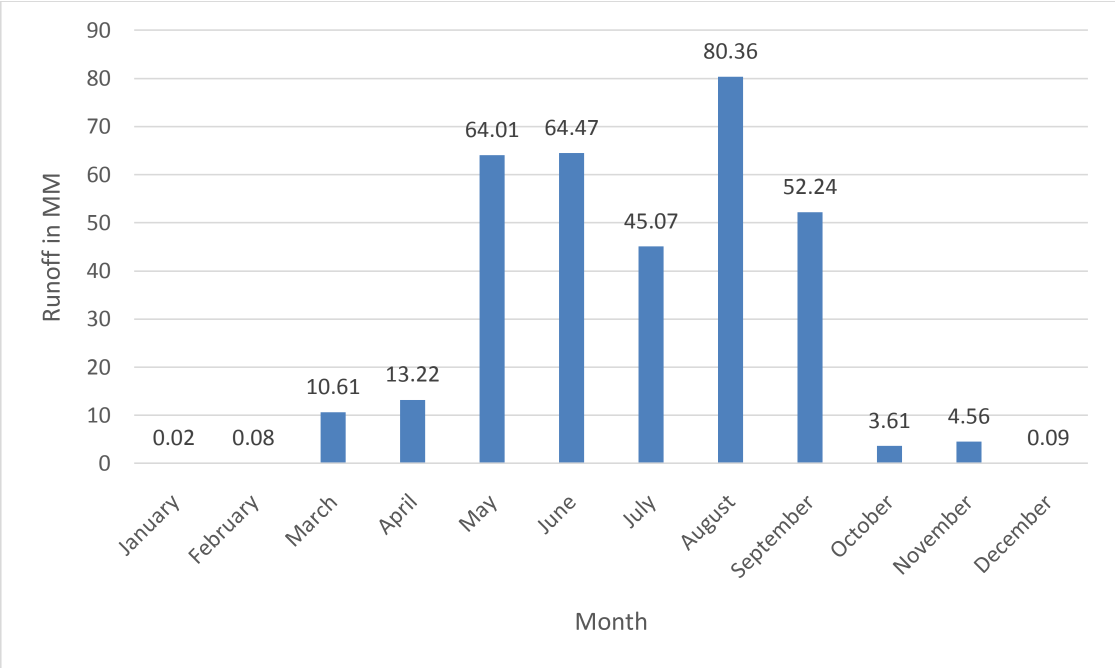


Fig 4.14: Average monthly values for runoff generated in KSC

Notably, the total monthly runoff generated generally corresponded to the total monthly rainfall amount. Both rainfall and runoff volumes were highest between May and September. Figure 4.15 shows a comparison of monthly rainfall and runoff amounts in mm in 2019.

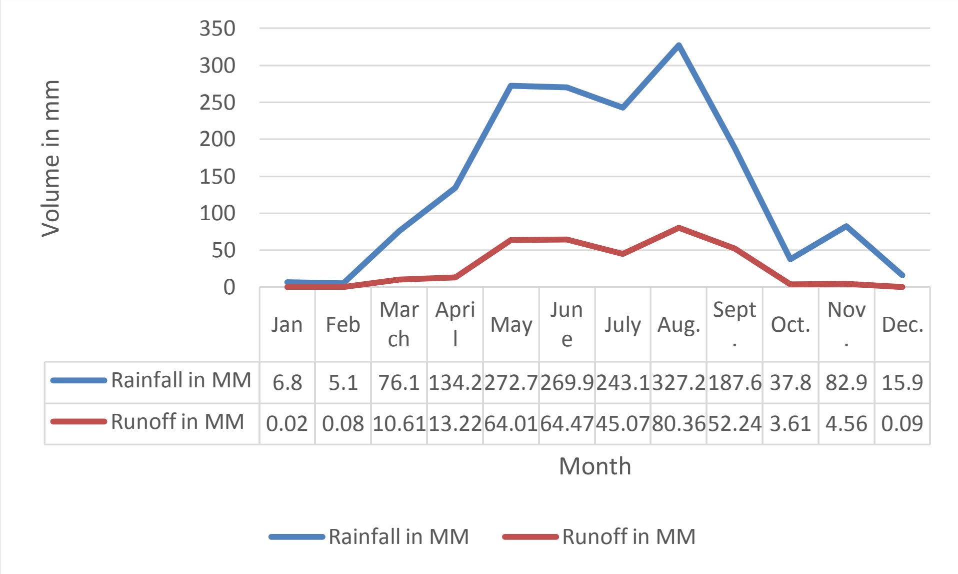


Fig 4. 15: Monthly rainfall and runoff in 2019

4.3.6 Identification of Suitable Stormwater Harvesting Sites

To identify suitable sites for stormwater harvesting, important criterion was established. The criterion included slope, proximity to roads, proximity to airport, proximity to schools and institutions, proximity to stream network and LULC. Their layers were prepared separately before weighed overlay was finally performed using ArcGIS. Soil type is an important factor to consider when siting reservoirs. The two soil types in KSC are orthic ferrasols and humic nitosols, both of which are highly suitable for stormwater harvesting as they are clayey. Soil type was therefore not subjected to weighted analysis.

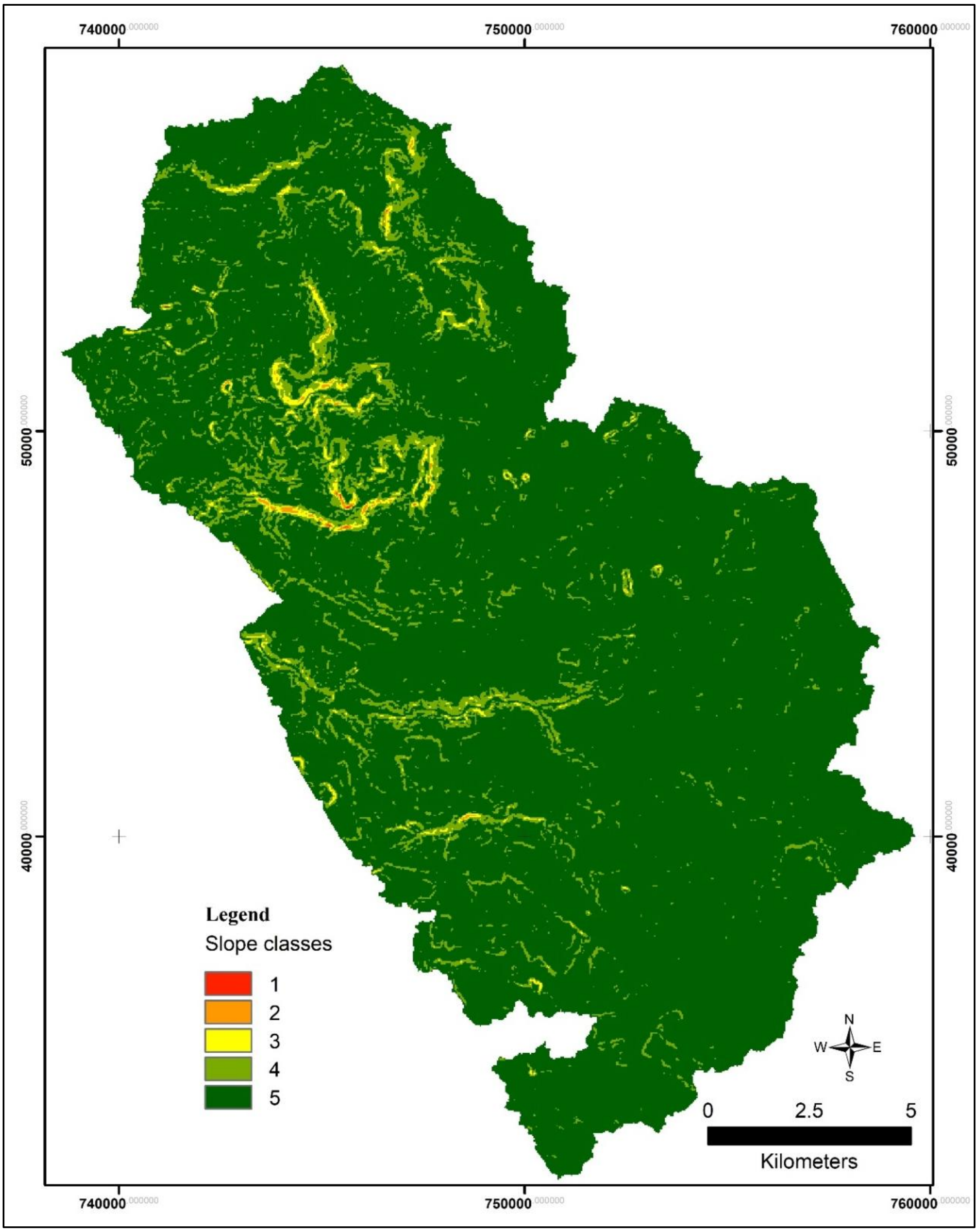
a) Slope

Majority of the land (262.68 km^2) in KSC is sloping gently as shown in Fig. 3.2. For the purpose of ranking, slope was reclassified into five classes of 0-10, 10-20, 20-30, 30-40 and over 40%. The most suitable location for dam siting was areas with gentle slope were ranked 5, while the least suitable areas with steep slopes were ranked 1, as shown in Table 4.34.

Table 4.34: Ranking with respect to percentage of slope

Percentage of Slope (%)	Class	Rank
0-10	1	5
10-20	2	4
20-30	3	3
30-40	4	2
40-46.67	5	1

Based on this ranking, the following map shows areas of highest to lowest suitability to site stormwater harvesting infrastructure in KSC based on slope. Notably, most of the area is gently sloping, hence highly suitable for stormwater harvesting. This is shown in Figure 4.16.

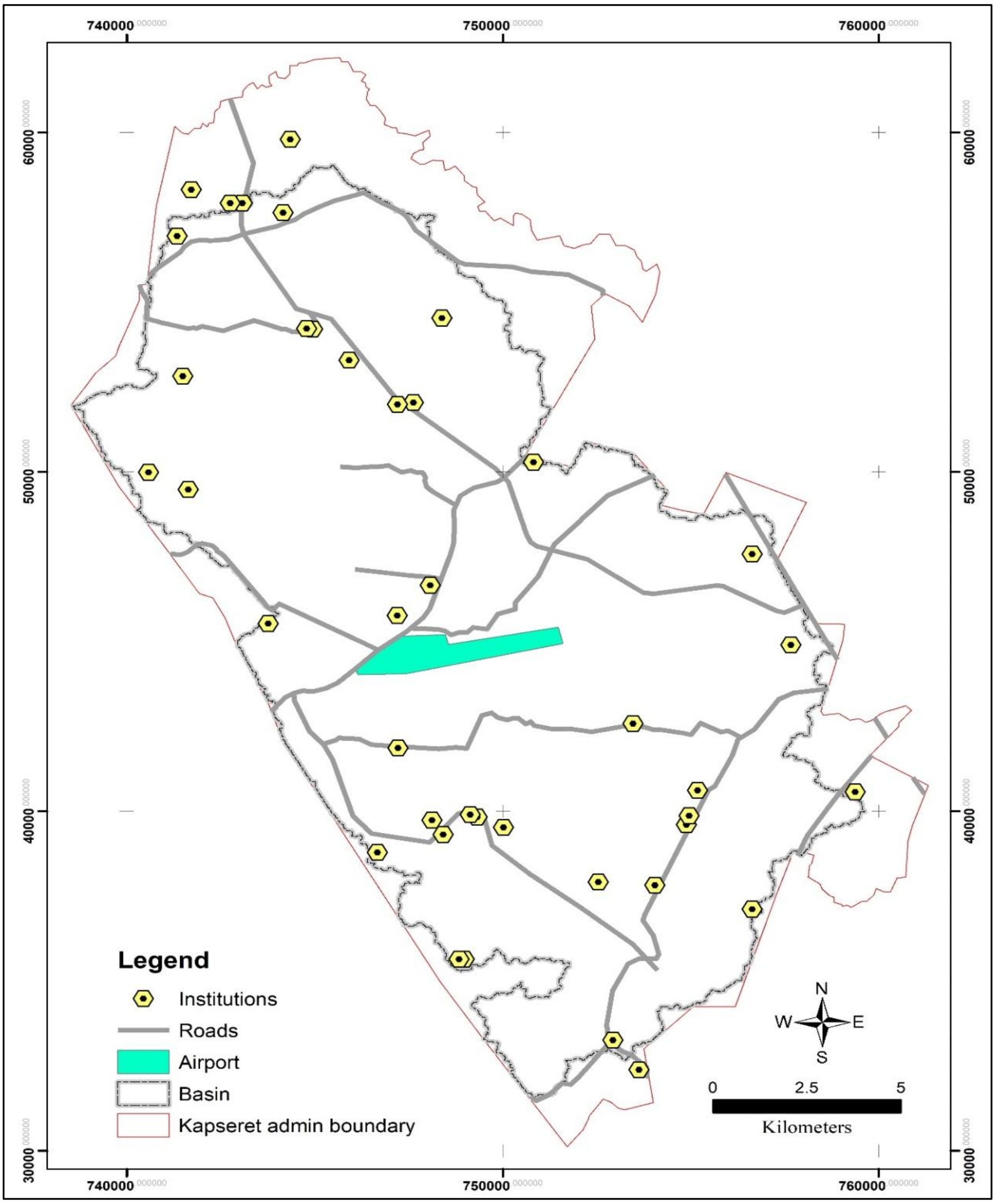


(Source: Author, 2022)

Fig 4. 16: Suitable locations for dam siting based on slope

b) Proximity to Institutions

The following institutions were identified in KSC; schools, health facilities, colleges, churches and the Ngeria Prisons as shown in Figure 4.17.



(Source: Author, 2022)

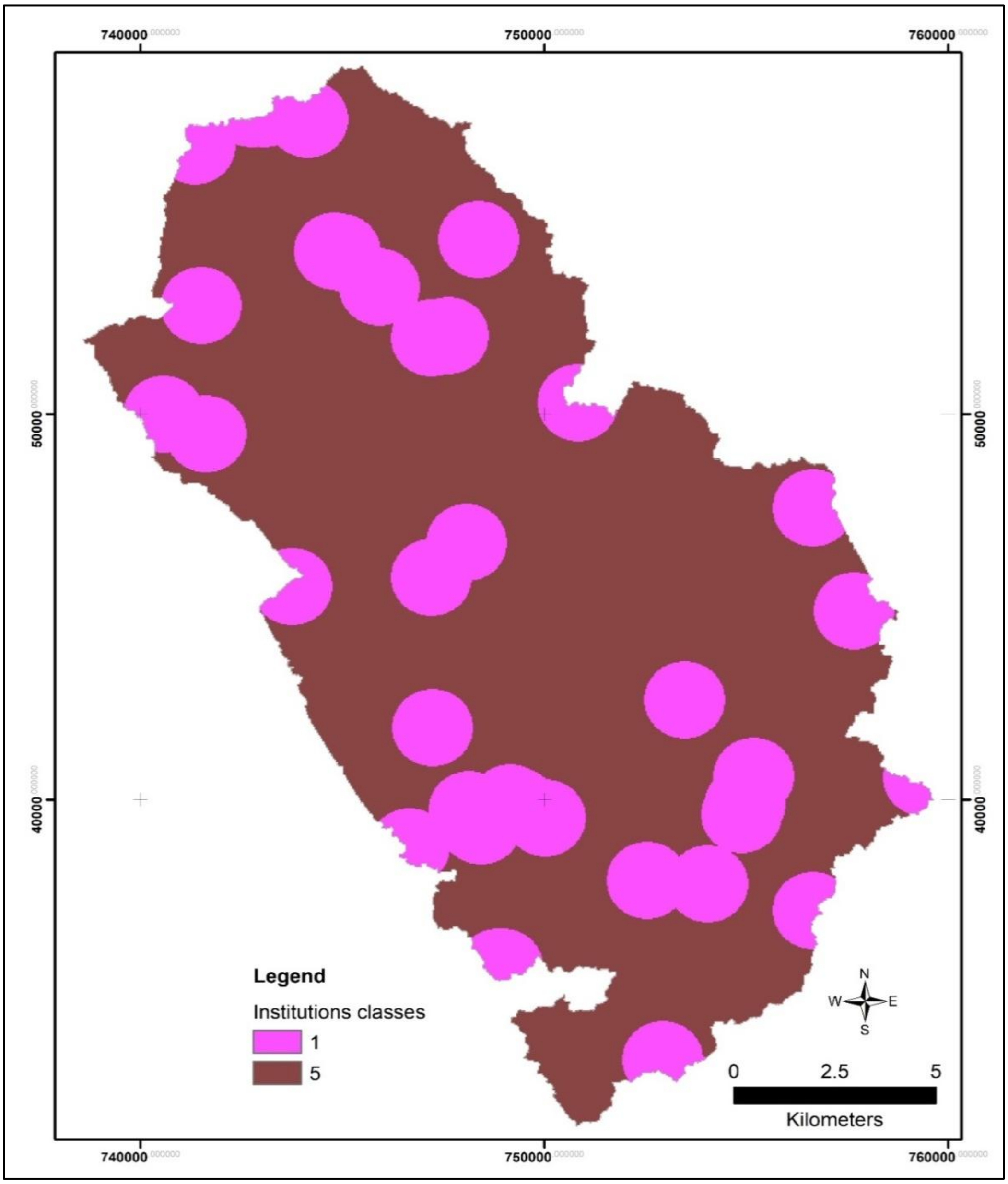
Fig 4. 17: Institutions in KSC

Proximity to institutions was reclassified into two classes. The farthest distance from any institutions was 11,838m. Areas nearest to institutions were considered least suitable for stormwater harvesting and were ranked lowest. This is captured in Table 4.35.

Table 4.35: Ranks with respect to proximity to institutions.

Proximity to institutions in meters	Class	Rank
0-1000	1	1
1000-11,838	2	5

Based on this ranking, Figure 4.18 indicates that significant portions of the area are suitable sites for stormwater harvesting.



(Source: Author, 2022)

Fig 4. 18: Suitable zones for Stormwater Harvesting based on proximity to institutions

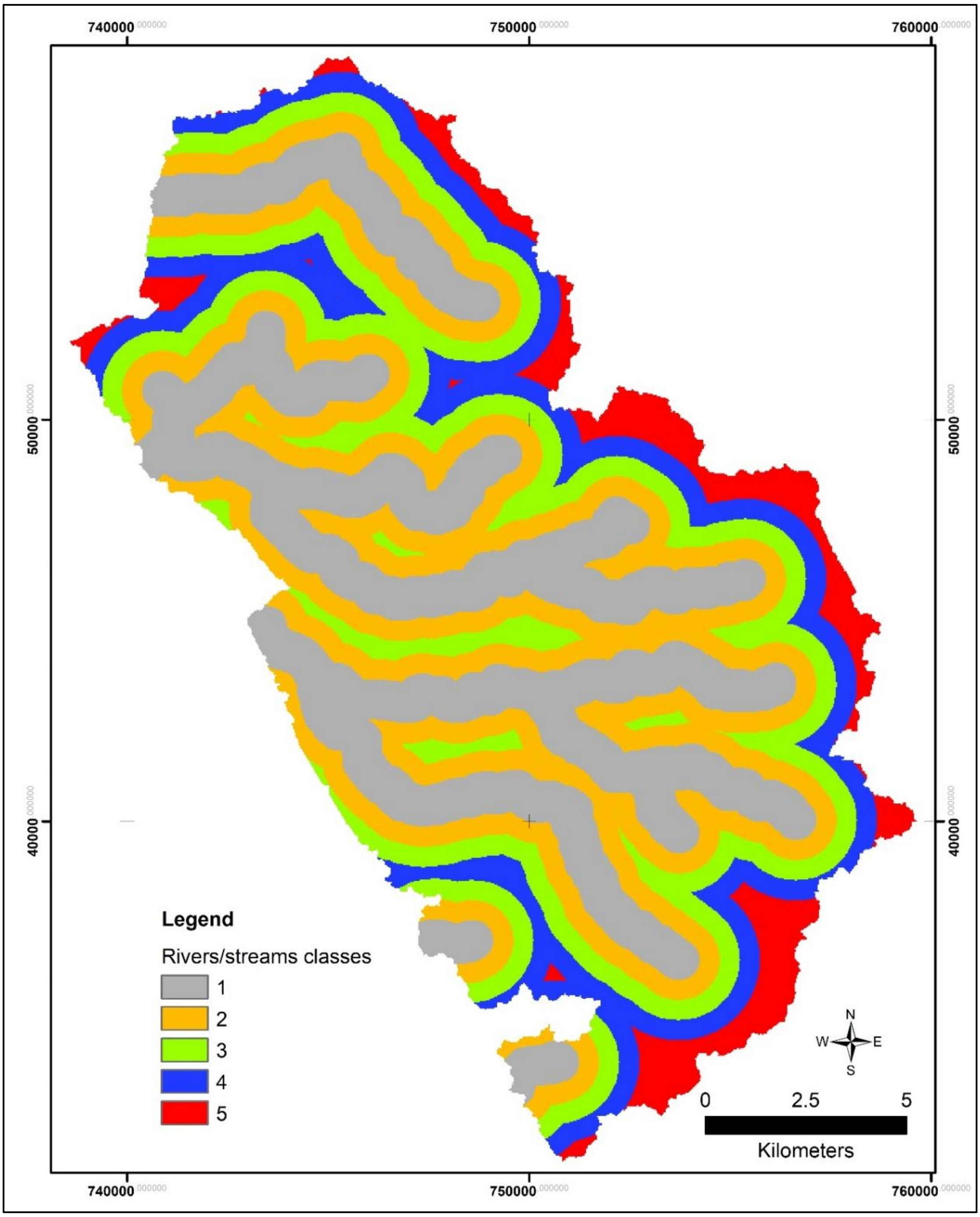
c) Proximity to Stream Network

The stream network was extracted from DEM, at 30 m resolution. Reclassification was done at intervals of 500 and over 2000. Areas near streams are considered most suitable for stormwater harvesting hence ranked highly compared to areas located far from stream network, as presented in Table 4.36.

Table 4. 36: Ranks based on proximity to stream network

Proximity to streams in meters	Class	Rank
0-500	1	5
500-1000	2	4
1000-1500	3	3
1500 -2000	4	2
2000-3308.7	5	1

Figure 4.19 depicts classes hence ranks for siting zones for stormwater harvesting based on proximity to stream network.



(Source: Author, 2022)

Fig 4. 19: Suitable zones for stormwater harvesting based on proximity to stream network.

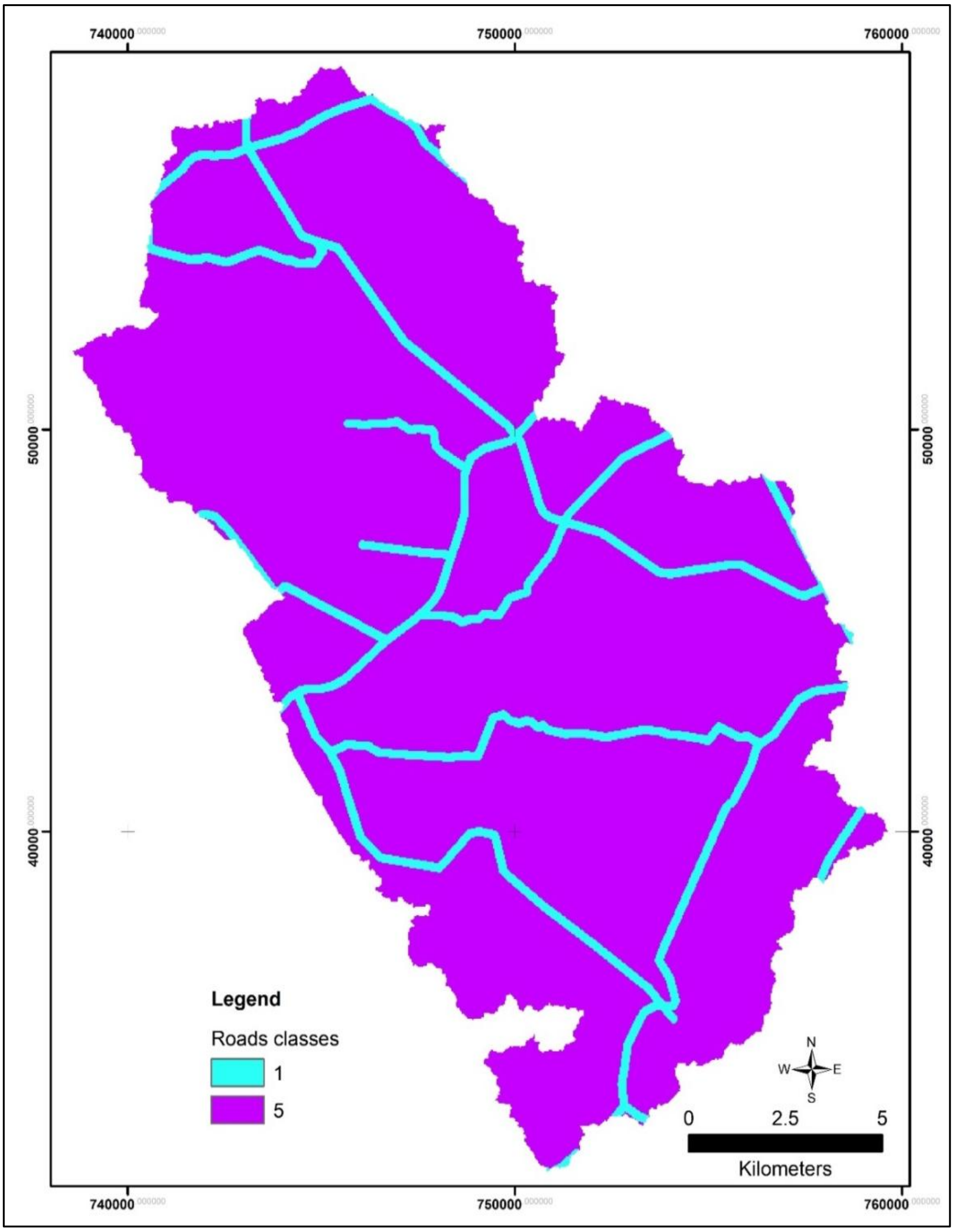
d) Proximity to road

Areas adjacent to roads were considered unsuitable for location of stormwater harvesting infrastructure, hence ranked lowest. The farthest point from any road network was 3814.13m. Roads were reclassified into two classes, as shown in Table 4.37.

Table 4. 36: Ranks based on proximity to roads

Proximity to roads in meters	Class	Rank
0-100	1	1
100-3814.13	4	5

Based on the ranks, the suitable areas for stormwater harvesting based on proximity to roads was generated, as presented in Figure 4.20.



(Source: Author, 2022)

Fig 4. 20: Level of Suitability For Stormwater Harvesting Based On Proximity To Roads.

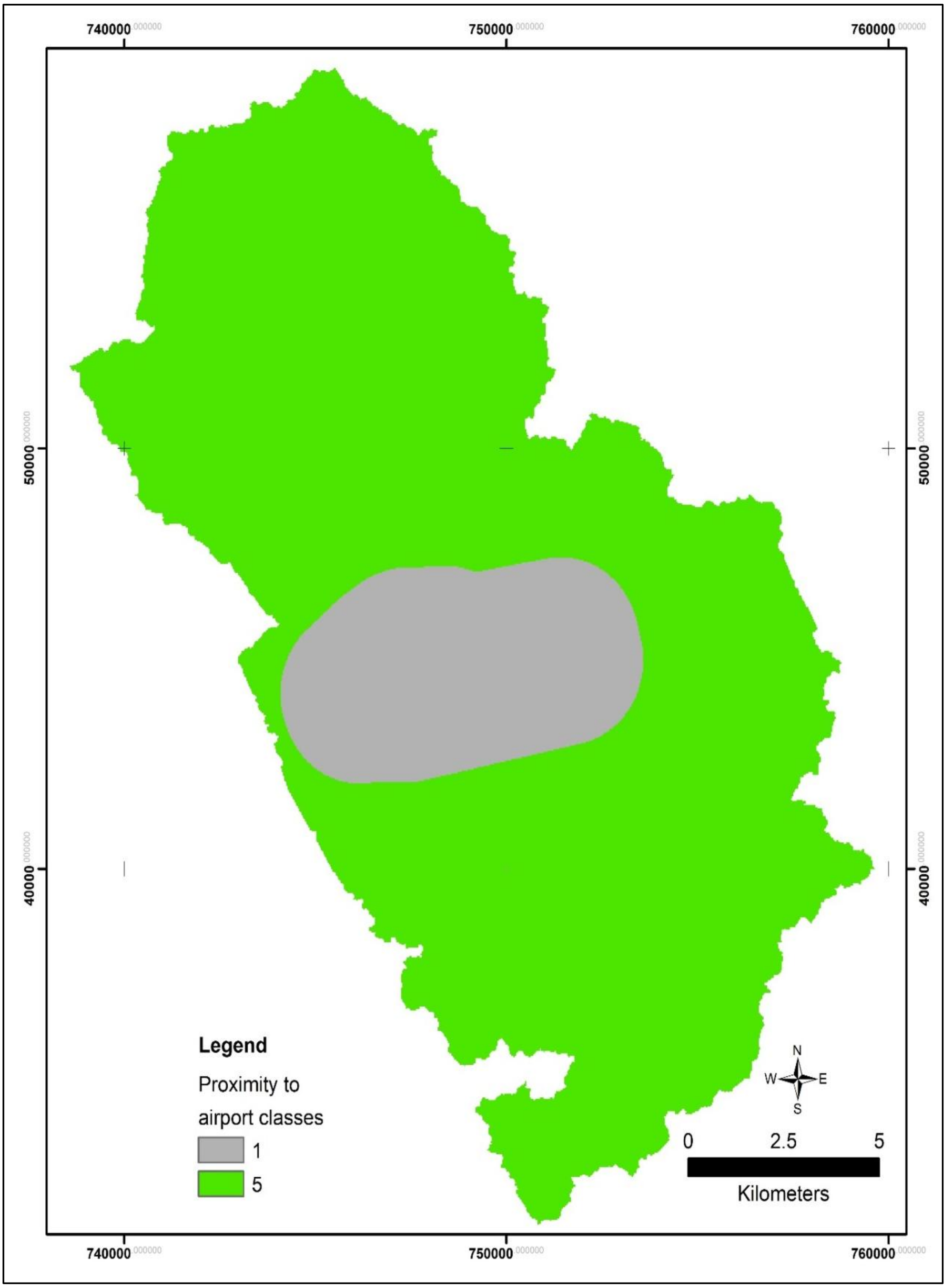
e) Proximity to airport

Proximity to the airport was subdivided into two classes of 0-1000 and 1000-14,036.7m. Class 1 represents the unsuitable areas and are restricted. Table 4.38 presents ranking with respect to proximity to the airport.

Table 4. 37: Ranking with respect to proximity to airport

Proximity to Airport in meters	Class	Rank
0-1000	1	1
1000-14,036.7	2	5

Based on this rank, Figure 4.21 shows the most suitable and least suitable sites for stormwater harvesting based on proximity to airport.



(Source: Author, 2022)

Fig 4. 21: Suitable sites for stormwater harvesting based on proximity to airport

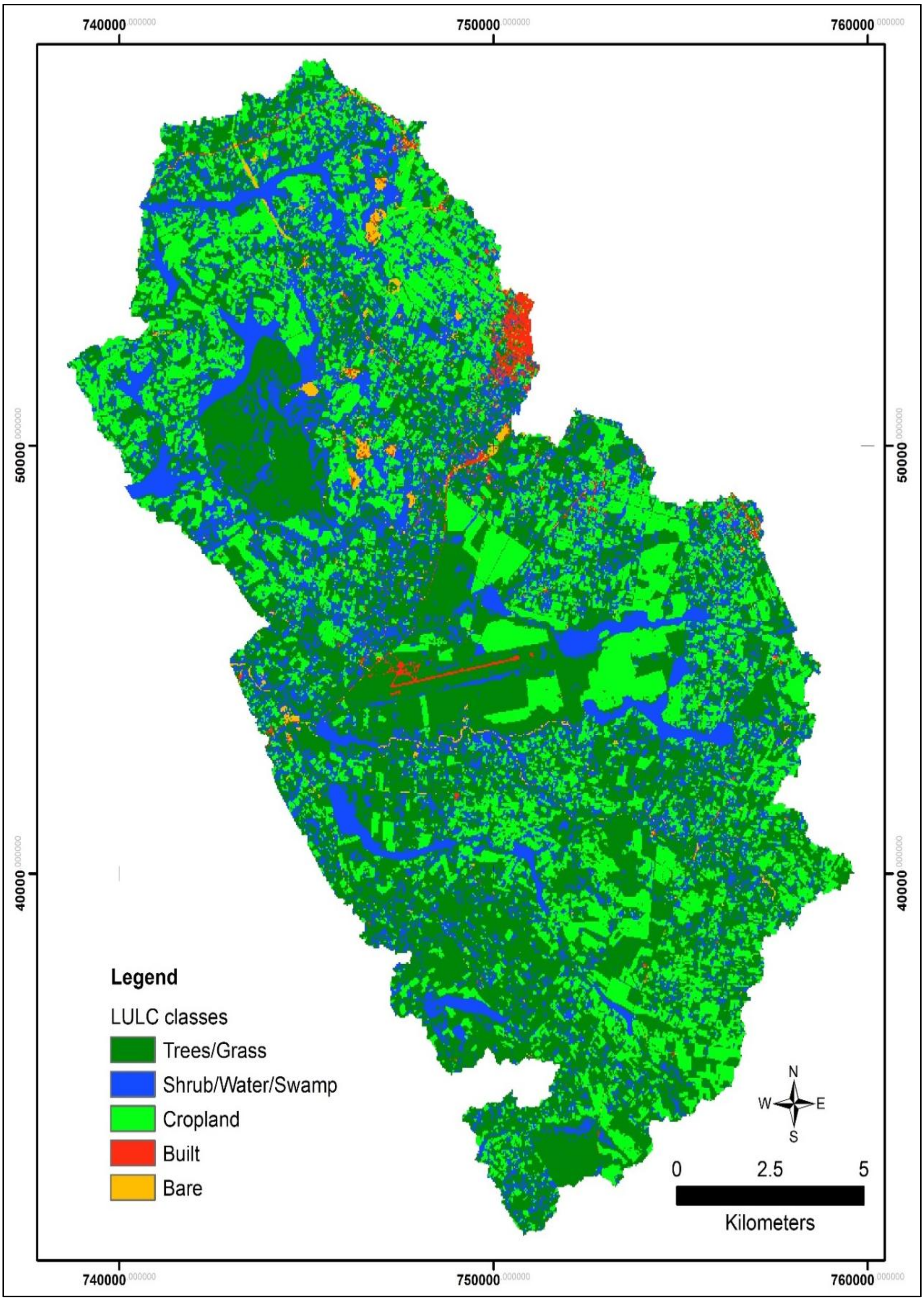
f) LULC

LULC was reclassified in into five classes namely built, bare land, cropland, trees and grass and combined water and swamp. LULC with generation of highest runoff was ranked highest, and those areas with minimal runoff were ranked lower. This is presented in Table 4.39.

Table 4. 38: Ranks based on LULC

LULC	New Class	Rank
Built	1	5
Bare land	2	4
Cropland	3	3
Trees/Grass	4	2
water/swamp	5	1

Based on the ranks assigned, Figure 22 shows the levels of suitability for siting stormwater harvesting infrastructure based on various LULC categories.

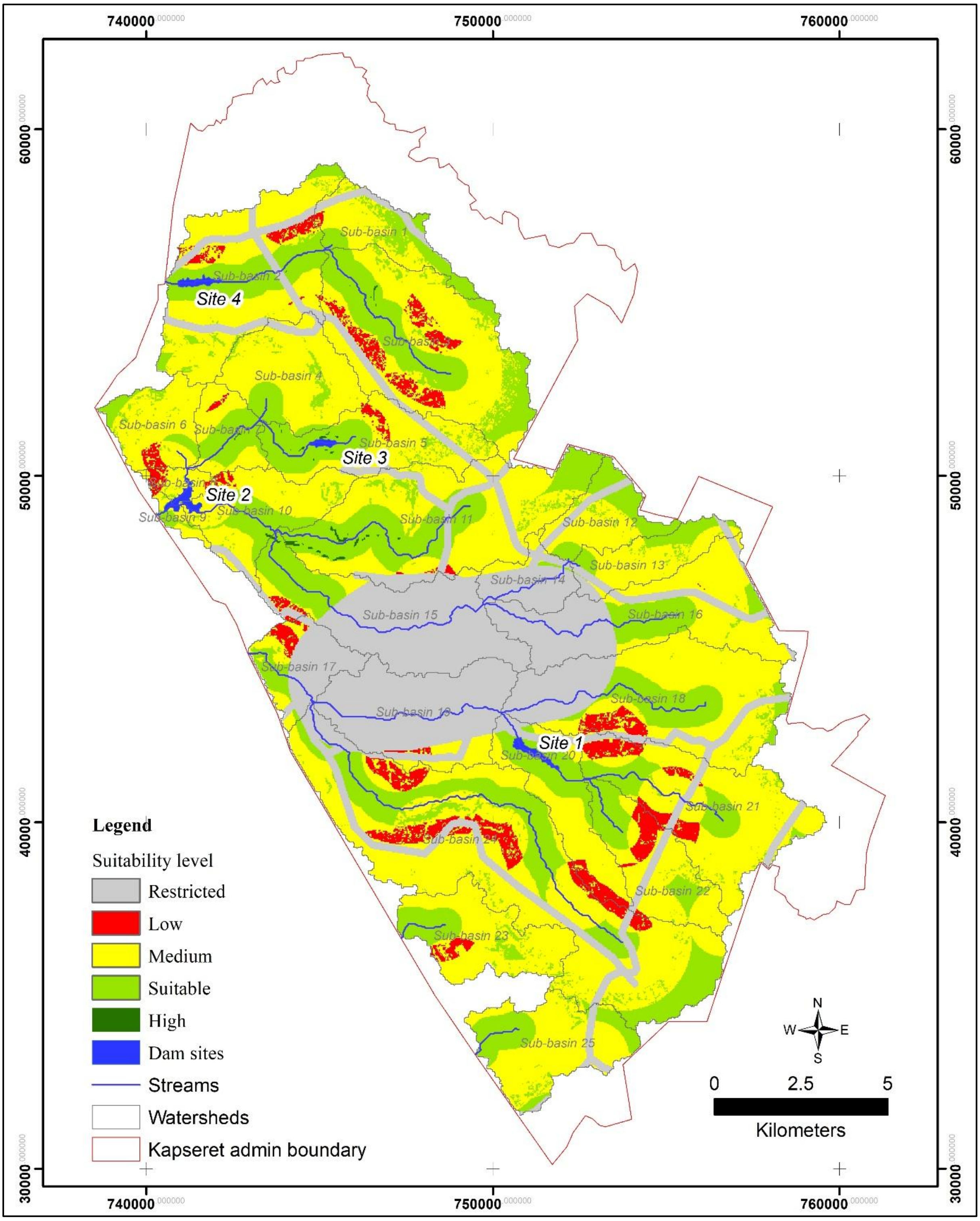


(Source: Author, 2022)

Fig 4. 22: Levels of suitability for siting stormwater harvesting infrastructure based on various LULC categories

g) Weighted Overlay Function

The Weighted Overlay tool in ArcGIS was used to overlay the criterion layers including slope, proximity to roads, proximity to airport, proximity to schools and institutions, proximity to stream network and LULC while adopting the weighting criteria so as to generate the stormwater harvesting site suitability map. As can be clearly seen in Figure 4.23, most of the area is rated as moderate to highly suitable.



(Source: Author, 2022)

Fig 4. 23: Suitable zones and sites for stormwater harvesting

Suitability level differed based on the prevailing criteria and the allocated weight. The moderate to highly suitable areas for stormwater harvesting covers 74.66% of the land surface. However, 21.37% of the area is restricted, while 3.96% has low suitability. These two areas are therefore unsuitable for siting stormwater harvesting infrastructure. This is shown in Table 4.40.

Table 4.39: Suitability level for stormwater harvesting

Suitability level	Area in km^2	Percentage of Area
Restricted	60.5052	21.37%
Low	11.2185	3.96%
Moderate	138.1284	48.79%
Suitable	72.9729	25.77%
Highly suitable	0.297	0.10%
Total	283.122	100.0000

From the zones identified as suitable and the highly suitable for stormwater harvesting, the analysis of contours marked four sites with natural depressions as the most suitable sites. The location of each site within the basin is shown in Figure 4.24.

Of the four sites identified, Site 1 has the largest capacity of 1,422,300 m^3, and longest dam barrier length of 205 meters. Site 2 is on the lowest contour of 1900 meters. It has the shortest dam barrier length of 35 meters, with a capacity of 637,575 m^3. Site 3 is on the 1980 meter contour, with a dam barrier length of 100 meters and has a capacity of 684,450 m^3. Site 4 lies on the 1920 contours with a dam barrier length of 160 meters and a capacity of 692,175 m^3.The four sites combined have a capacity of 3,436,500 m^3, which is equivalent to 3.44 billion liters. Considering basic indoor and outdoor uses of 240.8 liters per household, the harvested water is able to serve 59,746 households in KSC for 238 days. Table 4.41 shows the most suitable sites for stormwater harvesting and their capacities.

Table 4. 40: Suitable stormwater harvesting sites and their capacities

Site	Contour	Dam barrier coordinates	Dam barrier Length (m)	Area (m^2)	Volume (m^3)
1	2100	750736.6, 42427.5	205	206,100	1,422,300
2	1900	740727.9, 48965.6	35	274,500	637,575
3	1980	744722.8, 50911.5	100	100,800	684,450
4	1920	740913.6, 55536.7	160	176,400	692,175
Total				757,800	3,436,500

4.4 Stormwater Utilization

In order to establish determinants of stormwater utilization in Kapseret Sub County, the levels of access and level of utilization of stormwater were assessed.

4.4.1 Access to stormwater

The study established that only 28% of the households had access by being at close proximity to stormwater, while the majority (72%) did not have access. This is shown in Figure 4.24.

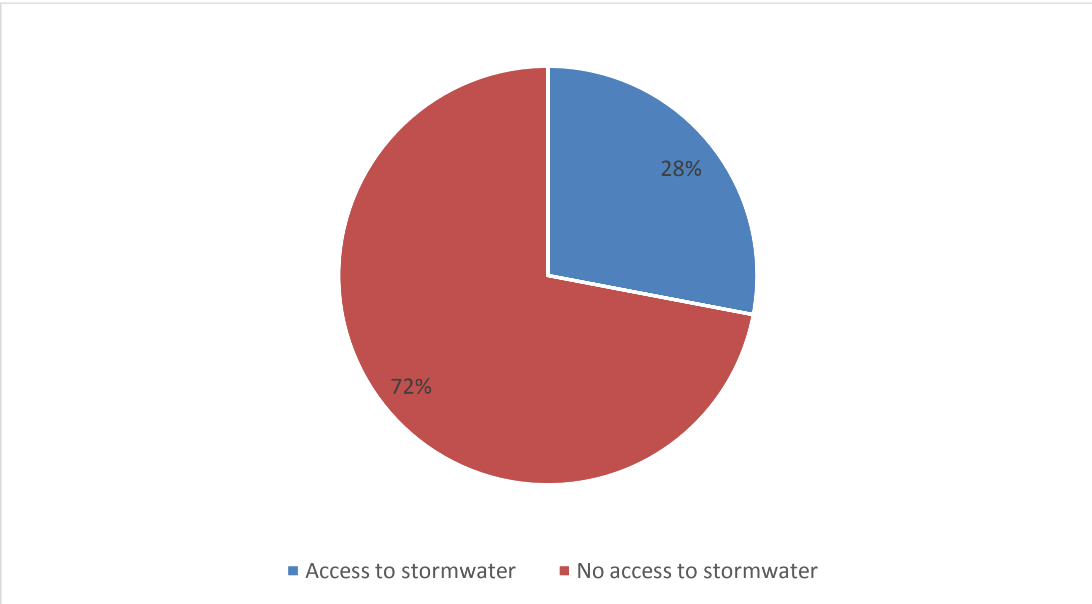


Fig 4. 24: Level of access to stormwater

Stormwater in the area of study occur in dams, streams, swamps, across farms and along roads and footpaths. Majority of the households that had access to stormwater said the stormwater was in streams (15.1%), swamps (0.7%) or dams (2.0%). Other households noted that runoff occurred only after a rain event, and flowed along the road/pathways (6.9%) and across the farms (3.2%).

Harvested stormwater is captured and stored in dams. Dams in Kapseret Sub-County were constructed either by county or national government (75%), institutions (12.5%) or individuals (12.5%).

Of the 8 dams sampled, 7 dams were used by communities and institutions. Only one dam was not utilized. The 7 dams being utilized serve an individual’s household (one private dam), an institution (one dam) and communities (five dams).

4.4.2 Level of Stormwater Utilization

The majority of households (88.6%) do not use stormwater for any domestic purposes, as shown in Figure 4.25.

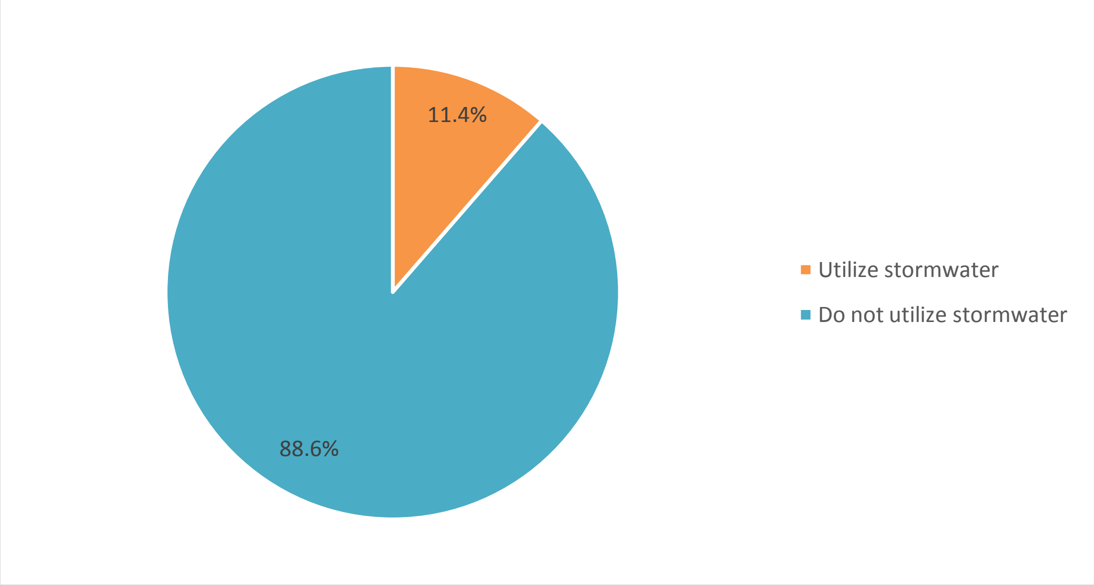


Fig 4. 25: Level of stormwater utilization in KSC

Amongst the households that utilized stormwater, the water was used for watering animals (9.9%), laundry (6.2%), bathing (4.5), cleaning house (3.5%), drinking and cooking (1%), irrigation (1%) and washing cars/motorcycles (0.5%). Some households utilized stormwater for multiple domestic uses. Table 4.42 shows the uses of stormwater in KSC.

Table 4. 41: Uses of stormwater

S/No.	Domestic Use	Frequency	Percentage
1.	Watering animals	40	9.9
2.	Laundry	25	6.2
3.	Bathing	18	4.5
4.	Cleaning house	24	3.5
5.	Drinking and cooking	4	1.0
6.	Irrigation	4	1.0
7.	Washing cars/motorcycles	2	0.5

It was established that many households (88.6%) did not utilize stormwater. Respondents gave various reasons for not using stormwater. Lack of access to stormwater was mentioned by most households (65.1%) as the reason why they do not utilize stormwater, while 26.7% of the respondents attributed their failure to utilize stormwater to low quality of stormwater. Only 8.4% of the respondents did not need to utilize stormwater because their main source of water was reliable. This is indicated in Table 4.43.

Table 4. 42: Reasons for non-utilization of stormwater by households

S/No.	Reason for not using stormwater	Frequency	Percentage
1.	Lack of access	263	65.1
2.	Stormwater is unclean/unsafe	108	26.7
3.	The main water supply is reliable	34	8.4

a) Perception About Stormwater

Perception of residents concerning particular aspects of stormwater was assessed. Majority of respondents (74%) agreed that stormwater is a source of water for domestic use while 7.2% strongly agreed. Only 11.9% disagreed, 0.7% strongly disagreed, while 6.2% were not sure.

On the need to harvest and store water for use in the dry season, households were asked if there was need to harvest stormwater for use in the dry season. From their responses, majority (83%) agreed, 9.9% strongly agreed, 4% disagreed, 0.25% strongly disagreed, while 2.7% were not sure.

On whether respondents perceived stormwater as unclean hence unsafe, 8.4% strongly agreed, 65% agreed, 10.5% were not sure, and 16.1% disagreed. Thus, generally, many residents perceived stormwater as unclean. This is shown in Table 4.44.

Table 4. 43: Perception of residents about stormwater

Statement	Percentage of Respondents				
	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Stormwater is a source of domestic water	7.2	74.0	6.2	11.9	0.7
There is need to harness stormwater	9.9	82.9	2.7	4.0	0.5
Stormwater is unsafe for domestic use	8.4	65	10.5	16.1	0

4.4.3 Determinants of Stormwater Utilization

To establish the determinants of stormwater utilization in the Kapseret Sub-county, binary logistic regression was used in data analysis. This method was selected because of its ability to handle discrete binary outcomes, and in this study, stormwater utilization response was a discrete binary outcome of whether a household had used stormwater or not. For this model, stormwater utilization response is confined to a probability value of 0 and 1 by transforming its scale to natural logarithms of odds of the outcome scale by using the logit function in SPSS. The dependent variable was stormwater utilization, that is, whether a household used stormwater for domestic purposes or not. The independent variables identified through literature review include housing type, home ownership type, household size, land size, household income, awareness of stormwater as a source of water, access to harvested stormwater, perception of stormwater as unclean, knowledge on stormwater management, experience of water shortage and domestic water use types.

The significance of all the dependent variables on stormwater utilization in the data were assessed by stepwise logistic regression where only statistically significant variables were selected as the determinants of the stormwater use. The statistically significant independent variables in 95% Confidence Interval, P<0.05, include: access to stormwater, perception that stormwater is unclean, awareness and domestic outdoor uses (OutdoorUses). Table 4.45 shows output from binary logistic regression between stormwater utilization and selected dependent variables

Table 4. 44: Predictors of stormwater utilization

Independent variable	B	S.E.	Wald	Df	Sig.	Exp(B)
Access to stormwater	3.557	.471	57.018	1	.000	35.041
Perception that stormwater is unclean	-3.157	.642	24.155	1	.000	.043
Outdoor uses	1.293	.556	5.415	1	.020	3.645
Awareness that stormwater is a source of water	1.376	.477	8.326	1	.004	.253
Constant	-.947	1.057	.802	1	.371	.388

Dependent variable: Stormwater utilization

The coefficient of determination from the logistic regression was 0.734, which is fairly high. This implies that the predictor variables in the model account for 73.4% of likelihood of stormwater utilization. This is shown in Table 4.46.

Table 4. 45: Binary Logistic Regression Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	98.007[a]	.373	.734

From coefficients detailed in Table 4.38, the following equation was derived.

Probability of Stormwater use = exponent(W)/1+exponent(W),

where W = 35.041*(AccessSW) + 3.645*(OutdoorUses) + 0.253*(Awareness) - 0.043*(SWUnclean)--Equation 1.

4.5 Stormwater Management

When asked their opinion on whether it is important to manage stormwater, majority of respondents agreed that it is important. While 8.2% of the respondents strongly agreed and 84.9% agreed, only 4% disagreed. Another 2.7% were not sure, while 0.3% strongly disagreed, as shown in the Figure 4.26.

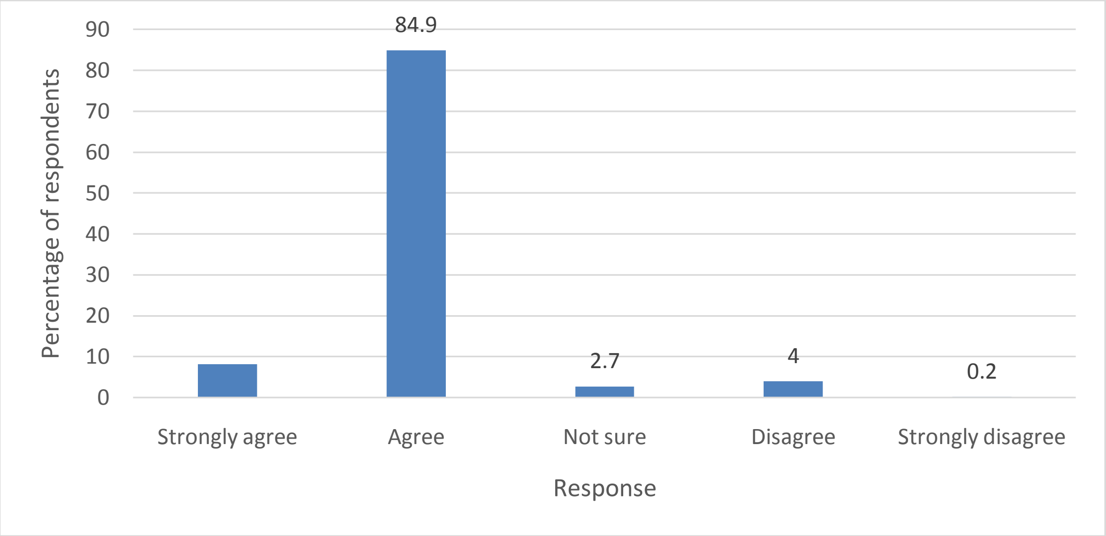


Fig 4. 26: Respondents' perception on whether it is important to manage stormwater

Although majority of respondents agree that stormwater management is important, it was established that only 16.6% of the respondents managed stormwater in their farms, as shown in Figure 4.27.

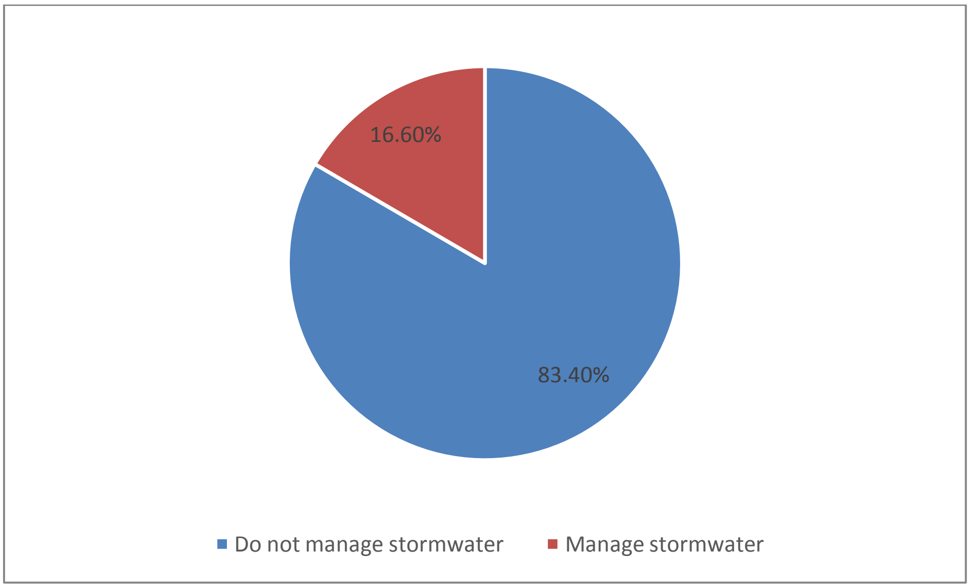


Fig 4. 27: Level of stormwater management

4.5.1 Stormwater Management Strategies

When probed about the strategies they use to manage stormwater, the response was as follows; maintaining vegetation in the farms (15.1%), ploughing across contours (11.1%), low impact development (5.7%), harvesting stormwater for farming, particularly vegetables and arrow roots (5.2%) and practicing agroforestry (5.2%). Various households applied multiple strategies in their farms. Figure 4.28 shows the various SWM strategies employed by residents in KSC.

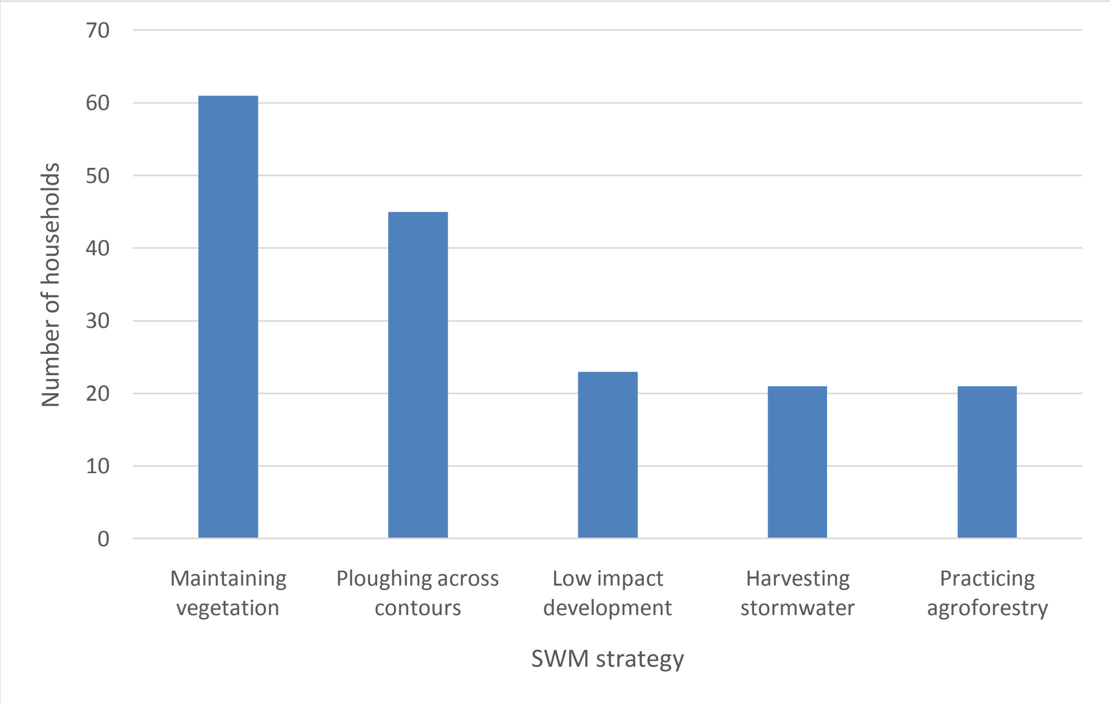


Fig 4. 28: Stormwater management strategies

4.5.2 Challenges of Stormwater Management

The majority of households (83.4%), however, do not manage stormwater in their farms because of various reasons including; lack of land to engage in stormwater harvesting (41.8%), lack of skills in stormwater management (24.0%), stormwater is not an issue in their farm (23.8%), lack of finances to engage in stormwater management (19.6%), lack of awareness (8.7%) and that stormwater is destructive and should be evacuated fast (3.2%) as presented in Figure 4.29.

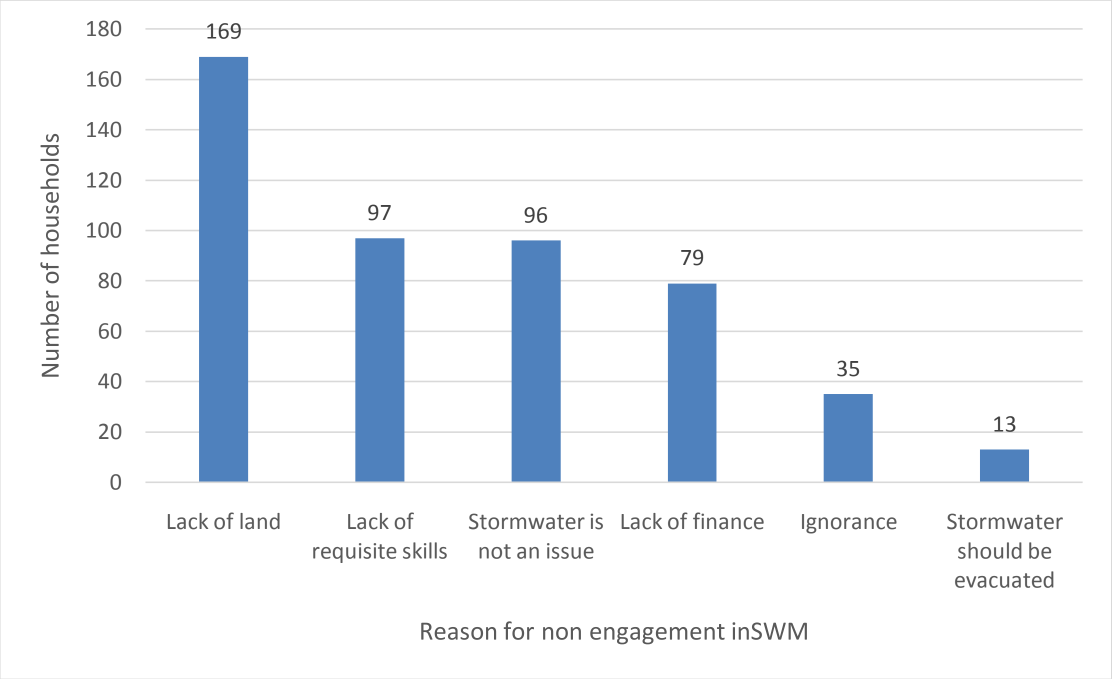


Fig 4. 29: Reasons for non-engagement in stormwater management

Binary logistic regression was used to identify factors that influence stormwater management. The significant variables include knowledge on stormwater management, size of land in acres and monthly income of household head. Table 0.47 shows the output from binary logistic regression between stormwater management and selected dependent variables

Table 4. 46:Predictors of stormwater management

Independent variable	B	S.E	Wald	Sig.	Exp(B)
Knowledge on stormwater management	3.703	.571	42.073	.000	40.582
Size of land	.100	.028	12.926	.000	1.105
Income of household head	.000	.000	7.566	.006	1.000
Constant	-4.175	.576	52.608	.000	.015

Dependent variable: Stormwater Management

a) Lack of awareness on stormwater management

Knowledge on stormwater management influences stormwater management by a factor of 40.582 as can be seen in Table 4.39. Majority of the respondents (54%) were not educated on stormwater management as shown in Figure 4.30.

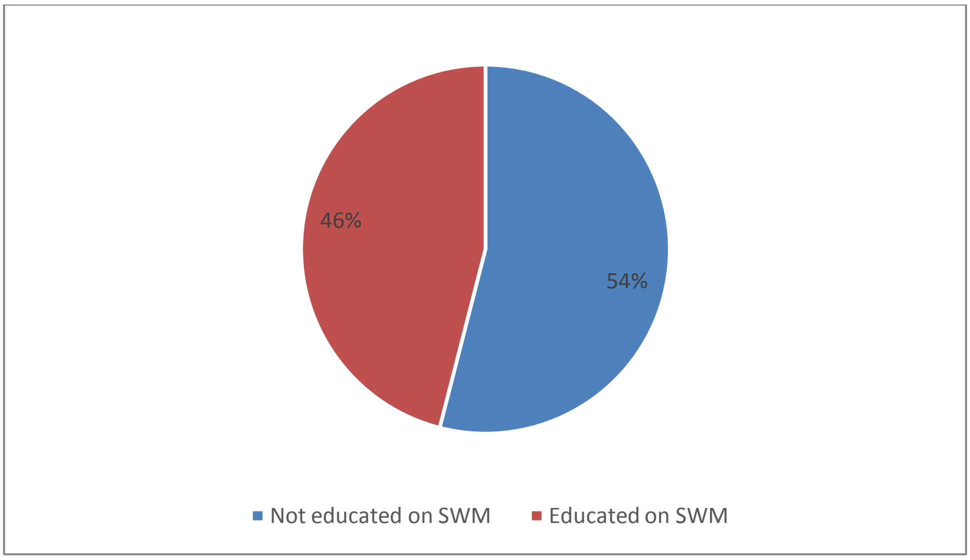


Fig 4. 30: Level of education on stormwater management

When probed further about the specific information received, 34% had been educated on both strategies and benefits of stormwater management, 8% had knowledge on benefits of stormwater management only, while 4% had been educated on only strategies of stormwater management. This is shown in Figure 4.31.

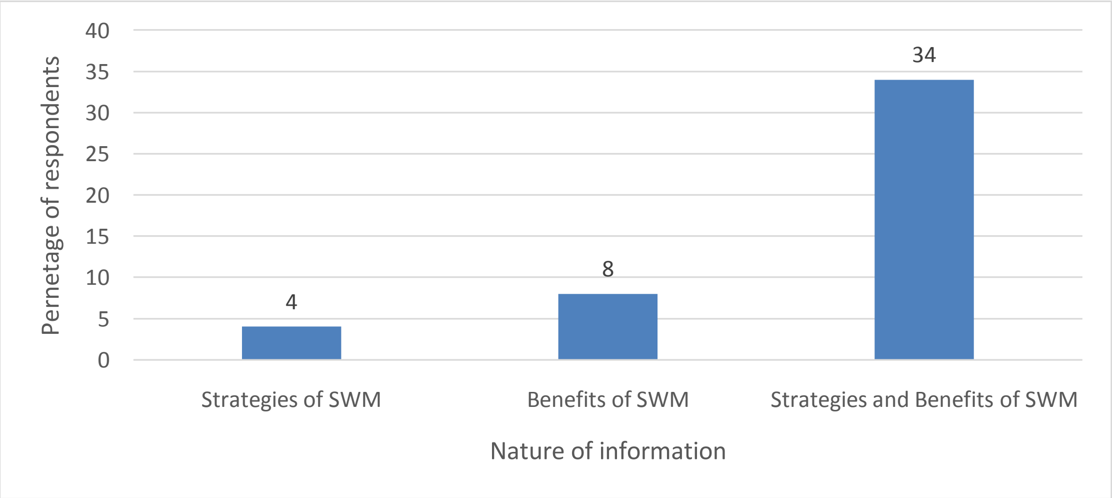


Fig 4. 31: Specific information received by residents on SWM

When asked where they acquired the education on stormwater management from, the largest percentage, (34.4%) got the education from school, 22.3% from the media, 3.2% from the county government and 5.2% from agricultural extension officers as shown in Figure 4.32.

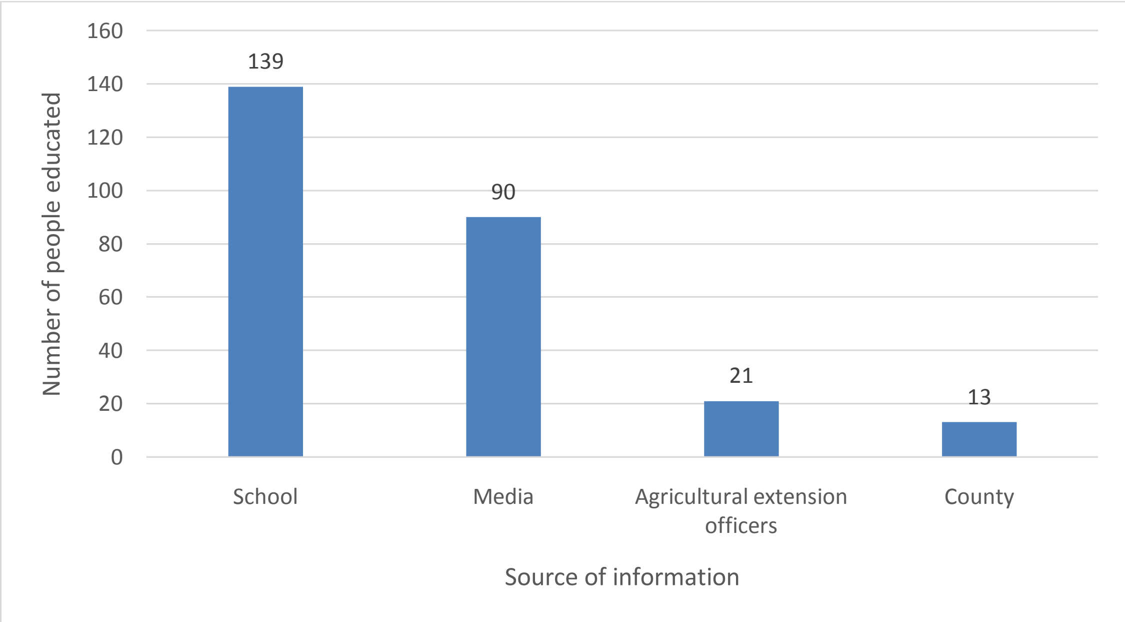


Fig 4. 32: Source of information on stormwater management

b) Lack of financial and technical capacity

Financial capability influences the amount of land one can acquire. For households, an increase in a unit of land increases the probability of stormwater management by a factor of 1.105. The key respondent noted that the unavailability of public land is a major constraint to development of stormwater harvesting infrastructure, particularly dams and pans.

On the part of infrastructural development, funding for stormwater management has been limited. Of all the monies allocated to the Department of Water since 2014/2015, no amount has been budgeted for stormwater development. There was negligible funding for stormwater management infrastructure for the period 2015/2020 as shown in Table 4.48.

Table 4. 47: Budgetary allocation for stormwater management in Uasin Gishu County

Financial Year	All water development projects	Stormwater Harvesting Projects
2015/2016	Not available	
2016/2017	328,500,000	Not Specified
2017/2018	485,144,523	Not Specified
2018/2019	470,144,523	Not specified
2019/2020	380.600,000	Not specified

(Source: Key Informant, UGC, 2022)

The county government is also strained technically in terms of personnel and equipment. Personnel in charge of stormwater management are insufficient in all cadres, as can be seen in Table 4.49.

Table 4. 48: Cadres of personnel involved in stormwater management

Cadre	Number	Are they sufficient?
Engineer	3	No
Technician	7	No
Craftsman	2	No
Plant operators	10	No

(Source: Key Informant, UGC, 2022)

In addition, equipment including excavators, bull dozers, tippers and compactors are all inadequate. The available equipment is shown in Table 4.50.

Table 4. 49: Number of county stormwater management equipment

Type of Equipment	Number	Are they sufficient
Long arm excavators	4	No
Crawler excavators	4	No
Bulldozers	2	No
Tippers	6	No
Flat roller compactors	2	No
Sheep foot compactors	1	No

(Source: Key Informant, UGC, 2022)

c) Lack of Supportive Institutional Framework

There is very little institutional engagement in stormwater management in the area of study. The majority of respondents (96.5%) had not benefitted from involvement of the Uasin Gishu county government in stormwater management.

The county government’s involvement in stormwater management was evaluated through various parameters including educating citizens on stormwater management (3.2%), construction of dams (1.2%) and distribution of tree seedlings (0.7%). Some respondents gave multiple responses. Figure 4.33 shows the proportion of households that have benefitted from Uasin Gishu County’s involvement in stormwater management.

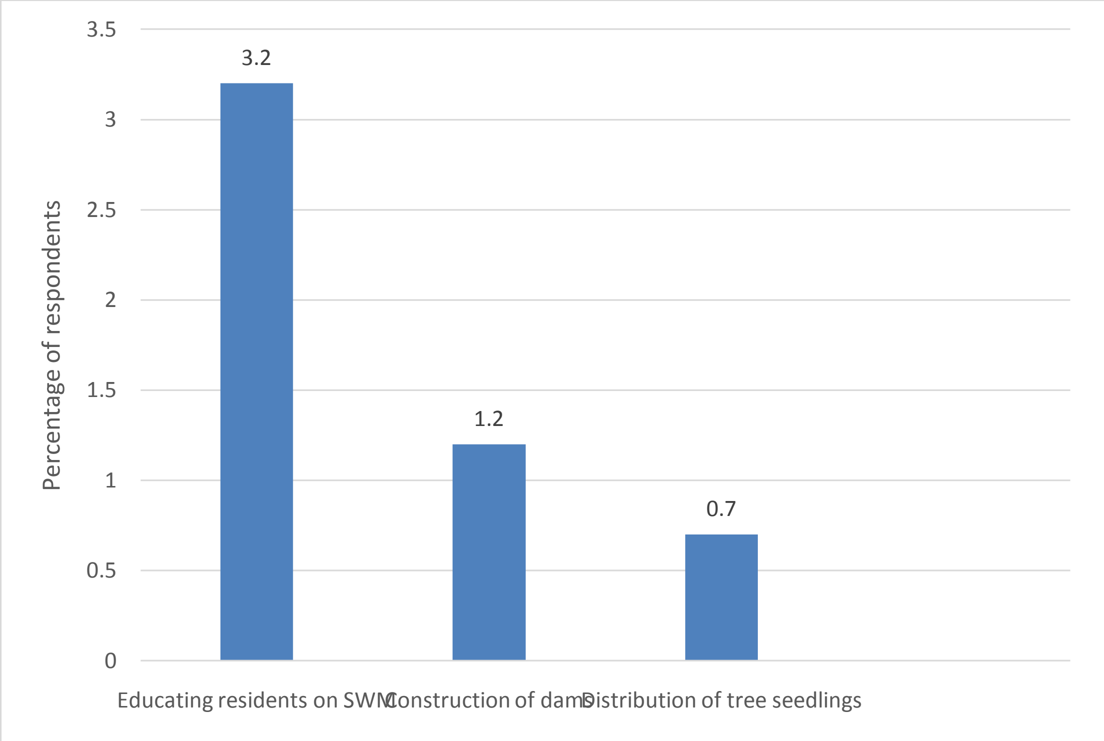


Fig 4. 33: County government's engagement in stormwater management

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This chapter involves discussion of findings presented in chapter four and comparison with findings from similar studies.

5.2 Domestic water consumption

Household water consumption in the area of study was computed as an aggregate of the individual, specified water uses. Crouch et al. (2021) noted that determination of household domestic demand using specific water use activities is a more realistic approach. There was notable variation in the water demand for individual water uses. Generally, the amount of water used in a household for indoor domestic activities including cleaning utensils, house cleaning, cooking and drinking, laundry and personal hygiene was lower in the dry season (149 liters) compared to 168.8 liters in the rainy season. On the other hand, outdoor uses accounting for non-human consumption exerted a higher demand for water in the dry season (91.8 liters) compared to the rainy season (70.7 liters). This can be attributed to the fact that water shortages experienced in the dry season force people to walk for longer distances to the main water source. Consequently, households that experience seasonal water shortages adopt various strategies to conserve water. The most common strategy was reusing water for non-potable uses like cleaning house floors and toilets. In dry seasons, 41.4% of the households reused water while 28.7% of the households minimized the amount of water used for various activities. Another 24.8% of the households took their animals, particularly cattle, to the water point. This strategy is attributed to the high intake of water by cattle in the dry season averaging 64.1 liters, compared to an average of 52.1 liters in the rainy season resulting from increased thirst directly caused by very high temperatures in the dry season. The water point could be a distant shallow well, river, dam or spring, once the shallow well around the home is dry. About 29% of the households opted to clean laundry occasionally instead of daily, while 29.7% took their laundry to the water point for cleaning. Lastly, 37.9% of the households avoided cleaning the house daily but opted to clean them occasionally so as to reduce water use. The various water conservation strategies are a welcome move towards managing water demand, and concur with the Dublin principle that states that water is a finite resource that must be conserved. However, the amount of water used for outdoor uses (watering animals and lawn irrigation) increased significantly in the dry season compared to the rainy season. This is because of the high temperatures in the dry season hence increased rate of evaporation, transpiration and perspiration. Jointly, lawn irrigation and watering cattle accounts for 32.2% of all household water consumption in the dry season compared to 23.5% in the rainy season. Thus, the demand for household water is much higher in the dry season, but the actual domestic amount consumed is significantly reduced because of water conservation, influenced directly by water shortage. This finding is in agreement with previous studies undertaken by Rathnayaka et al. (2014), Reynaud et al. (2018), and Lu et al. (2018), who observed that water demand is higher in hot environments.

Households in rural settlements of Kapseret Sub- County had access to multiple sources of water including shallow wells, harvested rain water, river, stream, borehole, metered piped water, unmetered piped water, dams and springs. Shallow well is the most common source of water for domestic use. These are the typical sources of water in many rural areas in Kenya including in Meru (Wagner et al.,

2019) and Makueni (Kimani et al., 2015). They noted that the main sources of water in those areas included shallow wells, boreholes, taps, taps, rivers, springs, swamps. However, in Meru, due to shortage of water in dry seasons, residents bought water from vendors, a scenario that was not observed in KSC. In KSC, most of the households had a private shallow well as majority of the residents (92.8%) owned the land. Majority of the households (74.5%) used water from shallow well in the rainy season while in the dry season, the percentage is higher (82.7%). This is because in the rainy season, households collected rainwater, accounting for 16.3% of the households. Households with tanks generally used more water, as water was available within the homestead. It was concluded that there is a huge potential for rainwater harvesting. However, this potential has been constrained by financial capacity to install rainwater harvesting infrastructure, particularly tanks. In fact, 71.3% of households did not own water tanks. Only 0.5% used rainwater as their main source of water in the dry season. Such households have invested in water storage tanks with reasonably large storage capacity. It was observed that some households had invested in more than one storage tanks so as to secure their households from water shortage in the dry season. However, the generally low income averages among households in KSC limit chances of meaningful investment in water storage facilities. The average income in the area of study was sh. 21,470.30, with a majority of households (72.8%) earning not more than sh. 20,000. Thus, the lack of a reliable water supply system by both UGC government and ELDOWAS, the Water Service Provider is largely to blame for the perennial water shortages experienced by rural households of KSC in the dry season. Households, though appreciating the benefits of rain water harvesting, are constrained financially by the cost of water tanks. This limits the tank capacity they can purchase. This resonates with the findings of WWAP (2019) and

WHO/UNICEF (2021), who observed that the lack of access to clean water in rural Africa is a developmental challenge, largely attributed to insufficient budgetary allocations for development of requisite water infrastructure.

Like most typical Kenyan rural settlement, majority of the households (63.6%) fetched water manually using a rope and container while 27.5% pumped water to a tank using electricity. In addition, only 28.7% of the households had invested in a tank, while the majority, (71.3%) carry and store water in 10 and 20 liter- jerricans. This menial work has negative impact on human health, particularly of women and girls who manually fetch and carry the water, who could not afford to pump water. The presence of a tank had a moderate and positive pearson correlation coefficient of 0.487 with income. This implies that ownership of a tank is related with high income, because of the cost implication of buying and installing a tank. Thus, poor households are more prone to water shortages as their water storage equipment are of limited storage capacity. Households with better incomes, on the other hand, can afford a water tank and pump water using electricity, thus protect their members from the tedious process of fetching water manually from shallow wells every day. There was also a pearson correlation coefficient of 0.523 between ownership of a tank and housing type. More often than not, homes with permanent houses are compelled, and have the financial capacity to invest in a tank so as to secure water supply because of the larger water requirement of such houses. This agrees with the finding of Kimani et al. (2015) who observed that households with higher incomes were more likely to own larger tanks to secure themselves against water shortage.

Water shortage was a common phenomenon in KSC, particularly in dry season. It was established that 44.8% of the household experienced water shortage in the dry season. This percentage is unacceptably high in a region with high annual rainfall of

>1000mm. In the dry season, people walked for long distances, up to 2 km, looking for water when the shallow wells around their homes dry up. This perennial water shortage exposes households to water insecurity, whereby they do not have water for their domestic needs in sufficient quantities and quality. These findings relate to those of Kimani et al. (2015) who observed that residents in Makueni searched for water for more than 3 kilometers, wasting hours every day. In Meru, Additionally, the finding agree with Wagner et al. (2019) who observed seasonal water shortages in the dry season when shallow wells and streams dry up. Clearly, this demonstrates the low level of development of water supply systems in rural areas. This finding is also in line with that of Njora & Yılmaz (2020), who concluded that rural areas in Kenya are yet to attain water security, and blamed this on a 'disconnect' in the approaches that seek to address water supply issues. In addition to insufficient quantity, the quality of domestic water in KSC is also wanting. In the rainy season, 36.6% of the households accessed water from unprotected sources, while in the dry season, the number was even higher (41.1%). The unprotected sources of water are at risk of contamination, especially in the rainy season when there is runoff. These include open shallow wells, streams, rivers, dams and unprotected springs. However, to improve drinking water quality, most households purified their water at home. Majority of the households (89.6%) boiled their drinking water, 20.3% used water treatment chemicals, 2.0% bought bottled water while 1.2% sourced for water from ELDOWAS for drinking. Only 3.0% of the households perceived no danger in drinking water directly from the source without prior treatment. This has a direct implication of energy use, on one hand, and potential to intake improperly treated water and related health effects on the other hand, as the water quality is not tested after 'treatment' at home. These findings relate with the findings of WHO/UNICEF (2021) who noted that 46% of people in

Sub-Saharan Africa lack access to safe drinking water. They also agreed with those of Hope et al. (2020), Assefa et al. (2019) and WWAP (2019), who noted that millions of households in developing countries continue to access water from unprotected sources. With regard to Kenya's Vision 2030 and global SDGs, efforts towards ensuring access to adequate and safe water for all must be increased significantly, as observed by UN (2021) who noted that many countries are not on track towards providing sufficient water for their populations, and that such interventions need to be escalated.

5.2.1 Estimating Per Capita Domestic Water Consumption

Per capita domestic water consumption was computed for each household given the household domestic water consumption and household size. This is the daily average amount of water consumed per person for domestic uses including cooking and drinking, cleaning utensils, bathing, cleaning house, laundry and flushing toilets. Non-human water uses include lawn irrigation and potted plants, and watering animals including poultry, sheep and goats, pigs, cattle and donkeys. The per capita domestic water consumption was slightly lower in the dry season (41 liters) compared to the rainy season (48 liters). It is worth noting that this amount is lower than the recommended standard for basis personal use set at 50 liters (WHO, 2017). The per capita domestic water consumption was particularly lower in the dry season when households experience water shortages. As a result, the level of sanitation is compromised because households struggle to allocate the little water available for various activities. This per capita domestic water consumption in KSC is similar to that in the rural areas of Wei River Basin, China, (46.5 liters) where households accessed water from public taps. Fan et al. (2013) noted that the per capita domestic water demand was lower in areas without private sources, while households with continuous water supply used an average of 71.3 liters per person. Further, per capita domestic water consumption in KSC was generally lower than that of Cambodia which was 72 liters (Basani et al., 2008), and significantly lower compared to 113 liters in Berlin, Europe (Martin et al., 2018), which is a city.

5.2.2 Factors influencing Domestic Water Consumption

Linear regression analysis revealed a number of factors that influence domestic water consumption in both dry and rainy seasons at 95% significance level including: main housing type, household size, income of household head, distance to main water source, education level of household head and capacity of water tank.

Main housing type influenced domestic water consumption in both dry and rainy seasons. The weight of its influence was 0.360 in the rainy season, compared to 0.186 in the dry season. The relationship between the dependent and independent variables was positive, implying that households with permanent houses use more water than those in semi-permanent houses. Temporary houses utilized the least water. This is because permanent houses generally occupy more space, as they are large. As a result, a lot of water is used, particularly for cleaning the larger surface area of floors. Temporary houses in KSC included houses made of earthen floors and accounted for 37.9%. The cleaning of such floors involve sweeping and occasional smearing. As a result, daily water demand for cleaning such houses is minimal, compared to plastered or tiled floors whose cleaning involves wiping daily with water. Additionally, permanent houses usually have more rooms including bathrooms, toilets and kitchen. This implies that more water will be required to clean the additional rooms. In homes having bathrooms fitted with shower heads, more water is usually spend in showering compared to bathing from a bucket. In addition, houses with running water in a kitchen, more water is used in a sink compared to washing utensils from a container such as a bucket. This concurs with the finding of Ojeda et al. (2016) who noted that number of bathrooms in a house increases household water consumption. Similarly, Hoyos & Artabe (2017) observed that bigger houses generally consume more water in cleaning and gardening. The weight was greater in the rainy season. This can be attributed to the need for more cleaning in the rainy season due to mud and reduced cleaning in the dry season due to water conservation resulting from water shortage.

Secondly, household size influenced domestic water consumption in both dry and rainy seasons positively. Although there are shared water uses like cooking, cleaning utensils, cleaning house and laundry, an additional member increases the demand for water for their individual needs like drinking water, bathing and toilet flushing. In addition, a large family will most likely live in a larger house with more rooms. This will then demand more water for cleaning the house. Generally, a large family consumed more water compared to a smaller family. This is in line with the findings of Aho et al. (2016), Ojeda et al. (2016), Rathnayaka et al. (2014) and Fan et al. (2013) who agreed that household size influences household water consumption positively. However, the weight is very small with a coefficient of 0.162 in the dry season and 0.267 in the rainy season. This means that household size influenced household domestic water consumption only to a small extent.

Another factor that influenced household domestic water consumption was income of the household head. Higher income was associated with increases water usage in both dry and rainy seasons. This is because wealthier homes can afford bigger houses with more rooms and more water using appliances like showers and sinks. In addition, activities such as cooking are more frequent in wealthy homes. In addition, people with high incomes are likely to invest in water supply, for instance sinking a deeper shallow well or investing in a water tan. As a result, their water sources are reliable irrespective of the season, having sufficient water for their domestic needs. Thus, such homes are not forced to engage in reactive conservation strategies because of water shortages. Hoyos & Artabe (2017), Ahmad et al. (2016), Navascues & Morales (2018) and Reynaud et al. (2018) noted that high incomes support a high standard of living, hence a higher water demand. The influence of income on domestic water consumption was fairly high with a coefficient of 0.787 in the dry season and 0.404 in the rainy season. In both seasons, income levels related proportionally with household domestic water consumption. This implies that in KSC, income was a very important predictor of domestic water consumption.

Distance to main water source influenced domestic water consumption in the dry season only. There was a negative relationship between distance to main water source and household domestic water consumption, with a coefficient of -0.300 in the dry season, while the factor was not significant in the rainy season. The relationship is negative, meaning that longer distances to main water source forced people to reduce significantly the amount of water used for domestic uses. Households with easy access to water used more water than those who are constrained by distance. This resonates with the finding of Singh and Turkiya (2013) that people in close proximity to a water source tend to use more water because they have easy access to the water.

In addition, education level of head of household also influenced domestic water consumption in the rainy season only with a coefficient of 0.267. The variable was not significant in the dry season. This means that in the rainy season, households with highly educated household heads consumed more water that households of their less educated counterparts. Generally, education level is correlated with high incomes hence a better standard of living. Such households also have the capacity to engage in activities which have a high water requirement like living in a self-contained and big house. This agrees with the finding of Hoyos & Artabe (2017) who noted that the level of education had a positive influence on household domestic water demand.

Finally, capacity of water tank influenced the amount of water a household consumed in the rainy season, with a coefficient of 0.360. This was applicable only in the rainy season when rainwater was harvested. Water tanks provide water at minimal distance hence negligible human effort is used in fetching and carrying the water. In addition, a big tank provides assurance of reliable water supply. Thus, households with big water tanks generally used more water than those households with no tanks or with tanks of limited storage capacity.

5.3 Assessment of the Potential of Stormwater

Firstly, the stormwater yield in 2019 in Kapseret Sub-County was estimated as 103.60 billion liters. This amount is quite high because of sufficient rainfall coupled with the relatively high weighed CN in Kapseret basin (78.94) that was influenced mainly by soil type, slope and LULC. There was evidence of a generally gentle slope across KSC which highly supports runoff generation. It was also observed that human activities such as massive deforestation, farming, construction and various forms of development on land, have acted to reduce the water infiltration capacity of soil. The land use that occupied the largest acreage (82.77km^2) was cropland, which also had the largest CN of 85, implying very low water infiltration rates hence generation of lots of runoff. In addition, grasslands with a CN of 79 occupied a significant portion of KCS (80.73 km^2). Being a rural settlement, majority of the households engaged in crop cultivation and livestock keeping. These were represented by 77.7% and 50.3%

of the households respectively. The lowest CN of 71 was apportioned to areas covered with trees, but which occupied only 48.15 km^2 of the land in KSC. There has been significant reduction of forest cover from the initial EATEC forests that covered significant portions of KSC. It was established that only 15.8% of the households maintained woodlots. Overall, the water infiltration rates in KSC was minimal due to influence of individual land uses, which have compacted the land surface and reduced water infiltration hence increasing runoff generation. It was observed that most of the runoff was generated between the months of May and September when the rainfall amounts were highest.

The population in KSC in 2019 was 198,499 persons (KNBS, 2019). The recommended minimum per capita water consumption by the UN is 1000m^3 per year. Therefore, if harnessed, 103.60 billion liters is sufficient to supply water to the population in the study area sufficiently for domestic purposes for approximately 522 days, that is more than one year. The potential for stormwater in the area of study is therefore extremely huge, but remains untapped. This agrees with the findings of Wijesiri et al. (2019) who observed that stormwater remains an underutilized resource which can be used to alleviate water scarcity. Pathak et al. (2020) and NASEM (2016) also noted that stormwater has a high potential to augment existing sources of water. Day & Sharma (2020) appreciated the role of stormwater in reducing pressure on freshwater sources and increasing resilience of communities to the impact of climate change.

Secondly, suitable sites for stormwater harvesting were identified. The terrain in KSC is generally gently sloping. In addition, the two soil types, orthic ferrasols and humic nitosols both have moderate to high clay ratio, and have a high capability to support stormwater harvesting. Thirdly, the region receives reliable rainfall within the rainy season, of >1000mm annually. These three factors, rainfall, slope and soil type, are crucial when considering suitability for stormwater harvesting. Based on the selected criterion and weights allocated to each criteria, multi-criteria analysis established that KSC is generally suitable for stormwater harvesting. Significant portion of the land, (74.6%) in KSC is categorized as moderate to highly suitable zones for stormwater harvesting. Thus, only 25.4% included areas restricted and those of low suitability. Based on contour analysis, four most suitable sites were identified for location of dams. These sites combined occupy an area of 757800 m^2, with an estimated capacity of 3436500 m^3. If used to harness stormwater, this would provide water for domestic use for households in KSC for more than 238 days in the dry season and hence protect them from perennial water shortages.

5.4 Stormwater Utilization

It was established that only 11.4% of the households in KCS utilized the stormwater, while the majority (88.6%) did not utilize stormwater at all. As a result, a lot of the runoff generated was not utilized, hence went down the drain.

Many respondents (65.1%) attributed their inability to utilize stormwater to lack of access to stormwater, particularly in the dry season. Majority of the households (72%) did not have access to stormwater. Only 28% had access to stormwater, mostly in the rainy season, when water supply was reliable with a variety of water sources. The stormwater was found in dams, streams, swamps, along footpaths and roads, and across farms. Only a paltry 2% had access to harvested stormwater in the dry season in dams. In the dry season, the sources of water are limited as many shallow wells dry up and there is no access to rain water due to limited tank storage capacity. In addition, seasonal streams dry up. As a result, close to half of the population, (44.8%)

experience water shortage. Under these circumstances, it was established that households who accessed stormwater utilized it mostly for non-potable hence reducing demand on potable sources. Stormwater in KSC was mostly used for non-potable uses (99%), while only 1% of the residents used stormwater for cooking and drinking in the study area. The highest percentage was for watering animals in streams, swamps and dams (9.9%) and cleaning clothes (6.2%), while the smallest proportion was used for irrigation (1%), drinking and cooking (1%) and washing cars and motorbikes (0.5%). The highest percentage of users of stormwater utilized it at the water point, for instance watering animals and washing clothes at the dam. This helped them to avoid carrying many jerricans of water, considering the distance to water source was longer in the dry season. These households therefore utilized stormwater as an alternative water source for particular domestic water uses due to seasonal water shortage. This agrees with the views of Hager et al. (2021), Mankad et al. (2021), Leeuwen et al. (2019) and Luthy et al. (2020) that stormwater can be used to enhance water supply.

Another reason why households did not utilize stormwater was because of quality concerns, as 26.7% perceived stormwater as unclean. These households, despite having access to stormwater did not utilize it completely as they viewed it as unsafe. Another 8.4% of the residents had a reliable water supply as they had access to other cleaner sources of water for domestic use. Thus, they did not need to utilize stormwater as stormwater was ‘unclean’. This finding agrees with that of Lopez-Ruiz et al. (2020) who called this the ‘yuck factor’ that discourages water reuse.

5.4.1 Determinants of Stormwater Utilization

From the model, the following factors were identified to influence stormwater utilization: access to stormwater, perception that stormwater is unclean, awareness that stormwater is a source of water and domestic outdoor uses as seen in Table 4.38.

Access to harvested stormwater was the principal factor in stormwater utilization as it was the variable with the strongest weight. Access to stormwater increased the probability that a household will utilize stormwater by a factor of 35.041. However, a majority of the residents (72%) did not have access to stormwater. Many of these households could only access stormwater in streams and on the roads during the rainy season, when there was no shortage of water. A very small percentage had access to harvested stormwater in the dry season as only 2.0 % of the respondents were in close proximity to a dam, at a time when water shortage was being experienced. This low level of access therefore limited to a large extent the level of stormwater utilization.

Secondly, outdoor household uses of water influenced stormwater utilization. Outdoor household water uses include watering livestock, washing cars and bikes and lawn irrigation. These are water intensive domestic activities and influence significantly the household water consumption patterns. Because of their high water demand, households preferred to utilize stormwater particularly in the dry season when water shortage is experienced, because of the low quality requirement of these water use activities. As a result, the scarce, higher quality water was preserved for potable uses while stormwater was used to water animals and irrigate surfaces. Residents usually took animals to the water point because of the longer distances to water source in the dry season. From the binary logistic model, engagement in outdoor activities increases the probability of utilizing stormwater by a factor of 3.645. This implies that engaging in outdoor activities increased the likelihood that a household will utilize stormwater by a factor of 3.645. Households who engaged in outdoor uses were more likely to utilize stormwater.

In addition, awareness that stormwater is a source of water influenced the likelihood of stormwater utilization. An increase in the level of awareness that stormwater is a source of water lead to an increase in the probability of utilizing stormwater by factor of 0.253. Thus, households that are aware that stormwater is a source of water for domestic use were more likely to utilize the resource. Generally, individuals that lack awareness about stormwater being a source of water are likely to view it as wastewater which should be quickly channeled to streams and rivers. The weight for the variable was relatively weak, evidenced by the fact that although a high percentage of residents (81.2%) were aware that stormwater is a source of water for domestic use, there was minimal stormwater utilization, at only 11.4%. Thus, although awareness of stormwater being a source of domestic water influenced stormwater utilization positively, not all individuals that had this awareness utilized stormwater.

Finally, perception that stormwater is unclean reduced the likelihood of stormwater utilization. Surface water, including stormwater is generally of lower quality compared to underground sources. This is because runoff transports pollutants from various sources including agriculture, industries and domestic wastes. The area is an agricultural dominant zone, with stormwater having high levels of turbidity in the rainy season. Low water quality was cited by 26.7% of the respondents as the reason why they did not utilize stormwater. As a result, they preferred not to utilize stormwater, and those who did used it mostly for non-potable uses. This perception reduced the chance of utilization of stormwater by a factor of 0.043. This finding agrees with that of Mankad et al. (2019) and Coombes et al. (2002) who noted that communities are not likely to utilize stormwater unless they are satisfied that it is treated appropriately.

5.5 Challenges of Stormwater Management

It was established that the level of stormwater management in KSC was very low. Although 93.1% of the respondents agreed that it is important to manage stormwater, only 16.6% of the households managed stormwater in their farms. This means that although they appreciate the need to manage stormwater, there exist some constraints to successful stormwater management. This finding on low level of stormwater management resonates with that of Kimani et al. (2015) & Shin & McCann (2017) on low uptake of adoption of water harvesting technologies in Makueni. However, the few households that managed stormwater in KSC employed various strategies towards stormwater management. The highest percentage of respondents maintained vegetation especially cover crops and trees in the farms to protect the soil (15.1%), while 5.7% of the residents adopted green infrastructure and LID around their homes, especially by planting grass in the compounds and reducing pavementation. In addition, 5.2% of the households harvested stormwater for farming usually by digging trenches in the farms and used the water to grow such crops as vegetables and arrow roots. Another 5.2% of the respondents practiced agroforestry. Households practiced different strategies based on their knowledge, skills and interests, either to benefit from stormwater utilization, or to mitigate the deleterious impacts of stormwater.

The largest percentage of respondents who did not practice any form of stormwater management (41.8%) attributed that to lack of land for stormwater harvesting. They noted that dams or pans utilize substantial pieces of land. Another 24% of the respondents noted that they did not have the requisite skills to manage stormwater, while 19.6% noted that they did not have the financial capacity to engage in stormwater harvesting. It is worth noting that no household interviewed had an individually owned dam or pan in their farms, although majority of respondents appreciated the need for stormwater harvesting for use in the dry season. This is directly attributed to the cost of excavation of such stormwater harvesting infrastructure. Other households accounting for 23.8%, did not see the need to manage stormwater since stormwater was not problematic to them. These are probably households that experience minimal runoff in their farms. A minority, 8.7% of the respondents did not manage stormwater because of ignorance. This includes households who had no knowledge about stormwater management options and benefits. In addition, 3.2% of the respondents were of the opinion that because stormwater can be destructive, it should be evacuated fast. These households then adopted the conventional strategy of stormwater management where stormwater drainage is enhanced to ensure fastest evacuation of stormwater. These households dug trenches in their farms for that purpose.

From analysis of responses from households and key respondent, the following challenges were identified with regard to stormwater management in KSC: lack of education on stormwater management, unavailability of land, lack of financial and technical capacity and poor governance due to institutional setbacks.

Lack of education on stormwater management was the greatest challenge to stormwater management. It was established that an increase in knowledge on SWM increased probability of stormwater management by a factor of 40.582 as seen in Table 4.39. Thus, households that have knowledge on importance and strategies of SWM are likely to practice them as opposed to individuals who are ignorant on the same. Although an overwhelming majority of respondents had a general awareness that it is important to manage stormwater, it was found that 54% of households lacked education on the benefits and strategies of stormwater management. In addition, this education seemed haphazard, with 34% having been educated on both strategies and benefits of stormwater management, 8% had knowledge on benefits of stormwater management only, while only 4% had been educated on strategies of stormwater management. Kimani et al. (2015), Salehi et al. (2021) and Martini & Nelson (2014) agreed on the role of education in stormwater management. They argued that individuals will only adopt SWM strategies that they are knowledgeable about.

Secondly, it was established that unavailability of land was a constraint to SWM. Linear regression on household responses revealed that unavailability of land restricts stormwater management. From the model, an increase in land size increases chance for SWM by a factor of 1.061. Thus, households with large farms are more likely and able to practice SWM. In addition, 41.8% of the respondents attributed their inability to manage stormwater to unavailability of enough land. The key respondent also noted that unavailability of public land hinders the development of stormwater management infrastructure by the UGC. This is in line with the conclusion of Luthy et al. (2020) and Kimani et al. (2015) who observed that stormwater harvesting infrastructure usually require a lot of space, and yet land in the suitable areas may not be readily available.

Thirdly, lack of financial and technical capacity was a constraint to SWM in KSC. Stormwater management requires significant financial investment. All the strategies of stormwater management including maintenance of vegetation, development of stormwater harvesting infrastructure such as dams, and maintenance of the reservoirs require funding. 19.6% of the residents related their inability to manage stormwater to lack of financial capacity as presented in Table 4.60. The lack of monetary resources limits engagement in various stormwater management strategies. This finding is in line with that of Gullo et al. (2020) and Luthy et al. (2020) who noted that the high cost of SWM strategies usually impact negatively on the uptake of these strategies. On the part of Uasin Gishu County, there is a lack of financial commitment towards stormwater management. For the period 2015-2020, allocation for stormwater management projects was unspecified as shown in Table 4.64. Another 24% of the respondents noted that they lacked technical knowhow to engage in stormwater management. It was found that the technical capacity for development and maintenance of stormwater management infrastructure in UGC is wanting, with insufficient personnel and equipment. This greatly reduced SWM in the area as households lack the much needed technical support. This finding resonates with those of Bassi et al. (2017), who observed that the absence of locally available specialized expertise is a major constraint to SWM. Ahmed & Yakimowich (2007) and Shin & McCann (2017) noted that lack of requisite equipment reduces uptake of specific SWM strategies.

Finally, the lack of a supportive institutional framework is a challenge to SWM in KSC. Although the Water Act 2016 envisioned robust management of water resources including stormwater, it was discovered that there has been insufficient institutional intervention to develop stormwater management infrastructure. The enforcement of existing legislation with regard to stormwater management as stipulated in the Water Act (2016) has another impediment to sustainable stormwater management. The Water Storage and Harvesting Authority is yet to be felt in KSC. In addition, the devolution of water resource management to the County level is yet to be actioned by the UGC with regard to SWM. In fact, only 3.5% of the residents had experienced

UGC's involvement in stormwater management. This is in the following ways; educating citizens on importance and strategies of stormwater management (3.2%) construction of dams (1.2%) and distribution of tree seedlings (0.7%).

Generally, there is lack of a proper strategy towards stormwater management in the Uasin Gishu County. The prerogative to develop stormwater harvesting infrastructure lies largely with the Member of County Assemblies. Currently, there is lack of a clearly outlined water harvesting policy. In fact, there is no operational water policy that guides on the management of water (and stormwater) resources in Uasin Gishu County. The UGC water policy, 2016 is yet to be gazetted.

In addition, the role of the County Government in coordinating stormwater management activities, providing financial and technical support and educating the populace cannot be overemphasized. The Constitution of Kenya, 2010, envisaged that the National Water Harvesting and Storage Authority would take a leading role in enforcing water harvesting strategies. Their impact in UGC is yet to be felt because there lacks proper coordination between the institutions established under the Water Act, 2016 and the UGC government. WWAP (2019) and Bassi et al. (2017) emphasized the role of institutional intervention for financial and technical support. The county did not have a budgetary allocation purposely for stormwater management up until 2019. Secondly, the technical personnel and equipment for stormwater management were insufficient. Finally, amongst respondents who had received education on stormwater management, only 3.2% had received the education on stormwater management benefits and strategies from the County government. This implies that there is still a large opportunity for local authorities to disseminate knowledge to communities on stormwater management strategies and benefits.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter presents summary of the findings, conclusions and recommendations from the study. In addition, areas for further research are suggested. The presentations are made following the order of study objectives.

6.2 Summary of Findings

The following is the summary of findings from the study.

6.2.1 Domestic Water Consumption

The level of water consumption for each domestic water activity was determined for both dry and rainy season. It was established that household domestic water consumption in KSC in the dry season was found to be 149 liters and 168 liters in the dry and rainy seasons respectively. In addition, per capita domestic water consumption in the dry and rainy seasons was 41 liters and 48 liters respectively, which falls below the recommended WHO standard of 50 liters per person per day. Water consumption for routine activities including drinking, cooking, bathing, toilet flashing, cleaning house and cleaning utensils was higher in the rainy season than in the dry season. This is because in the dry season when some households experience water shortage, they conserved water, thus a lower water consumption value for these activities compared to the rainy season when there was plenty of water. Water conservation reduced domestic water consumption.

The factors that influenced household domestic water consumption include household income, household size, distance to water source, main housing type, education level of household head and capacity of water tank. Increase in household income, level of education, water storage capacity and household size led to an increase in household domestic water consumption. The distance to the water source had a negative influence on the amount of water used in a household. Households with permanent housing consumed more water than those with temporary and semi- permanent houses.

6.2.2 Potential of Stormwater

Stormwater yield in KSC was influenced by rainfall amount, catchment area, LULC, soil type and slope. Stormwater yield in KSC in 2019 was estimated to be 353.38mm, which is equivalent to 103.60 billion liters. This volume of water is able to sustain the Kapseret Sub-County population for 521 days at 1000m^3 per capita per year. Thus, if harvested and stored appropriately, this amount is sufficient alleviate perennial water shortages experienced in the dry seasons.

Suitable zones and sites for stormwater harvesting were identified. The factors that were considered in siting stormwater infrastructure included slope, soil, proximity to streams, roads, airport and institutions and LULC. It was established that significant portions of KSC (74.66%) is categorized as moderate to highly suitable for stormwater harvesting. Thus stormwater harvesting infrastructure can be developed at various locations to harvest the high volumes of runoff generated each year during the rainy seasons within the Kapseret basin. Specifically, four suitable sites for stormwater harvesting, with a total holding capacity of 3.43 billion liters were mapped.

6.2.3 Factors Influencing Stormwater Utilization

Stormwater utilization in the area of study was found to be low. Only 11.4% of the residents utilized stormwater, mostly for non-potable uses. Only 1% utilized stormwater for drinking and cooking. The biggest proportion used stormwater to water animals at the source. The factors that influenced stormwater utilization include access to stormwater, perception that stormwater is unclean, awareness that stormwater is a source of water, and domestic outdoor uses. The principal predictor to stormwater utilization was identified to be access to stormwater.

6.2.4 Challenges of Stormwater Management

Stormwater management is practiced minimally. Only 16.6% of households practice stormwater management in their farms. The major challenges to stormwater management were identified as: lack of education on stormwater management, unavailability of land, lack of financial and technical capacity and lack of supportive institutional framework.

6.3 Conclusions

Based on the findings from the study, the following conclusions were made:

First, water security is far from being achieved in the area of study. Towards achieving water security as envisaged in SDG 6 and Vision 2030, KSC is not on track. In the dry season, up to 44.8% of households experienced seasonal water shortages despite the region having moderate to heavy rainfall. This is evidenced by a higher average distance to the main source in the dry season. Coupled with the manual methods of fetching and carrying water, people are faced with negative effects on their health. In addition, many households do not access water from protected sources in both dry and rainy seasons, which expose them to health risks. It was concluded that water supply in KSC has not been given due attention by the relevant institutions, including Water Service Provider in conjunction with the UGC government, as envisaged in the Water Act, 2016, to ensure that all citizens have access to safe and adequate drinking water. As a result of rampant water shortages in the dry seasons, households adopted various water conservation strategies including rainwater harvesting, water reuse, enhancing water efficiency and utilizing water at the water point. Water conservation played a significant role in reducing water consumption. It was concluded that water conservation is an important strategy in managing water demand.

Secondly, huge volumes of runoff, (over 103.02 billion liters in 2019) are generated during the rainy seasons. This amount, if harnessed, is sufficient to meet domestic water needs in KSC during the dry season. Although the region is generally suitable for stormwater harvesting, SWH infrastructure is barely developed. It is therefore concluded that there is a high untapped potential for stormwater to augment existing sources and alleviate water shortage in the dry season.

In addition, stormwater utilization was low in KSC. The level of stormwater utilization was influenced by a multiple of factors including: access to stormwater, perception that stormwater is unclean, awareness that stormwater is a source of water and domestic outdoor uses. The principal predictor of stormwater utilization was access to harvested stormwater. It was therefore concluded that increasing access to harvested stormwater in dams and pans can significantly increase stormwater utilization.

Finally, the level of stormwater management in KSC was generally low, at 16.6%. The main challenges to stormwater management were identified as: lack of land for stormwater management, lack of financial and technical capacity and lack of education among individuals concerning the various stormwater management strategies and benefits. It is concluded that community education on SWM strategies and benefits will go a long way in encouraging uptake of various SWM strategies.

6.4 Recommendations

From the conclusions of the study, the following recommendations were made.

6.4.1 Policy Recommendations

With regard to water resource management, the County Water Policy needs to be finalized and its publication hastened. Within the water policy, there is need to develop clear stormwater management guidelines for implementation in the county. This policy will then guide the provision of the requisite financial and technical resources for sustainable SWM, and ensure that communities are adequately educated on SWM benefits and best practices.

Secondly, although the Constitution of Kenya guarantees all Kenyans access to safe water in sufficient quantity as a socio-economic right, households in many rural areas and informal areas in towns still grapple with water insecurity. The equalization fund must be operationalized fully so as to provide sufficient funding for water distribution amongst rural and marginalized communities.

6.4.2 Theory Oriented Recommendations

Firstly, cognizant of the fact that water demand is constantly increasing, there is need to expand water supply by including all the untapped water sources so as to augment the existing sources. Stormwater harvesting provides an opportunity to alleviate seasonal water shortages given the huge volumes of runoff generated during rainfall events in the rainy season. Integrated water resource management must be actualized as envisaged in the IWRM approach, which the Government of Kenya adopted.

Secondly, institutions in the water management sector must work seamlessly towards provision of this critical resource. The Uasin Gishu government in conjuction with the National Water Harvesting and Storage Authority needs to plan, budget for, develop and maintain SWM infrastructure based on appropriate technologies. This should include collection, storage, treatment of stormwater and eventual distribution of water to households.

6.4.3 Recommendations Based on Planning Practice

Firstly, water resource planners must proactively develop infrastructure for a rapidly increasing population. ELDOWAS and other stakeholders must prioritize expansion of their existing water distribution networks to rural and peri- urban areas.

Secondly, whilst many households within KSC experienced water shortages in the dry season, there is a huge untapped potential of SWM in the area of study to augment the existing water sources. The County Government, in conjunction with the Water Service Provider needs to mobilize resources so as harness stormwater, hence develop a more reliable water supply system that will cushion communities from the social, economic and health effects associated with water scarcity, hence uphold human dignity. This should entail distribution of treated water to homesteads.

Finally, since stormwater utilization in the area is generally low, there is need to educate the population on stormwater utilization. Households should be encouraged to utilize stormwater for the non-potable uses so as to reduce pressure on the potable sources. In addition, education campaigns need to be carried out to sensitize the public on the social, economic and environmental benefits of stormwater utilization.

6.4 Suggestions for Further Research

The following areas could be considered for further research.

i. To assess the interconnection between climate change and stormwater in UGC.
ii. To assess the role of stormwater management in aquifer recharge in KSC.
iii. To assess the quality of stormwater in KSC with a view to recommend the appropriate end uses

REFERENCES

Abubakar, I. R. (2019). Factors influencing household access to drinking water in Nigeria, *Util. Pol. 58*, 40-50

Ahmed, A. R., & Yakimowich, P. E. (2007). *Stormwater Management-Challenges and Solutions*. Georgia Institute of Technology.

Aho, M.I & Akpen, G.D & Ivuwe, P. (2016). Determinants of Residential Per Capita Water Demand of Makurdi Metropolis. *Nigerian Journal of Technology. 35* (2), 424-431.

Ajmal, M., Waseem, M., Kim, D., & Kim, T.-W. (2020). A Pragmatic Slope-Adjusted Curve Number Model to Reduce Uncertainty in Predicting Flood Runoff from Steep Watersheds. *Water*, *12*(5), 1469. doi:10.3390/w12051469

Akram, F., Rasul, M., Khan, M., & Amir, M. (2014). A Review on Stormwater Harvesting and Reuse. *International Journal of Environmental, Earth Science and Engineering*, *8*(3),178– 187.

Al-Ghobari, Hussein; Dewidar, Ahmed; Alataway, Abed (2020). Estimation of Surface Water Runoff for a Semi-Arid Area Using RS and GIS-Based SCS-CN Method. *Water, 12*(7), 1924–. doi:10.3390/w12071924

AMEC,Center for Watershed Protection, DeboandAssociates,JordanJonesandGoulding,& Atlanta Regional Commission. (2001). *Georgia Stormwater Management Manual Volume 1*: Stormwater Policy Guidebook First Edition. United States of America. http://www.georgiastormwater.com/.

Anim, D.O., Fletcher, T.D., Pasternack, G.B., Vietz, G.J., Duncan, H.P. and Burns, M.J., (2019). Can catchment-scale urban stormwater management measures benefit the stream hydraulic environment? *Journal of Environmental Management*, 1-11.

Anwar, F. (2019). *Managing Stormwater: Practices and Challenges for Reuse and Recycling*.

Armitage, N., Vice, M., Fisher-Jeffes, L., Winter, K., Spiegel, A., & Dunstan, J. (2013). The South African guidelines for sustainable drainage systems. *Report TT558/13. Pretoria: water research commission*.

Arnold, J. G., Kiniry, J. R., Srinivasan, R., Williams, J. R., Haney, E. B., & Neitsch, S. L. (2013). *SWAT 2012 input/output documentation*. Texas Water Resources Institute.

Assefa, Y.T.; Babel, M.S.; Sušnik, J.; Shinde, V.R. (2019). Development of a Generic Domestic Water Security Index, and Its Application in Addis Ababa, Ethiopia. *Water* , *11*(1), 37.

Atampugre, G., Botchway, D. V. N., Esia-Donkoh, K., & Kendie, S. (2016). Ecological modernization and water resource management: A critique of institutional transitions in Ghana. *GeoJournal*, *81*(3), 367-378.

Ayeni, A. O., Kapangaziwiri, E., Soneye, A. S. O., & Engelbrecht, F. A. (2015). Assessing the impact of global changes on the surface water resources of Southwestern Nigeria. *Hydrological Sciences Journal*, *60*(11), 1956-1971.

Baalousha, H. M. & Ouda, O. K. M. (2017). Domestic water demand challenges in Qatar. *Arabian Journal of Geosciences*, *10*(24): 537–549.

Basani, M., Isham, J., & Reilly, B. (2008). The determinants of water connection and water consumption: Empirical evidence from a Cambodian household survey. *World development*, *36*(5), 953-968.

Bassi, A., Cuéllar, A., Pallaske,G., & Wuennenberg, L., (2017) *Stormwater Markets: Concepts and applications.* IISD REPORT. The International Institute for Sustainable Development.

Batalini D., Macedo D., Ambrogi C., and Mario E., (2019) Stormwater volume reduction and water quality improvement by bioretention: Potentials and challenges for water security in a subtropical catchment. *Sci. Total Environ. 647*: 923–931

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., (2008) Climate Change and Water. *Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva*.

Berland, A., Shiflett, S. A., Shuster, W. D., Garmestani, A. S., Goddard, H. C., Herrmann, D. L., & Hopton, M. E. (2017). The role of trees in urban stormwater management. *Landscape and urban planning*, *162*, 167-177.

Biswas, A. K. (2008). Integrated water resources management: is it working?. *International Journal of Water Resources Development*, *24*(1), 5-22.

Bolstad, P., & Lillesand, T. M. (1991). Automated GIS integration in landcover classification. In Technical papers ACSM-ASPRS annual convention, Baltimore, 1991. 3, 23-32

Boserup, E. (1965). *The Conditions of Agricultural Growth*. Allen & Unwin, London.

Brehm, J. M., Pasko, D. K., & Eisenhauer, B. W. (2013). Identifying key factors in homeowner's adoption of water quality best management practices. *Environmental Management*, *52*(1), 113-122.

Buraihi, F. H., & Shariff, A. R. M. (2015). Selection of rainwater harvesting sites by using remote sensing and GIS techniques: a case study of Kirkuk, Iraq. *Jurnal Teknologi*, *76*(15).

Burns, M., Fletcher, T., Hatt, B., Anthony, R., & Walsh, C. (2010). *Can Allotment-scale Rainwater Harvesting Manage Urban Flood Risk and Protect Stream Health.* 7th International Conference on sustainable techniques and strategies for urban water management. 1-10

Chang, Ni-Bin; Lu, Jia-Wei; Chui, Ting Fong May; Hartshorn, Nicholas (2018). Global policy analysis of low impact development for stormwater management in urban regions. *Land Use Policy, 70*, 368–383.

Christman, Z., Meenar, M., Mandarano, L., & Hearing, K. (2018). Prioritizing suitable locations for green stormwater infrastructure based on social factors in Philadelphia. *Land*, *7*(4), 145.

Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote sensing of environment*, *37*(1), 35-46.

Coombes P.J., Kuczera,G., Kalma,J.D., Argue,J.R.(2002). An Evaluation of the Benefits of Source Control Measures at the Regional Scale. *Urban Water, 4*, 307–320.

Cosgrove, W. J., and D. P. Loucks (2015), Water management: Current and future challenges and research directions, *Water Resource Research, 51*, 4823–4839.

Cousins, J. J. (2018). Remaking stormwater as a resource: Technology, law, and citizenship. Wiley Interdisciplinary Reviews: *Water, 5*(5), e1300.

Creswell, J. W. (2009). *Research design: Qualitative, Quantitative and Mixed Methods Approach.* University of Nebraska-Lincoln: SAGE Publications, California, USA.

Critchley W and Siegert K (1991) *A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production*. Food and Agriculture Organization of the United Nations, Italy.

Crouch, Melissa; Jacobs, Heinz; Speight, Vanessa (2021). Defining domestic water consumption based on personal water use activities. *Journal of Water Supply: Research and Technology-Aqua 70* (7): 1002–1011.

Crump, K. S. (2003). Quantitative risk assessment since the Red Book: Where have we come and where should we be going. *Human and Ecological Risk Assessment 9*(5): 1105-1112.

Dandy, G. C., Marchi, A., Maier, H. R., Kandulu, J., MacDonald, D. H., & Ganji, A. (2019). An integrated framework for selecting and evaluating the performance of stormwater harvesting options to supplement existing water supply systems. *Environmental Modelling & Software*, 122, 104554.

Daniel, E. B., Camp, J. V., LeBoeuf, E. J., Penrod, J. R., Dobbins, J. P., & Abkowitz, M. D. (2011). Watershed modeling and its applications: A state-of-the-art review. *The Open Hydrology Journal*, *5*(1).

Day, J. & Sharma, A. (2020) Stormwater harvesting infrastructure systems design for urban park irrigation: Brimbank Park, Melbourne case study. *Journal of Water Supply: Research and Technology-Aqua.69* (8): 844–857.

Day, St John (2009). Community-based water resources management. *Waterlines, 28*(1), 47–62.

Deletic, A., Zhang, K., Jamali, B., Charette-Castonguay, A., Kuller, M., Prodanovic, V., & Bach, P. M. (2019). Modelling to support the planning of sustainable urban water systems. In *New Trends in Urban Drainage Modelling: UDM 2018 11* (pp. 10-19). Springer International Publishing.

Dietz, M. E., Clausen, J. C., & Filchak, K. K. (2004). Education and changes in residential nonpoint source pollution. *Environmental Management*, *34*(5), 684-690.

Dowsett, B. (1994). *The Management of Stormwater: From a Problem to a Resource: an Initial Report Prepared for the Water Board (Sydney-Illawarra-Blue Mountains) as Part of the Sydney Water Project*. Sydney Water Project.

Falkenmark M, Widstrand C. (1992) Population and Water Resources: A Delicate Balance. *Popul Bull. ;47* (3), 1–36.

Falkenmark, M. (2003). *Water management and ecosystems: Living with change* (Vol. 9). Stockholm: Global water partnership.

Fan L, Liu G, Wang F, Geissen V, Ritsema CJ (2013) Factors Affecting Domestic Water Consumption in Rural Households upon Access to Improved Water Supply: Insights from the Wei River Basin, China. *PLoS ONE 8*(8): e71977.

FAO, IFAD and WFP (2014). *The State of Food Insecurity in the World 2014. Strengthening the enabling environment for food security and nutrition*. Rome, FAO

Fisher, D. R., & Freudenburg, W. R. (2001). Ecological modernization and its critics: Assessing the past and looking toward the future. *Society & natural resources*, *14*(8), 701-709.

Gallo, E., Bell, C., Mika, K., Gold, M., & Hogue, T. S. (2020). Stormwater Management Options and Decision-Making in Urbanized Watersheds of Los Angeles, California. *Journal of Sustainable Water in the Built Environment, 6*(2), 04020003.

GOK (2021). *Vision 2030 Flagship Projects Progress Report* (FY 2019/2021)

Goonetilleke, A., Liu, A., Managi, S., Wilson, C., Gardner, T., Bandala, E. R., Walker L., Holden J., Wibowo M.A., Suripin S., Joshi H., Bonotto D.M. & Rajapaksa, D. (2017). Stormwater reuse, a viable option: Fact or fiction?. *Economic Analysis and Policy*, *56*, 14-17.

Goulden, S., Portman, M. E., Carmon, N., & Alon-Mozes, T. (2018). From conventional drainage to sustainable stormwater management: Beyond the technical challenges. *Journal of Environmental Management, 219*, 37–45. doi:10.1016/j.jenvman.2018.04.066

Government of Kenya , GOK (2006). *Disaster Risk Reduction Strategy for Kenya 2006 – 2016: A Resilient and Safer Nation*. Government Printer. Nairobi, Kenya

Government of Kenya ,GOK (2016). *The Water Act*. Government Printer. Nairobi, Kenya

Grubb, M., Koch, M., Thomson, K., Sullivan, F., & Munson, A. (2019). *The'Earth Summit'Agreements: A Guide and Assessment: An Analysis of the Rio'92 UN Conference on Environment and Development* (Vol. 9). Routledge.

Hager, J. K., Mian, H. R., Hu, G., Hewage, K., & Sadiq, R. (2021). *Integrated planning framework for urban stormwater management: one water approach*. Sustainable and Resilient Infrastructure, 1–22.

Hammes, G., Thives, L.P., & Ghisi, E (2018). Application of stormwater collected from porous asphalt pavements for non-potable uses in buildings. *Journal of Environmental Management, 222*, 338–347.

Harvey, P. A. & Reed, R. A. (2004). *Rural Water Supply in Africa: Building Blocks for Handpump Sustainability*. WEDC, Loughborough University, UK

Hope, R., Thomson P., Koehler J., & Foster T., (2020) Rethinking the economics of rural water in Africa, *Oxford Review of Economic Policy*, *36*(1), 171–190.

Hoyos, D., & Artabe, A. (2017). Regional differences in the price elasticity of residential water demand in Spain. *Water resources management*, *31*(3), 847-865.

Junjie, M., & Yingxin, M. (2022). The Discussions of Positivism and Interpretivism. *Global Academic Journal of Humanities and Social Sciences*, 4(1), 10-14.

Karki, R., Srivastava, P., Bosch, D. D., Kalin, L., Lamba, J., & Strickland, T. C. (2020). Multi-variable sensitivity analysis, calibration, and validation of a field-scale SWAT model: building stakeholder trust in hydrologic and water quality modeling. Transactions of the ASABE, 63(2), 523-539.

Khalil, R. (2017). Determination of Potential Runoff Coefficient Using GIS and Remote Sensing. *Journal of Geographic Information System*, *9*(6), 752-762.

Kimani, M. W., Gitau, A. N., & Ndunge, D. (2015). Rainwater harvesting technologies in makueni county, Kenya. *International Journal of Engineering and Science*, *5*(2), 39-49.

Kipyego, S., & Ouma, Y. (2018). Analysis of nonpoint source pollution loading on water quality in an urban-rural river catchment using GIS-PLOAD model: Case study of Sosiani River watershed. *Civil and Environmental Research*, *10*(3), 70-84.

KNBS (2019) *2019 Kenya Population and Housing Census, Volume II: Distribution of Population by Administrative Units*. KNBS, Nairobi.

KNBS (2010) *The 2009 Kenya Population and Housing Census. "Counting Our People for the Implementation of Vision 2030*. KNBS, Nairobi

Koutiva, I., Gerakopoulou, P., Makropoulos, C., & Vernardakis, C. (2017). Exploration of domestic water demand attitudes using qualitative and quantitative social research methods. *Urban Water Journal*, *14*(3), 307-314.

Kubbinga, B (2015*). Road Runoff Harvesting in the Drylands of Sub-Saharan Africa: Its Potential for Assisting Smallholder Farmers in Coping with Water Scarcity* *and Climate Change, Based on Case Studies in Eastern Province, Kenya*. Masters thesis submitted to Free University Amsterdam.

Larson, B., Minten, B., & Razafindralambo, R. (2006). Unravelling the linkages between the millennium development goals for poverty, education, access to water and household water use in developing countries: evidence from Madagascar. *The Journal of Development Studies*, *42*(1), 22-40.

Leeuwen, J. V., Awad, J., Myers, B., & Pezzaniti, D. (2019). Introduction to Urban Stormwater: A Global Perspective. *In Urban Stormwater and Flood Management (pp. 1-28).* Springer, Cham.

Lenton, R., Lewis, K., & Wright, A. M. (2008). Water, sanitation and the millennium development goals. *Journal of International affairs*, 247-258.

Leonard, R., Walton, A., Koth, B., Green, M., Spinks, A., Myers, B., Malkin, S., Mankad, A., Chacko, P., Sharma, A., & Pezzaniti, D. (2014). *Community Acceptance of Water Sensitive Urban Design : Six Case Studies Goyder Institute for Water Research*. Goyder Institute for Water Research Technical Report Series No. 14/3. Adelaide, Australia.

Lim, M.H. & Leong, Y.H. & Tiew, K.N. & Seah, H. (2011). Urban stormwater harvesting: A valuable water resource of Singapore. *Water Practice and Technology*. *6*(4).

LMNO Eng., (2012). *V-notch (Triangular) weir discharge calculator and equations. LMNO Engineering*, Research and Software, Ltd., USA.

Lopez-Ruiz, Samara; Moya-FernÃ¡ndez, Pablo J.; GarcÃa-Rubio, Miguel A.; GonzÃ¡lez-GÃ³mez, Francisco (2020). Acceptance of direct potable water reuse for domestic purposes: evidence from southern Spain. *International Journal of Water Resources Development, (37)*5, 772-792.

Louangrath & Sutanapong (2018). Validity and reliability of survey scales. *International Journal of Research & Methodology in Social Science, 4*(3), 99-114.

Lu, S., Gao, X., Li, W., Jiang, S., & Huang, L. (2018). A study on the spatial and temporal variability of the urban residential water consumption and its influencing factors in the major cities of China. *Habitat International*, *78*, 29-40.

Lundy, L., Revitt, M., & Ellis, B. (2018). An impact assessment for urban stormwater use. *Environmental Science and Pollution Research, 25*(20), 19259–19270.

Lusigi E.M., Mbuge D.O., Obiero J.P.O., Ondieki S.C., & Ndiba P.K. (2017) 'Quality Assessment of Rain and Stormwater Runoff in Nairobi City Industrial and Sub-urban Areas'. *International Journal of Innovative Research in Engineering and Management. (4)*1

Luthy, R. G., Sharvelle, S., & Dillon, P. (2019). Urban Stormwater to Enhance Water Supply. *Environmental Science & Technology*, *53*(10), 5534-5542.

Mankad, A. Walton, A. Gardner, J. (2019). Psychological predictors of public acceptance for urban stormwater reuse. *Journal of Hydrology, 572*, 414–421.

Mao, K., Zhang, Q., Xue, Y., & Weeks, N. (2020). Toward a socio-political approach to water management: successes and limitations of IWRM programs in rural northwestern China. *Frontiers of Earth Science, 14*(2), 268–285.

Marsden Jacob Associates, Marsden, J., & Pickering, P. (2006). *Securing Australia's Urban Water Supplies: Opportunities and Impediments: a Discussion Paper*. Marsden Jacob Associates.

Martini, N.F., and K.C. Nelson. 2014. "The Role of Knowledge in Residential Lawn Management." *Urban Ecosystems 18*(3), 1031–1047.

Massoud, M. A., Kazarian, A., Alameddine, I., & Al-Hindi, M. (2018). Factors influencing the reuse of reclaimed water as a management option to augment water supplies. *Environmental Monitoring and Assessment, 190*(9), 1-11.

Mbilinyi, B. P., Tumbo, S. D., Mahoo, H., & Mkiramwinyi, F. O. (2007). GIS-based decision support system for identifying potential sites for rainwater harvesting. *Physics and Chemistry of the Earth, Parts A/B/C, 32*, 1074-1081.

Metto R. A., Kiptum C. K., & Kipkorir E. C. (2020) Effects of Infiltration Trenches and Bio-Retention Ponds on Stormwater Runoff in Eldoret Town. *International Journal of Engineering Research & Technology (IJERT) 9*(5).

Migosi, P. (2014). Effects of urban storm water management strategy in reducing flooding; a case of Mombasa. *Int. J. Manag. Stud. Res*, *2*(4), 82-90.

Mimi, Z., & Smith, M. (2000). Statistical domestic water demand model for the West Bank. *Water International*, *25*(3), 464-468.

Ministry of Agriculture, Livestock and Fisheries (2017). C*limate Risk Profile for Uasin Gishu County*. Kenya County Climate Risk Profile Series. Nairobi, Kenya

Mitchell, V., Deletic, A., Fletcher, T. D., Hatt, B. E., & McCarthy, D. T. (2007). Achieving multiple benefits from stormwater harvesting. *Water science and technology*, *55*(4), 135-144.

Mol, A. P. (2002). Ecological modernization and the global economy. *Global environmental politics*, *2*(2), 92-115.

Moser, C. A., & Kalton, G. (1985). Survey methods in social investigation Aldershot. *UK: Gower*.

Mwihaki, Nyika Joan (2018). Decentralisation as a tool in improving water governance in Kenya. *Water Policy, 20* (2), 252–265.

National Academies of Sciences, Engineering, and Medicine (2016). *Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits*. Washington, DC: The National Academies Press

National Research Council (2012) *Water Reuse. Potential for Expanding the Nation's Water Supply through reuse of Municipal Wastewater*. Washington, DC: National Academy Press

National Water Policy (NWP) (1999). *The Republic of Kenya*, Nairobi, Government Printer

Natural Resources Conservation Service, NRCS. (1986). "*Urban hydrology for small watersheds."* Technical release No. 55, U.S. Dept. of Agriculture, Washington, D.C.

Nauges, C., & Van Den Berg, C. (2009). *Perception of health risk and averting behavior: An analysis of household water consumption in Southwest Sri Lanka*.

Nauges, C., & Whittington, D. (2010). Estimation of water demand in developing countries: An overview. *The World Bank Research Observer, 25*(2), 263-294.

Neitsch, S. L., Arnold, J. G., Kiniry, J. R., & Williams, J. R. (2011). *Soil and water assessment tool theoretical documentation version 2009*. Texas Water Resources Institute.

Newburn, D., A. Alberini, A. Rockler, and A. Karp. 2014. *Adoption of Household Stormwater Best Management Practices. CANRP Extension Bulletins*, University of Maryland, College Park.

Ng'etich, M. J., Kiplagat, A. K., & Ng'etich, J. (2018). An Investigation into Domestic Water Consumption Patterns in Iten Town, Kenya. *Africa Environmental Review Journal*, 3(1), pp-200.

Ngigi, S.N. (2003*). Rainwater Harvesting for Improved Food Security: Promising Technologies in the Greater Horn of Africa*. Trondeihm, Norway. Longhorn; 2003.

Njora, B. &, Yılmaz, H (2021). Evaluation of Water Accessibility, Distribution, Water Use Policies and Management in Kenya. *International Journal of Water Management and Diplomacy: 1*(3)*,* 5-16

O'Connor, G. A., Elliott, H. A., & Bastian, R. K. (2007). Degraded Water Reuse: an Overview. *Journal of Environmental Quality, 37*(5), 158-168.

Oageng, I. & Mmopelwa, G. P. (2014) Water consumption patterns in a rural setting in Ngamiland district, Botswana: the case of Boro village: *Journal of Water, Sanitation and Hygiene for Development. 4* (4), 720–726.

OECD (2015). *Stakeholder Engagement for Inclusive Water Governance, OECD Studies on Water,* OECD Publishing, Paris, France.

Ojeda, A, Álvarez, C. R., Ramos, M., Soto, F. (2016). *Determinants of domestic water consumption in Hermosillo, Sonora, Mexico. Journal of Cleaner Production*, *142:*1901-1910.

Okedi, J., & Armitage, N. P. (2019). Benefits of real time control for catchment scale stormwater harvesting in Cape Town, South Africa. In *New Trends in Urban Drainage Modelling: UDM 2018 11* (pp. 587-591). Springer International Publishing.

Ondigo, D.A., Kavoo, A.M. & Kebwaro, J. (2018) Water Resources and Management under Increasing Urban Demography: A Kenyan Perspective—A Review. *Journal of Water Resource and Protection, 10,* 919-938.

Oyerinde, A. O. & Jacobs H. E. (2022) Determinants of household water demand: a cross-sectional study in South West Nigeria. *Journal of Water, Sanitation and Hygiene for Development 12* (2), 200–207.

Parajuli, P. B., Nelson, N. O., Frees, L. D., & Mankin, K. R. (2009). Comparison of AnnAGNPS and SWAT model simulation results in USDA- CEAP agricultural watersheds in south-central Kansas. *Hydrological Processes: An International Journal*, *23*(5), 748-763.

Pathak, S., Garg, R. D., Jato-Espino, D., Lakshmi, V., & Ojha, C. S. P. (2019). Evaluating hotspots for stormwater harvesting through participatory sensing. *Journal of Environmental Management, 242*, 351–361.

Payne, E. G., McCarthy, D. T., Deletic, A., & Zhang, K. (2019). Biotreatment technologies for stormwater harvesting: critical perspectives. *Current opinion in biotechnology*, *57*, 191-196.

Philp, M., Mcmahon, J., Heyenga, S., Marinoni, O., Jenkins, G., Maheepala, S., & Greenway,M.(2008).*Review of Stormwater Harvesting Practices Urban Water Security* Research Alliance Technical Report No . 9. Camberwell, Victoria,Australia.

APPENDICES

Appendix I: Questionnaire for Households

UNIVERSITY OF ELDORET

SCHOOL OF ENVIRONMENTAL STUDIES

DEPARTMENT OF ENVIRONMENTAL MONITORING, PLANNING AND MANAGEMENT

SECTION A: INTRODUCTION

I am a Postgraduate student at University of Eldoret undertaking a research entitled "The Potential for Stormwater in Augmenting Domestic Water Supplies in Kapseret Sub County, Uasin Gishu County". I request you to be a participant in my research by completing this questionnaire. The information collected will be used for academic purposes only and will be handled with utmost confidentiality. Thank you.

SECTION B: BACKGROUND INFORMATION

1. Which ward do you live in?

S/No.	Ward	Tick
1	Megun	
2	Ngeria	
3	Simat/Kapseret	
4	Kipkenyo	

2. What is the GPS location of your home? ________________________
3. What is your home ownership type ?

S/No.	Home Ownership Type	Tick
1	Rented	
2	Owned	
3	Other, specify____________	

4. What is your main housing type?

S/No.	Main Housing Type	Tick
1	Temporary	
2	Semi-permanent	
3	Permanent	

5. What is the main construction material for floor?

S/No.	Main construction material for floor	Tick
1	Mud/earth	
2	Wood	
3	Concrete/plaster	
4	Tiles	

6. What is the main construction material for wall?

S/No.	Main construction material for wall	Tick
1	Polythene	
2	Mud/earth	
3	Wood	
4	Iron sheet	
5	Bricks	
6	Blocks	
7	Building stones	

7. What is the main roofing material?

S/No.	Main roofing material	Tick
1	Polythene	
2	Grass	
3	Iron sheets	
4	Tiles	

8. What is the size of your land in acres?______________________
9. How do you utilize your land in acres?

SNo	Land Use Type	Acreage
1	Farming /Cultivation	
2	Grazing/Grassland	
3	Settlements/covered by buildings	
4	Access roads	
5	Woodlots/tree cover	
6	Others specify	

SECTION C: HOUSEHOLD CHARACTERISTICS

10. What is your household size?___________
11. Kindly provide the following details

S/No	Age	Gender	Education Level	Occupation	Monthly income	Tick if she/he fetches water
Household head						
Member 1						
Member 2						

Member 3						
Upto last member						

SECTION D: DOMESTIC SOURCES OF WATER

12. List all the sources of water for domestic use in your locality

S/No.	Source of Water	Tick
1.	Shallow well	
2.	Harvested rainwater	
3.	River	
4.	Stream	
5.	Dam	
6.	Borehole	
7.	Metered water	
8.	Unmetered_water	
9.	Spring	
10.	Water kiosk/Vendors	

What is your main source of water in the dry season?

S/No.	Source of Water	Tick
1.	Shallow well	
2.	Harvested rainwater	
3.	River	
4.	Stream	
5.	Dam	
6.	Borehole	
7.	Metered water	
8.	Unmetered_water	
9.	Spring	
10.	Water kiosk/Vendors	

11. What is your main source of water in the rainy season?

S/No.	Source of Water	Tick
1	Shallow well	
2	Harvested rainwater	
3	River	
4	Stream	
5	Dam	
6	Borehole	
7	Metered water	

8	Unmetered_water	
9	Spring	
10	Water kiosk/Vendors	

12. Is your main water source is protected?

S/No.	Response	Tick
1	Yes	
2	No	

13. List your other sources of water in the rainy season

S/No.	Source of Water	Tick
1	Shallow well	
2	Harvested rainwater	
3	River	
4	Stream	
5	Dam	
6	Borehole	
7	Metered water	
8	Unmetered_water	
9	Spring	
10	Water kiosk/Vendors	

14. List your other sources of water in the dry season.

S/No.	Source of Water	Tick
1	Shallow well	
2	Harvested rainwater	
3	River	
4	Stream	
5	Dam	
6	Borehole	
7	Metered piped water	
8	Unmetered piped water	
9	Spring	
10	Water kiosk/Vendors	

15. How do you purify your drinking water?

S/No.	Response	Tick
1	We don’t treat as it is already safe	
2	Boiling	
3	Using chemicals like chlorine	
4	It is treated before distribution	
5	We buy bottled water	

16. How is water fetched in your home?

S/No.	Response	Tick
1	Manually using rope and gallon	
2	Using a pulley	
3	Hand pump	
4	Electric pump	
5	Rainwater is channeled into a tank	
6	It is piped	
7	Other-specify__________________	

17. Gender of the person who usually fetches water in your home

S/No.	Response	Tick
1	Male	
2	Female	

18. How is water stored in your home?

S/No.	Response	Tick
1	In 20, 10 and 5 liter containers	
2	In a tank	

19. If stored in 5,10 or 20 liter containers, how many of these do you use in day?_______
20. If water is stored in a tank in 18 above, what is the capacity of your tank in liters?_________________
21. How many days does water in the tank last when full?_______________
22. How much do you pay to fetch/pump water in shillings per month?_______________
23. The tank is-

S/No.	Response	Tick
1	Underground	
2	On the ground	
3	Elevated	

24. What material is the tank made of?

S/No.	Response	Tick
1	Plastic	
2	Concrete	
3	Other-Specify_______________	

25. If you buy water, how much do you pay in Ksh. per month?_______________

26. Do you experience water scarcity in the dry season?

S/No.	Response	Tick
1	Yes	
2	No	

27. How do you conserve water when you experience water scarcity?

S/No.	Response	Tick
1	No conservation	
2	Reusing water	
3	Cleaning house occasionally	
4	Cleaning clothes occasionally	
5	Using little amounts of water and avoid wastage	
6	Watering animals at the water point	
7	Washing clothes at water point	
8	Others- specify____________________	

28. What is the distance to your main water source in the rainy season? _______________
29. What is the distance to your main water source in the dry season? _________________

SECTION E: DOMESTIC WATER USES

30. Indicate the quantity of water used in the rainy season in liters for various home uses

S/No.	Response	Quantity in liters
1	Cooking and drinking	
2	Cleaning utensils	
3	House cleaning	
4	Bathing	
5	Laundry-daily	
6	Laundry-occasionally	
7	Flushable toilets	
8	Poultry	
9	Sheep/goats	
. 10	Cattle/donkeys	
. 11	Washing cars/motorbikes	
. 12	Potted plants/garden	
. 13	Others- specify____________________	

31. Indicate the quantity of water used in the dry season in liters for the various activities at home.

S/No.	Response	Quantity in liters
. 1	Cooking and drinking	
. 2	Cleaning utensils	
. 3	House cleaning	
. 4	Bathing	
. 5	Laundry-daily	
. 6	Laundry-occasionally	

. 7	Flushable toilets	
. 8	Poultry	
. 9	Sheep/goats	
. 10	Cattle/donkeys	
. 11	Washing cars/motorbikes	
. 12	Potted plants/garden	
. 13	Others- specify____________________	

32. If you keep domestic animals, indicate the number.

S/No.	Response	Number
1	Cows	
2	Sheep	
3	Goats	
4	Donkeys	
5	Poultry	
6	Others, specify___________	

33. If your source of water is metered supply, how much water in m^3 do you use per month in the dry season___________
34. If your source of water is metered supply, how much water in m^3 do you use per month in the rainy season___________
35. How much do you pay per month for metered water supply? _____________

SECTION F: STORMWATER UTILIZATION

36. Do you have access to stormwater?

S/No.	Response	Tick
1	Yes	
2	No	

37. If yes in 36 above, the stormwater is found in:

S/No.	Response	Tick
1	Dam	
2	Pan	
3	Stream	

38. Who constructed the dam/pan?

S/No.	Response	Tick
1	Colonialists	
2	National government	
3	County government	
4	Private/Public institution	
5	Community	
6	An individual	

39. Who uses the dam/pan?

S/No.	Response	Tick
1	Institution	
2	Individual household	
3	Community-many households	
4	It is not being utilized	

40. Is the stormwater treated?

S/No.	Response	Tick
1	Yes	
2	No	

41. Do you use stormwater?

S/No.	Response	Tick
1	Yes	
2	No	

42. If yes in 41, for what purposes do you use the stormwater?

S/No.	Response	Tick
1	Drinking and cooking	
2	Cleaning house	
3	Cleaning utensils	
4	Bathing	
5	Laundry	
6	Watering domestic animals	
7	Lawn/garden irrigation	
8	Washing motor vehicles/motorbycicles	
9	Others, specify________________	

43. If yes in 41 above, how do you fetch stormwater?

S/No.	Response	Tick
1	Fetching manually	
2	Pumping	
3	We use it at source/water point	
4	Others-specify____________	

44. If no in 41 above, why?

S/No.	Response	Tick
1	We don't have access	
2	We don't need to-water is sufficient	
3	The stormwater is unsafe-poor quality	
4	Others-specify____________	

SECTION G: STORMWATER MANAGEMENT

Statement	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
45. Stormwater is a source of domestic water					
46. You have knowledge on stormwater management strategies					

47. There is need to harvest and store stormwater for use in the dry season					
48. It is important to harvest and manage stormwater					

49. Specify the kind of knowledge that you possess on stormwater management

S/No.	Response	Tick
1	No knowledge	
2	Stormwater harvesting e.g. dam	
3	Maintaining vegetation-trees and grass	
4	Low impact development/ Green infrastructure	
5	Good farming practices like ploughing across contours, agroforestry	
6	Others, specify______________________	

50. What, in your view are the benefits of stormwater management?

S/No.	Response	Tick
1	Water will be used in the dry season for non-potable use e.g. irrigation	
2	Water may be used in the dry season for potable use e.g. cooking	
3	It will reduce flooding downstream	
4	Stormwater causes destruction e.g. on roads	

51. Do you manage stormwater in your farm?

S/No.	Response	Tick
1	Yes	
2	No	

52. If yes in 51 above, which strategies have you employed?

S/No.	Response	Tick
1	Stormwater harvesting e.g. dam	
2	Maintaining vegetation-trees and grass	
3	Low impact development/ Green infrastructure	
4	Good farming practices like ploughing across contours, agroforestry	
5	Others, specify______________________	

53. If no in 51 above, why?

S/No.	Response	Tick
1	I have not thought about it	
2	I don’t have the financial capacity to engage in stormwater management	
3	Stormwater is not an issue in our farm	
4	I don’t have the land to allocate to stormwater harvesting e.g. dam	

5	I don't have the skill to engage in stormwater management	

54. Have you ever been educated on stormwater management?

S/No.	Response	Tick
1	Yes	
2	No	

55. If yes in 54 above, by whom?

S/No.	Response	Tick
1	School	
2	County government	
3	Through media	
4	Other, specify____________	

56. How is the county government engaged in stormwater management in your locality?

S/No.	Response	Tick
1	Not involved	
2	Educating residents on stormwater management (SWM)	
3	Construction of dams/pans	
4	Maintenance of dams/pans	
5	Distribution of seedlings	
6	Others, specify__________________	

57. In your opinion, what are the challenges to stormwater management?

S/No.	Response	Tick
1	Lack of awareness	
2	Lack of finances to construct dams/pans and distribute water to households	
3	Lack of finances to plant trees, maintain vegetation	
4	Lack of knowledge and skills on SWM strategies	
5	Lack of technical knowhow to maintain/manage existing dams	
6	Lack of land for stormwater harvesting	
7	Others, specify____________________	

SECTION H: ADDITIONAL INFORMATION

58. Kindly provide any other information not captured in this questionnaire which may be relevant to this study
____
____
____
____

Thank you.

Appendix II: Interview Schedule for Key Informant

I am a Postgraduate student at University of Eldoret. I am undertaking a research titled "The Potential for Stormwater in Augmenting Domestic Water Supplies in Kapseret Sub County, Uasin Gishu County". I request you to be a participant in my research by completing this questionnaire. The information collected will be used for academic purposes only and will not be divulged.

1. Number of dams in Uasin Gishu and in the various wards of Kapseret Sub-County in the years indicated.

	2013	2014	2015	2016	2017	2018	2019
Uasin Gishu County							
Langas Ward							
Kipkenyo Ward							
Kapseret/Simat Ward							
Ngeria Ward							
Megun Ward							

2. Kindly fill in the table below with regard to stormwater reservoirs in 2019

S/No	Co-ordinate/Location	Capacity	Ownership	Management status

3. List all the known sources of water for domestic use in Kapseret Sub County

i. ____________________________

ii. ____________________________

iii. ____________________________

iv. ____________________________

4. a) Give the percentage of accessibility and coverage of residents of Kapseret Sub County to safe drinking water as at 2019________________________

b) What is the average distance to water source in meters? _________________________

5. Explain the plans and achievements of the UG County government towards provision of clean water to all residents of rural settlements

____

____

____

____

____

6. Provide information on plans or strategies by Uasin Gishu County to harvest stormwater in Kapseret Sub County____

____

____

____

____

7. How much funds are allocated for water supply in Uasin Gishu County and in Kapseret Sub County in particular in the last 5 years in Ksh?

Year	Uasin Gishu County-All water supply projects	Uasin Gishu County-Stormwater Harvesting	Kapseret Sub County-All water supply projects	Kapseret Sub County-Stormwater Harvesting
2015/2016				
2016/2017				
2017/2018				
2018/2019				
2019/2020				

8. a) List the community support initiatives (education, technical or financial) that the Uasin Gishu county government is engaged in towards stormwater development?

____

____

____

____

____

b) List the institutions and stakeholders engaged in stormwater management in Kapseret sub-county

____

____

____

____

9. Provide a list of the policies at county level that aim at stormwater management (e.g. on stormwater harvesting, land uses that encourage infiltration, etc.).

____

____

____

b) Are these policies fully implemented?

Yes	
No	

c) Outline the challenges to stormwater management?

i. ____

ii. ____

iii. ____

iv. ____

10. Does the UGC have the following in relation to stormwater management:

S/No	Item	Number	Are these sufficient?
1	Professional staff e.g. engineers	Cadre______________number____ Cadre______________Number____ Cadre______________Number____ Cadre______________Number____	
2	Technical personnel e.g. machine operators	Cadre______________number____ Cadre______________Number____ Cadre______________Number____ Cadre______________Number____	

11. Kindly provide information on stormwater management equipment available at the county (e.g. the various types of machines and their numbers)

S/No	Type of Equipment	Number	Is this number sufficient?

12. Kindly provide any other information that you may find useful in this study

____

____

____

____

____

Thank you.

Signed: ………………………..

Gladys Biwott

PHD Candidate

University of Eldoret

Appendix III: Observation Schedule

Date______________________

1. Evidence of runoff

S/No	Observable parameter e.g. flashfloods by the roadsides, farms	Area /Coordinate	Slope	Land use	Vegetation cover	Remarks
1						
2						
3						
4						

2. Stormwater Harvesting Infrastructure

S/No	Observable Parameter e.g. dams, pans	Area/Coordinate	Uses of Stormwater	Level of siltation	Remarks
1					
2					
3					
4					

3. Any other relevant observations

____

____

____

____

____

Appendix IV: Interview Schedule for Eldoret Metereological Station

I am a Postgraduate student at University of Eldoret. I am undertaking research titled "The Potential for Stormwater in Augmenting Domestic Water Supplies in Kapseret Sub County, Uasin Gishu County". I request you to be a participant by providing the following data in the attached sheets. The information collected will be used for academic purposes only. Thank you.

1. Total yearly data for 35 years for UGC between 1985 to 2019.
2. Average monthly rainfall in MM for every year between 2010-2019 for UGC.
3. Daily rainfall in MM for 2019 for UGC.

Signed: ………………………..

Gladys Biwott

PHD Candidate

University of Eldoret

Appendix V: Rainfall Data

a) Daily rainfall data-2019

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1	0	0	0	0	0	9.8	3	6.4	80.4	TR	0.2	1.3
2	0	0	1.5	0	0	0	0	0.6	0.2	19.3	2.7	10.2
3	0	0	9.3	0	0	0.3	4.5	0	1.6	14.7	8	11.8
4	7.3	0	1.2	0	0	5	13.5	1.5	1	0	9.5	15.2
5	0.4	0	2.4	0	0	11.8	9.1	0	9.6	0	1.8	23.6
6	TR	0	TR	0	0.9	0	0.6	2.7	20.7	TR	8.8	3.2
7	0	0	0	0	0	TR	0	5.5	TR	5.8	5	1.8
8	TR	0	0	0	TR	50.3	3	11.7	11.7	0	0	0
9	0	0	TR	0	11	31.8	TR	52.8	1.1	0	TR	13.8
10	0	0	0	0.6	2.3	2	0	7.9	2.4	9.3	0.2	8.6
11	0	0	0	TR	0	2.5	0	14	9.7	1.3	0	0
12	0	0	0	0	TR	13	7.2	TR	7.2	0.9	0.2	1.6
13	0	0	0	0	0.5	8.1	1.8	7.7	0.5	1.4	TR	1.2
14	0	0	0	0	0.2	TR	10.8	23.8	0.3	1.8	0	3.7
15	0.6	0	0	0	0	27.2	2.6	6.3	5	0.3	0	TR
16	4	0.2	0	TR	0	1	0	11.5	0	0	0	0
17	1.5	0	0	0	0	43.4	0	0	0	0.3	0	0
18	0	0	0	0	0	3.1	0	25	1.6	21.3	0	0
19	5.5	0	0	0	0	0	0	17.8	1.1	27.6	0	0
20	0	TR	0	0	10.2	0	0	6.5	0	27.8	0	0
21	TR	1.4	0	0.3	24.7	0.1	59	3.5	0	14	4.7	1
22	17.5	0	0	7.8	0	1.1	2	2.1	2.6	4.6	11.8	0
23	0	5.3	0	43.5	0.3	TR	1.8	9	46.4	2.2	28	15.9
24	0	4.5	0	2.9	2.9	1.7	0.7	1.3	TR	11.5	14	2.8
25	0	10.4	0	0	9.3	3	0.4	0	6.5	0	1.2	0
26	0	0	6.9	1.5	0	2.8	0	1	0.3	0	0	3.6
27	0	0	0	15.1	TR	0	16.4	8.1	8.2	1	0	37.1
28	0	0	7.4	16.4	0	0	0	19.8	13.3	8.3	0	14.8
29	0	0	0	0	0	2.5	1.1	12.6	0	22.5	14.3	0
30	0		0	0	0	5.2	0	0	0	21.1	4.6	0
31	0		0		TR		13.5	27.6		1.1		0

b) Monthly rainfall data for 10 years (2010-2019)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
2009	12.9	0.6	8.2	147.9	134.5	91	100.4	105.7	102	68.7	14.3	137.5
2010	83.5	203.3	88.6	64.6	323.9	77.6	202	161	106.2	101.4	24.2	25.3
2011	6.7	33.7	75.7	114.3	88.8	219.8	207.2	298.5	94.4	72.4	264.8	18.4
2012	0	12.7	13.8	209.4	382	220.7	141.1	298.1	212.4	104.4	92.5	153.6
2013	48.6	15.4	158.5	304.1	145	181.1	145.7	197.8	168.1	95	160.9	106.4
2014	38.3	60.1	86.4	51.4	185.1	91.5	166.8	272.1	83.1	216.8	61.3	31.4
2015	7.6	78.7	17.5	255.9	150.6	105.1	118.7	144.7	56.8	140.8	278.9	89
2016	64.3	7	100	190.5	246.5	147.1	207.4	171.8	102.7	36.1	29.6	TRACE
2017	69.1	39.8	47.9	148.5	50.1	74.4	197.3	265.4	149.9	270.4	92.3	5.5
2018	6.6	42.2	143.6	357	243.4	233.2	199.1	188.5	20.7	62	5.7	76.3
2019	36.8	21.8	28.7	88.1	72.1	218.9	154.4	360.7	151	218.7	116.1	192.9

c) Annual rainfall data for 35 years (1985-2019)

YEAR	RAINFALL IN MM	YEAR	RAINFALL IN MM
1984	624.9	2004	1225.7
1985	936.1	2005	1220
1986	770.9	2006	1634.4
1987	1147.7	2007	1534.5
1988	991.1	2008	1622.7
1989	1253.3	2009	923.7
1990	1009.5	2010	1461.6
1991	999.3	2011	1494.7
1992	1094.6	2012	1840.7
1993	689.4	2013	1726.6
1994	999.3	2014	1344.5
1995	985.9	2015	1594.9
1996	1089.9	2016	1312.4
1997	1213.5	2017	1485.6
1998	1709	2018	1578.2
1999	1458.6	2019	1660
2000	1170		
2001	1534.5		
2002	1319.4		
2003	1277.9		

Appendix VI: Nacosti Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 737896

Date of Issue: 21/August/2019

RESEARCH LICENSE

This is to Certify that Ms.. GLAYDYS BIWOTT of University of Eldoret, has been licensed to conduct research in Uasin-Gishu on the topic: THE POTENTIAL OF STORMWATER IN AUGMENTING DOMESTIC WATER SUPPLIES IN KAPSERET SUB-COUNTY, UASIN-GISHU COUNTY, KENYA for the period ending : 21/August/2020.

License No: NACOSTI/P/19/721

737896

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

Appendix VII: Research Authorization from UGC

REPUBLIC OF KENYA
COUNTY GOVERNMENT OF UASIN GISHU

Tel. NOs:direct line:053-2016215
053-2016000
053-2016125

Fax: +254-053-2062884
Website:www.uasingishu.go.ke
Email:info@uasingishu.go.ke

THE CHAMPIONS

When Replying, Please Address to:
County Secretary
Uasin-Gishu County
P.O. Box 40 – 30100
Eldoret, Kenya.

REF: UGC/ADM.1/31/GEN/2020/VOL.I/(2) **19 May, 2020**

Ms. Gladys C. Biwott,
P.O. Box 1776 - 30100,
ELDORET.

APPLICATION FOR AUTHORIZATION TO CARRY OUT RESEARCH WITHIN THE COUNTY GOVERNMENT

Your letter in which you made the above request is relevant.

Authority is hereby granted to you to carry out your research within Uasin Gishu County Government, in Kapseret Sub-County for your academic use and we request you to share your findings with the Office of the undersigned. Your findings may be useful in addressing water shortages in the County.

By copy of this letter, the Chief Officer, Environment, Water, Natural Resources, Tourism & Wildlife Management is notified accordingly.

Edwin Bett
COUNTY SECRETARY/
HEAD OF COUNTY PUBLIC SERVICE

c.c. Chief Officer, Environment,

Appendix VIII: Similarity Report

University of Eldoret

Certificate of Plagiarism Check for Synopsis

Author Name	GLADYS CHELAGAT BIWOTT SES/DPHIL/017/14
Course of Study	Type here...
Name of Guide	Type here...
Department	Type here...
Acceptable Maximum Limit	Type here...
Submitted By	titustoo@uoeld.ac.ke
Paper Title	ASSESSING THE POTENTIAL OF STORMWATER IN AUGMENTING DOMESTIC WATER SUPPLIES IN KAPSERET SUB-COUNTY, UASIN-GISHU COUNTY, KENYA
Similarity	11%
Paper ID	994071
Submission Date	2023-10-02 09:48:38

Signature of Student Signature of Guide

Head of the Department

* This report has been generated by DrillBit Anti-Plagiarism Software