ANALYSIS OF HOUSEHOLD WATER DEMAND, DISTRIBUTION AND COMMUNITY MANAGEMENT STRATEGIES IN NYANGORES SUB-CATCHMENT, BOMET COUNTY, KENYA

By

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DECLARATION

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

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I confirm the work reported in this thesis was carried out by the candidate and has been my approval as the Supervisor.

Signature... Date...

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DEDICATION

To my beloved mother Taplelei, dear wife Milcah and children for their love and encouragement throughout this study.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

DEFINITIONS OF KEY TERMS AND CONCEPTS

Community: This is a social group of any sizes whose members reside in a specific locality, share resources and often have a common culture and historical heritage.

Distance to water source: Distance to water source is an indicator of availability and access to water demand by households. Significant amount of time is spent by women in rural villages to haul water from water sources to their homes (Dale, 1990). This variable requires the actual measuring of distance between the selected households and the closest water access point, then computing an average distance. The London School of Hygiene (2009) states that water access points should be a maximum of 500 meters from every household.

Family size: Family size is the actual number of respondent's family members. It is a reflection of the quantity of household water demand and use and is central to any measurement of socio-economic status of rural families (Trivedi, 1963).

Income: The income indicator is used to describe the living standards of the sub-catchment community and the ability to meet the cost of water demand. For the purposes of this study, the average annual earnings of all members of the family was used as a measure of income.

Livelihood: Comprises capabilities, assets and activities required for living.

Livestock holding: Livestock holding plays an important role in the socio-economic status of the local communities. Livestock provides a regular supplementary income and employment not only to producers in rural areas but also to very large number of people engaged in livestock related business. It is an important occupation and source of family income. Livestock holding size is also a determinant of the amount of livestock water requirement.

Size of land holding: Size of land holding refers to the number of acres of cultivable land possessed by a household. Land holding is an important part of the physical asset base.

Strategic management: Strategic management is a future oriented conception which consists of analysis, decisions and actions an organization undertakes to create and sustain competitive advantage.

Sub-catchment: Means a small area of land bound by hills or mountains from which all run-off water flows to the same low point or into ground water system. The low point could be a lake, dam or the mouth of a river where it enters the ocean.

Time taken to fetch water: Figures on time taken to fetch water is a reflection of the length of the queue at water access point because it takes time to fill the containers. This is especially true if water is available only for a short period each day.

Unaccounted for water: Is the difference between the quantity of water produced for distribution in the network and the quantity of water billed. UfW consists of the technical losses due to leakage and commercial losses due to illegal connection and unbilled customers.

Water distribution management: Function related to the management, maintenance of structures, pipes, valves, pumps, meters or any other associated equipment used in connection with the water supply.

ACRONYMS AND ABBREVIATIONS

ASL	-	Above Sea Level
CWAM	-	Co-operate Water Allocation Model
DFID	-	Department for International Development
EF	-	Environmental Flows
EWAS	-	Environmental Water Allocation System
FAO	-	Food and Agricultural Organisation
GIS	-	Geographic Information System
GWP	-	Global Water Partnership
HRBA	-	Human Rights Based Approach
IWAM	-	Integrated Water Allocation Model
IWMI	-	International Water Management Institute
IWRM	-	Integrated Water Resources Management
KARI	-	Kenya Agricultural Research Institute
MDGs	-	Millennium Development Goals
MWI	-	Ministry of Water and Irrigation
NEMA	-	National Environmental Management Authority
NWRMS	-	National Water Resources Management Strategy
NWSS	-	National water services strategy
SCAMP	-	Sub-Catchment Management Plan
SPA	-	Service Provision Agreement
SPSS	-	Statistical Package for Social Sciences

TLU	-	Tropical Livestock Unit
UfW	-	Unaccounted for Water
UNCSD	-	United Nations Commission on Sustainable Development
UNEP	-	United Nation Environmental Programme
UNWWAP	-	United Nations World Water Assessment Programme
WAP	-	Water Allocation Plan
WARMA	-	Water Resources Management Authority
WDM	-	Water Demand Management
WHO	-	World Health Organisation
WRI	-	World Resource Institute
WSPs	-	Water Service Providers
WSS	-	Water Supply Services

ABSTRACT

Access to quality water remains a key indicator of an improved social and economic life of any community. Due to an increasing human population, changes in land use activities and climate variability, Nyangores Basin in Kenya has been under pressure and for this reason, availability and access to quality and sufficient quantity of water has been adversely affected. Despite government plans to ensure all households access piped water; this has not been achieved as coverage is still very low. The main cause of lack of access to quality water from improved sources for household use is unclear. In addition, household access, distribution and management of improved water demand including rural water supply coverage and maintenance of water distribution systems in the basin is not documented. The objectives of this study were to determine the magnitude of household water demand, identify key factors that influence the magnitude of water demand and distribution and to examine the effectiveness of the current water use management strategies in Nyangores sub-catchment. The study employed descriptive statistics based on survey responses from a total of 300 households picked from Silibwet, Bomet and Sigor divisions. Household level data was supplemented with key informant interviews of 20 professionals from the Ministry of Water and Irrigation, Water Service Board and WRMA officials. The study also relied on secondary data from the National Housing and Population Census report and the meter reading reports at the District offices. Data was entered, coded and analysed using SPSS version 19 and Ms-excel. Results indicate that income, household size and distance from homesteads to water sources are major determinants of domestic water demand. Human population has been growing rapidly and is putting a lot of pressure on available water resources, whose quality has greatly deteriorated due to intensified human activities such as agriculture and livestock production. The current mean water demand stands at 9,745 m^3 per day, which is largely met by unsafe water sources. Women and girls bear the greatest brunt of water related access constraints because they spent a lot of time fetching water and this also exposes them to health and safety risks. The expansion of piped water supply is slow with only 5.3% coverage since 2003. The community water use management strategies are below 30% and UfW is 53.77% up from a benchmark of 25%. Non-payment of water bills is increasing at the rate of 4 % per month. Management strategies currently employed include rationing, public education on efficient water use while metering, pricing and enforcement of legislation on water governance are employed on a limited extent. The study recommends the county and national governments to promote watershed and basin protection, harnessing of underground water resources and investment in more rain water harvesting infrastructure to reduce reliance on rivers. It is important to promote efficient use of water by the local community, promote growth of non-agricultural income generating activities to create effective demand for water and aim to supply safe water to within a radius of 200 metres from homes.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Water is one of the most important natural resources because it is viewed as key to prosperity and wealth (Arbue's *et al*., 2003). However in the last few decades, many countries have witnessed an emerging problem of falling water tables and aquifers getting depleted (Brown, 2001). In addition, water systems and resources are unable to provide basic functions to the rapidly growing population due to threat posed by pollution arising from various human activities (Gichana, 2014).

According to the American Water Works Association (1999), 11 % of the global population or 783 million people are still without access to clean water. The world population will continue to grow and will not only affect the demand for water but also its cost. For this reason, per capita water use is expected to decline with higher population densities. It is well documented that lack of access to quality and adequate water contributes to prevalence of poverty in the society. According to Jerald(2008) and Swaminathan (2001), less than 10 countries have about 60% of globally accessible water, suggesting that even though water is abundant, its availability and accessibility for drinking, agriculture and industrial use are limited and unevenly distributed geographically. For households to fully benefit from an improved water supply, it must have indoor access to safe and reliable water sources. However, very little attention is paid to modern scientific approaches for protecting headwater catchments, important for replenishing the surface water systems (Sharma *et al*., 1996; Furst, 2014). While this is almost always found in developed countries, such access is far from reality in developing countries.

The location of adequate supplies of water for domestic and industrial use has shaped the geographic distribution of population, its quality of life and culture. Adequate supply of quality water is central to the integrity of the environment and the maintenance of the ecosystem (Govt. of Australia, 2009) and (Veronica, 2010). It enormously contributes to economic productivity and social wellbeing of the human population (GWP, 2000). UNEP (2000) estimated that in 2000, 20% and 50% respectively of the world's population lacked safe drinking water and access to safe sanitation systems hence leading to serious water shortages and waterborne related diseases. With the world's population growing at the rate of 80 million people annually, there is need to add about 64 billion m^3 of water annually (GWP, 2000).

Due to rapid population growth and changes in socio-economic activities, urbanization and industrialization and the water- intensive lifestyles has greatly contributed to a global water crises (UNEP, 2000). Globally, fresh water and water resources are unevenly distributed in regions such as Asia and Pacific, Europe and Central Asia, Latin America and Caribbean, North America and West Asia where overall fresh water consumption has increased six fold between 1900 and 1995. As the state's population grows and industries such as mining, agriculture and horticulture expand, the competition for accessing water resources has increased. The demand for water resources has doubled over the past 20 years and is expected to double again by 2020 (Water and Rivers Commission, 2000a).

Although domestic water consumption accounts for only 7% of the total water use in Africa (Hinrichsen *et al*., 1997), the benefits related to an improved water supply, such as effects on health, time savings and high productivity are quite immense.

Kenya like many other developing countries is facing formidable freshwater planning and management challenges. Less than 65% of the population has access to safe drinking water (Furst & Hermegger, 2014). In spite of the crucial nature of access to quality water demand and distribution for sustainable development and improved livelihoods, its decline is becoming a worldwide problem. Whittington, (2007) found that only one third of the population in Kenya has access to improved water facilities while the rest are water stressed.

High water demands and lack of effective and sustainable strategies for addressing natural and man-made problems affecting water resources including climate variability projects Kenya to be a physically and economically water stressed by 2025 (Mati, 2005) ad (Seckler *et al*., 1998). However, current reports indicate that about 58% of the people living within the Kenya's major basins have no access to portable water, making them vulnerable to extreme water shortage despite the government's target to have provided water to all by the year 2000 (Kenya and UNICEF, 1998).

According to WRI(2007) Kenya briefing report, increased abstraction and declining access to downstream water users and the lack of regulations compounded by high level of corruption impacted upon the rights of access and distribution of water supply, rendering majority of the people in Nyangores and other basins excluded from access to safe drinking water for extended periods of time. The scarcity of water has led to huge and ever mounting water related problems. This scarcity is linked to climate change, demand that exceed available water resources and most importantly unsustainable use (Ogallo, 1996; Orie, 1995).

Water demand and availability in the Mara basin in Kenya is reported to have decreased due to high population growth rate of 7%, increased demand for food, rapid economic growth and climate change (Gichana, 2014). This has led to many other challenges such as inability to meet the basic human need of 25 litres of water per capita per day for all people. In addition, the low flow of most rivers of the world including Nyangores are on average maintained below 80% at all times, and this represents a threat to ecologically sustainable development and livelihoods, absolute water scarcity and subsequent conflicts (Cave *et al*., 2003). During the dry period, people make frequent visits to Nyangores River, a tributary of Mara basin to abstract water for domestic and livestock needs, wash clothes, vehicles, bathe and swim because other sources of water such as rainwater or pipe water are lacking.

SCMP (2011) reported that many communities living within the Nyangores basin experience water woes rooted in deteriorating access to quality water, unreliable availability of water and the inefficiency of water providers (DFID, 2002). Villagers in Nyangores area fear that the vital source of food, water and livelihoods is threatened. Women and young girls bear the burden of water collection usually in unsafe environments, making them vulnerable to sexual assault and accidents. The time and energy spent walking and hauling water from distant sources and the resulting water borne diseases keeps them from school work and care of their families (UN Water/ Africa, 2003). Water is central to the conservation of ecosystems and also for the development of health, agriculture, power generation, livestock production and other important economic activities (Winpenny, 1994). DFID (2002) village report, affirms that there is hardly no enough water in Nyangores basin to sustain any worthy investment as the river water pollution increased to the highest limit in 2001 at which over 100 cases of typhoid were reported.

The increasing competition for domestic water use exacerbated by inconsistent water supply and the ever mounting demands from other water sectors has led to an abuse of the river. For example, people use the river unhygienically (e.g. to bathe and wash clothes) while point pollution from cattle dips along the river has greatly affected water quality of Nyangores River. These water challenges call for the need for new water demand management strategies and expansion of water distribution networks (Conradie, 2002).

The inadequate access to quality water in the area is a priority problem just as river water pollution. Inadequate knowledge in rain water harvesting techniques has played an important role in contributing to water shortage. Water is fetched from Nyangores River mainly using donkeys, women and children (Gichana, 2014). This is a threat that has pushed many communities living in rural areas into abject poverty (Molden, 2007). Efficient management of water resources to benefit rural and urban communities requires a full understanding of existing patterns of water demand (Nyong, 1999).

Demand analysis is an important tool for the economic analysis of household behaviour with regard to water use. The rapid growth of urban and rural population together with the increasing growth of mega towns and cities with expansive and intensified agricultural and industrial activities has resulted in economic water scarcity which deters access to meet human demands (UN-ESCAP, 2000).

Decision-making in the basin is dominated by knowledgeable individuals and this excludes the vulnerable groups such as women and the poor in the community, who often lose out in the process of water resource formulation because they lack the resources (knowledge, time, travel and money required to obtain formal authorisation) (UNDP, 2006). Little guidance is given in the legislation on how equitable distribution of water is applied to households and other sector demands. Furthermore, inequitable allocation of water is contributed by poor response to water rights, lack of transparency and accountability in the Ministry of Water and Irrigation (MWI), poor financial mechanisms by the government together with corrupt officials and poor rehabilitation of water catchments. The fact that local regulations for Environmental Flows is lacking, monitoring and controlling of water resources has not been thoroughly implemented (GoK, 2002). The different activities such as deforestation, water abstraction for livestock and agricultural irrigation among others are heavily affecting the ecosystem (Mati *et al*., 2008), but the major cause of deteriorating access of quality household water demand from improved sources remains unknown.

1.2 Statement of the problem

Safe and clean water is important for socio-economic development and the ecosystem services. However, this resource is gradually diminishing in most sub-catchments in Kenya including Nyangores. For example, in 1970 renewable freshwater availability in Kenya was 1,500 m^3, this reduced to 600 m^3 in 2007 and declined further to 500 m^3 in 2010 and is projected to reach 250 m^3 in 2025 suggesting deteriorating access to improved water resources. The reliance on the information that there is availability of 743040 m^{3}/d in Nyangores basin is misleading because the water is unsafe for drinking and other domestic uses. The current population growth rate of 2.3 % p.a coupled with growth in development and urbanization may raise daily water demand by 43.65 % and lead to a deficit of 48.02 % in the year 2032. This suggests future increase in water demand accompanied by a decrease in access to improved water supply in Nyangores sub-catchment.

Seasonal and spatial variation in water availability in Nyangores River basin and the current demand that outstrips supply is an indication of water scarcity and diminishing access to improved water supply. Inadequate access to improved and affordable water is a major cause of public health problems. From 1990 to 2000 water pollution in Nyangores River was low with no cases of water related diseases but from 2001 to 2013 water pollution was at peak and about 210 cases of typhoid were reported and over 50 people died of cholera in 2014 alone. This problem is as a result of low public water connection coverage rate of 5.3% with limited efforts to increase protection of existing water resources to meet improved water demand and supply. The cost of access to a unit of water for the rural households is higher compared to their urban counterparts that receive subsidization. The disparity has widened the gap between the haves and have-nots instigating frequent water conflicts and loss of lives.

Several studies have been conducted in the Mara Basin in Kenya. An example of these includes Hoffman (2009) who conducted an analysis of water availability, demand and use. However, household access, distribution and management of improved water demand including rural water supply coverage and maintenance of water distribution systems still remains a grey area that require further investigation. Adequate information is still required on basic daily minimum and maximum household water requirement from improved water sources and the effectiveness of the current rain water harvesting techniques among rural communities in Nyangores basin. This study therefore sought to fill these gaps in literature; specifically the extent rural and urban households are likely to choose improved water sources amidst unsafe alternative sources and the factors which determine their choice of supply including management of water use.

1.3 Research Questions

i. What is the magnitude of household water demand in the rural and peri-urban regions of Nyangores sub-catchment?

ii. What are the key factors that influence the rate of water demand and distribution in Nyangores sub-catchment?

iii. How effective are the current water use management strategies in Nyangores area?

1.4 Objectives of the study

The main objective of the study was to analyse household water demand, distribution and community management strategies for efficient water use and conservation in Nyangores sub-catchment of South West Mau in Bomet County.

Specific objectives

The specific objectives were to:

i. Determine the magnitude of household water demand in Nyangores sub-catchment.

ii. Identify the key factors that influence rate of water demand and distribution in the study area.

iii. Examine the effectiveness of the current water use management strategies in Nyangores sub-catchment.

1.5 Justification of the study

Nyangores is one of the many sub-catchment areas found in Bomet County in Kenya. It is a major tributary of Mara River, lies at the edge of the largest water tower in Kenya, Mau forest, where majority of the rivers originate and flow in the south western direction (Veronica, 2010). Lack of access to safe and clean water is mainly caused by the increasing poverty levels, people living below the poverty line is now standing at 58.7% and those that suffer food poverty are 36.2% (Bomet, 2010) of the population. The basis for conducting the study was guided by the following reasons; first Nyangores sub-catchment flows from Mau forest the major water tower, with an average flow volume of $8.6m^3/s$ and a length of 94km (Nyangores Sub-catchment Plan, 2011), therefore ascertains availability of water throughout the year. Moreover Nyangores River is an important source of livelihood to urban and rural communities in Bomet County.

Even though the issue of water is observed as a general problem for both the urban and the rural population (Peter, 2004), women and children bear the greatest burden because of their social gender role of collecting water for their households (Rose, 2009). They often walk 3 to 4 kilometres daily carrying heavy buckets of contaminated water to their homes (Alison, 2004). They also suffer from water borne diseases, limited participation in education, income-generating activities and political issues. Several studies have been carried out to analyze people's perception and attitude about the drinking water source quality and accessibility.

The rapid and uncontrolled population growth has influenced environmental degradation as a result of deforestation, overgrazing, excessive land use, fast growing settlement pressure and agricultural practices, the encroachment of the forest area has led to a decrease in area under forest in Kenya from 37% to 24% between 1987 to 2000 (DAAD, 2008). The cutting down of trees for timber and fuel and overgrazing activities has increased the surface run-off in rainy season. Deforestation has caused irreparable damage to surface and underground water resources as this has accelerated the rate of water evaporation and as a result many streams are drying up (UNESO; 2010). The result of high grazing pressure has affected the regeneration rate of herbs and shrubs which has completely been destroyed. A combined human settlement, high population growth, deforestation and agricultural activities have influenced the macro climate change which has an adverse effect on freshwater recharge, availability of flows; catchment degradation, water pollution and low flows resulting from an increasing frequency of droughts thus affecting the volume of surface and groundwater resources.

In fact, out of an estimated 111,258 households in Bomet County, living in rural, urban and peri-urban slums, only 26,100 households have access to improved water from an average walking distance of more than 4km a day. Household distribution per time taken to fetch drinking water is over 60 minutes, showing that the largest proportion of the population do not have access to clean drinking water, but rather rely on unimproved water supplies (Bomet, 2010). Furthermore, there is limited information about water demand and distribution in Nyangores sub-catchment, water use management strategies and the proportion of population without sustainable access to safe drinking water (DFID, 2002).

The river is highly polluted with animal waste, soil and solid waste. The water crisis in the study area is attributed to the wave of drought, catchment degradation and population growth which has negatively impacted on the economic activities of the local communities. The water shortage due to high water abstraction and low freshwater recharge needs to develop a strategy to quantify water resources so as to exploit them rationally and maintain quality. Poor allocation and supply of water resources threaten long- term economic development with direct effect on food production. With the rainfall getting increasingly erratic and unreliable in the region, per capita water has experienced a decline in the recent years with consequent intensification of industrial, agricultural and domestic use of water (FAO, 2008). Socio-economic problems related to inadequate distribution of water are being felt by many people as water for domestic use is purchased at high prices from water vendors. There was an alarming deterioration and an increasing scarcity of fresh water resources caused mainly by the growing population pressure as shown in the Table 1.1 below. It is due to these reasons and the need to fill the gaps of information that Nyangores sub-catchment was selected.

Table1.1: Population, water demand and distribution in Nyangores

Year	Population	Water demand(M^3)	Storage capacity (M^3)	Pipe water coverage (Km^2)
2006	141,305	39,787	200	2.80
2007	144,805	40,772	200	3.03
2008	148,264	41,746	200	3.20
2009	151,804	44,745	200	3.60
2010	155,182	47,870	200	4.20
2011	158,883	71,135	400	5.80
2012	162,442	75,667	400	6.25

Source: Bomet water supply, 2013

1.6 Significance of the study

The results of this study are expected to provide new insights to the demand and the distribution of water resources to various users and understand how total and disaggregated supply and consumption of water evolve over time in major sectors of the economy in the Nyangores basin. Results from the study will form a basis for policy formulation and planning for efficient water distribution, management and conservation to sustain the scarce resource and as a basis for the solution of water conflicts among users. It is meant to establish a governance framework that ultimately enables more rational water distribution in order to minimize the vast number of people without access to basic water facilities as well as to improve the lives of the poor and the marginalised in Nyangores sub-catchment through utilization of the scarce water resources. This will help strengthen social harmony and economic productivity as well as maintaining a sustainable water resource and ensure adequate water supplies for urban and rural uses. The study will provide an incentive for more efficient water use in agriculture, industry, domestic and other uses.

1.7 Scope and limitations

This study intended to determine the magnitude of household water demand and spatial distributions of pipe water coverage based on population projection from 2007 to 2025, land use activities and income levels and also investigate households accessed to water systems in the study area. It identified key factors that determine the choice of water source, the rate of water consumption and also examined the effectiveness of the current water use management strategies.

The study was conducted in the lower part of Nyangares, a tributary of Mara River in Silibwet, Bomet and Sigor geographical areas. A sample of 300 households was selected to provide information based on their perceptions and norms on demographic, sources of potable water, estimated distances and time taken to fetch water. The study focused only on selected aspects of the problem while certain areas of interest such as availability of water per source at a given time and season and disaggregated households according to water use from improved, unimproved or both was limited by inadequate information at the time of study especially the temporal and spatial distribution of improved water coverage.

1.8 Conceptual framework

The literature provided examples of attempts to conceptualize the different phases of water resource development and management in response to water demand, distribution and use. This framework was developed to reflect the element of the supply-demand balance. It was designed to address issues related to water shortage in conditions where domestic and agriculture represent an important part of the demand for water. The framework proposes step-wise approach to water demand, distribution and water use management strategies at household and community levels to maximize the benefits obtained from a given amount of water available to users (Molden *et al*., 2010).

Keller and Davids (1998) and Keller (2000) suggest three phases of river basin development: exploitation, conservation and re-allocation. The exploitation stage is dominated by direct surface diversion and later stage with progressive building of storage and water distribution. During the conservation phase-demand management and efforts towards efficiency increase would be more important followed by systematic water treatment. Water shortage begins to appear and competition for water emerges between different sectors and within sectors. Water quality deteriorates and aquatic ecosystems are damaged due to reduced water quality and quantity. Water policies focus on improving water management and conservation and at the same time water pollution and withdrawals call for better and more effective regulation. Water has become a rare commodity and is no longer sufficient to satisfy aggregate demand from all sectors. Policies are directed towards the economic optimization of water with emphasis on re-allocation of water from low value to high value uses, Keller and Davids (1998).

The demand management theory (Stephenson, 1998) supports the fact that water demand management is an alternative to increase water supply. The control of water use can be affected by the supplier or the consumer. The supplier can use various methods to limit supplies such as physical, sociological and economical methods. The components of the physical method include pressure control, installing of water saving devices such as small and double action cisterns, low volume showers and automatic tap closers. Sociological methods include appeals through the media, changes in the ways of life by increasing water costs and public relations campaign. Legal enforcement of water restrictions, if associated with fines can be effective but costly to apply. Consumer awareness can encourage local re-use of grey water such as water for gardening. The economic methods include water tariffs, metering or charges on discharges. Theoretically, the best system would be to charge prices which reduce the wastage to meet availability (Moor, 1989).

The components of water demand management such as water demand forecast, water allocation policies and strategies, reliability requirements, cost of supplying water and expected returns and hydrological impacts are potential for improving efficiency in the distribution of water resource and reducing demands of the catchment (Pieter, 2003). Due to spatial and temporal uneven distribution of precipitation (Radif, 1999) rapidly increasing water demands driven by world population and other stresses as well as the degradation of water environment (UN- CSD, 1994) has led to increasing scarcities of water resources. Recent concerns about increasing efficiency of water utilization, demand and distribution have centred on economical optimal water allocation at the river basin level (Mckinney *et al*., 1999).

Water Evaluation and Planning (WEAP) is unique in its capability of representing the effects of demand management on water systems. Water requirement is derived from a detailed set of water uses in different economic sectors which provide end-use goods and services at the foundation of water analysis and allows an evaluation of effects of improved technologies on these uses and the effect of changing prices on quantities of water demanded (Jack, 2011). Water demand and supply are relatively sensitive to slight changes in population growth, urbanization, industrialization and the expansion of irrigated agriculture besides contributing to the rise of water pollution (Sieber, 2005).
Water Demand Management (WDM) is an essential part of the challenge to sustain the water resources. The main principle of WDM is efficient use of water in order to maintain vital environmental flow and to reduce dependence on costly infrastructure project (Sungai, 2005).

Hydro-economic models represent spatially distributed water resource systems, infrastructure, management options and economic values in an integrated manner. Water allocation and management are driven by the economic value of water to provide policy insights and reveal opportunities for better management (Gleick, 1986).
Water demand is related to how much water is needed and water management is related to what to do to increase the supply and reduce the demand. Water availability is

affected by external pressures such as high population, climate variability, pollution, exploitation, urbanization and land use (WWAP, 2009).

Fundamental objectives for river regulation highlight major issues on watershed protection measures and priority allocation of water for domestic, environmental and industrial use. This contributes to maximum satisfaction of basic water needs leading to an improved livelihood to the local community (Kenny, 2005). The security of water through improved management of water resources guarantees availability and effective distribution. This is necessary for achieving the Millennium Development Goals (MDGs) such as eradication of extreme poverty and hunger, gender equity, maternal health, combating major disease and environmental sustainability (WHO, 2004). Combination of these factors results in food security, good health, poverty alleviation in urban and rural areas, economic development, rural livelihood consolidation, environmental protection and sanitation (Tue, 2004).

The variables in the framework are interrelated and dynamic. Availability of water determines the allocation of water to water utilities which play a major role in influencing water demand requirements by different sectors (Figure 1.1). More demand for water is inevitably created by the drivers of water demand especially population and economic growth. How growth takes place affects how much additional water is needed and how much it will cost to deliver in terms of demand, infrastructure and efficiency. On the same note, pressures of water demand affect water distribution leading to water scarcity with a negative impact on water use and livelihoods. Community Management Strategies especially water reforms and policies, awareness creation and information dissemination influence water-related livelihoods such as health, poverty alleviation and aspirations and in turn affects infrastructure, water use and water resources. At the same time communities face two growing and related issues: huge financial needs for infrastructure and concerns about availability of water are also related to the quality of existing and potential sources of water. Low- density and dispersed development increase the cost of delivering water. This requires longer pipes, which lose more water through leakage and raise transmission costs therefore making livelihoods unsustainable.

Conceptual Framework

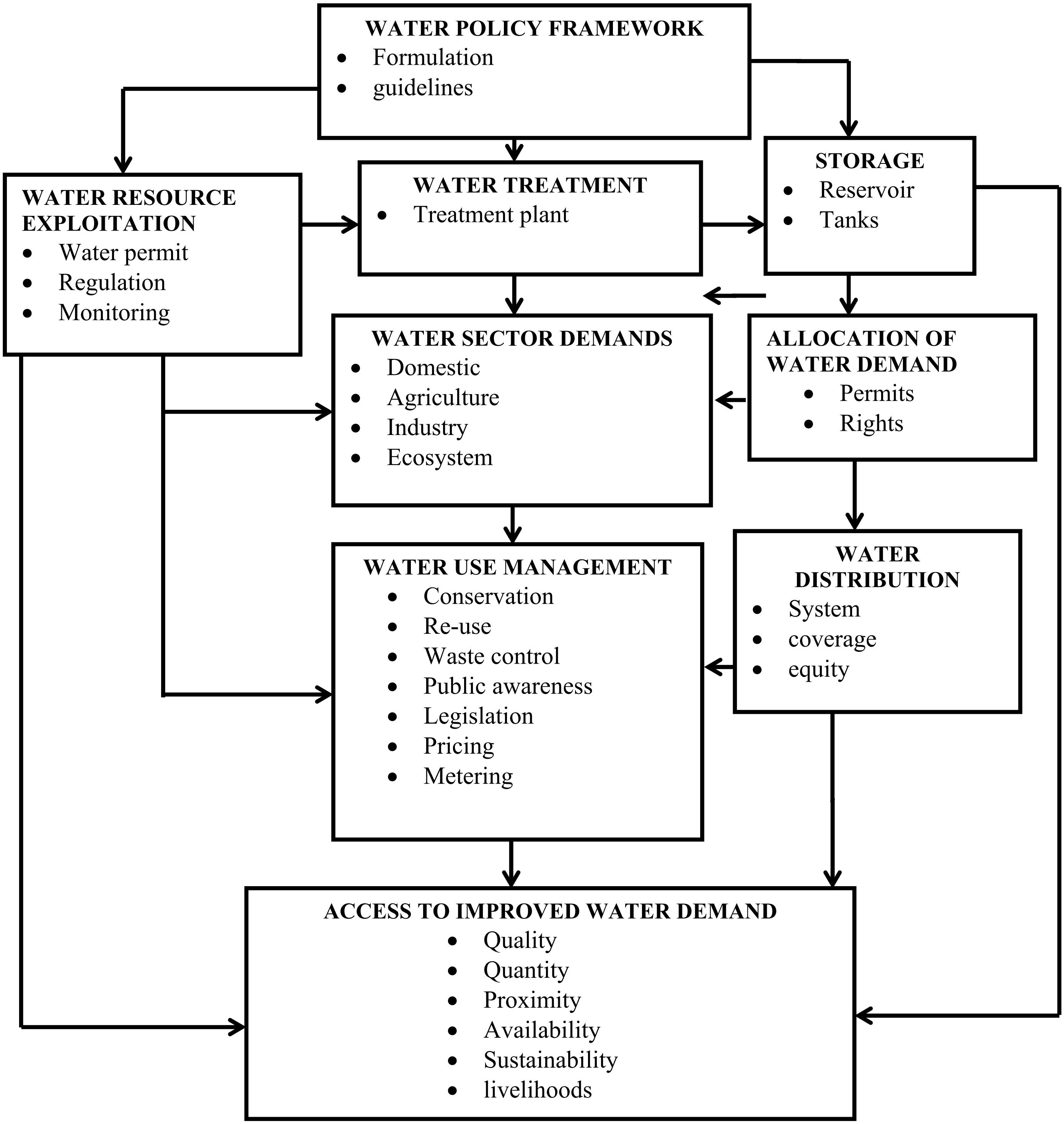


Figure1.1: Conceptual framework for access to improved water demand
Source: Author's synthesis of literature

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a critical review of water demand, distribution and management strategies focusing mainly on the concept of magnitude and factors affecting the demand and the effectiveness of the current water use management strategies. It also address issues of availability, accessibility and reliability of household water demand through effective management of water resources, even distribution and treatment of water and modelling of complex water systems to satisfy the needs of the watershed community. A brief review of determinants and techniques used to determine the magnitude of water demand and also among the critically reviewed sections are the methods, findings and designs presented by other researchers who tried to contribute solutions related to the problem of the study.

2.2 Freshwater availability

Water accessibility depends on its physical location and timely availability (Osei, 2004). Ariyabandu (1999) express the fact that easy accessibility, reliability and timely availability of adequate safe water to satisfy human needs ensures household water security for basic needs and economic activities. Globally, the main sources of freshwater for socio-economic activities include rivers, pipe water, protected and unprotected springs, open wells, protected wells, roof catchments, dams, earth pans, boreholes, streams, lakes, reservoirs and underground aquifers resulting from a complex hydrological cycle (UNEP, 1999).

2.2.1 Rivers

According to Baseline Survey of the Mara River Basin, (Alison, 2004), Bomet County has several permanent rivers such as Amalo River which flows along the southern boundary of Bomet district, Nyangores River which flows from the south western Mau forest through Tenwek, Bomet town and joint Amalo River at Kaboson to form the Mara River. The distribution of households by source of water in the basin indicates that 56.4% get water from river, 5.9% from pipe, 6.9 % from protected springs, 17.6% from unprotected springs, 2.2% from open wells, 1.1% from protected wells, 6.3% from roof catchments, 21.5% from dams and earth pans and 0.2% from boreholes (Alison, 2004). Households in less developed countries face a chance set of diverse sources which include house tap connections, public or private wells and taps, water vendors and tank trucks.

The Nyangores River experiences a decline in water flow and the drying up of some parts of the river course is due to indiscriminate deforestation of the Mau forest complex and the planting of eucalyptus trees on riparian land (SCMP, 2011). Eucalyptus trees pose the biggest danger to the springs occasioning reduced yields. The quality of water flowing in the river has also been adversely affected through point source of wastewater into the Nyangores River such as cattle dips, car washing, slaughter houses and municipal wastewater. Bathing in the river is very common in parts of Nyangores and residents carry household goods, clothes, and utensils to wash in the river. Following the baseline survey of the Mara River Basin, (Alison, 2004), found that 76% of households in Bomet have adequate water at one time or the other during the year and the quality of water has been declining over time as 36% of households in Bomet treat water while 64% do not treat their water. The Mara River is one of the most important freshwater ecosystems for Kenya and Tanzania. The river has a catchment area of 13,504 Km^2, with 65 % in Kenya and 35% in Tanzania (Veronica, 2010). With the main source of this Trans – Boundary River being the Mau forest, it flows through diverse landscapes with a total length of 395 Km discharging into Lake Victoria through Tanzania (Figure 2.2). The climatic conditions within the basin vary with altitude. At 2,915 m a.s.l in the Mau forest the precipitation in the upper basin has an annual mean of 1,400 mm/year and decreases to 600mm/year at lower altitudes of 1,140m a.s.l before discharging into Lake Victoria (Mati, 2005).

2.2.2 Rain water

Hydrometereological studies have shown that annual precipitation levels have not changed significantly over time, but there is variation within the seasonal and monthly distribution (Melesse et *al*., 2008). The dire situation regarding water resources is a direct consequence of poor management, corruption and a lack of political resolve to address the crisis (SCMP, 2011). The water storage in Nyangores especially the upper part of the catchment is endowed with plenty of rainfall while the lower part experiences semi-arid conditions. This therefore, creates a suitable condition for rain water harvesting at the upper catchment and development of water pans in the lower part (SCMP, 2011).

2.2.3 Dams, springs and boreholes

Dams and springs are important sources of water for domestic use and in most cases dams are silted and most of the springs are unprotected. The dams in the sub-catchment include Tenwek mission dam (Figure 2.1), Chebara, Cheboin, Keringet, Kamanyowa, Kapkores and Kapsimbeiywo. The unprotected springs are Bararget, Milimet, Kapkwen and Kapkoin. Boreholes and shallow wells are mainly used in the middle and lower parts of the catchment and as the demand for water increases, there is need for more storage to meet the demand (SCMP, 2011).

Figure 2.1: Tenwek Dam Community protected spring
Source: Chebotuiya (PDO; Nyangores Sub-catchment Plan; 2011)

The Mara River Basin

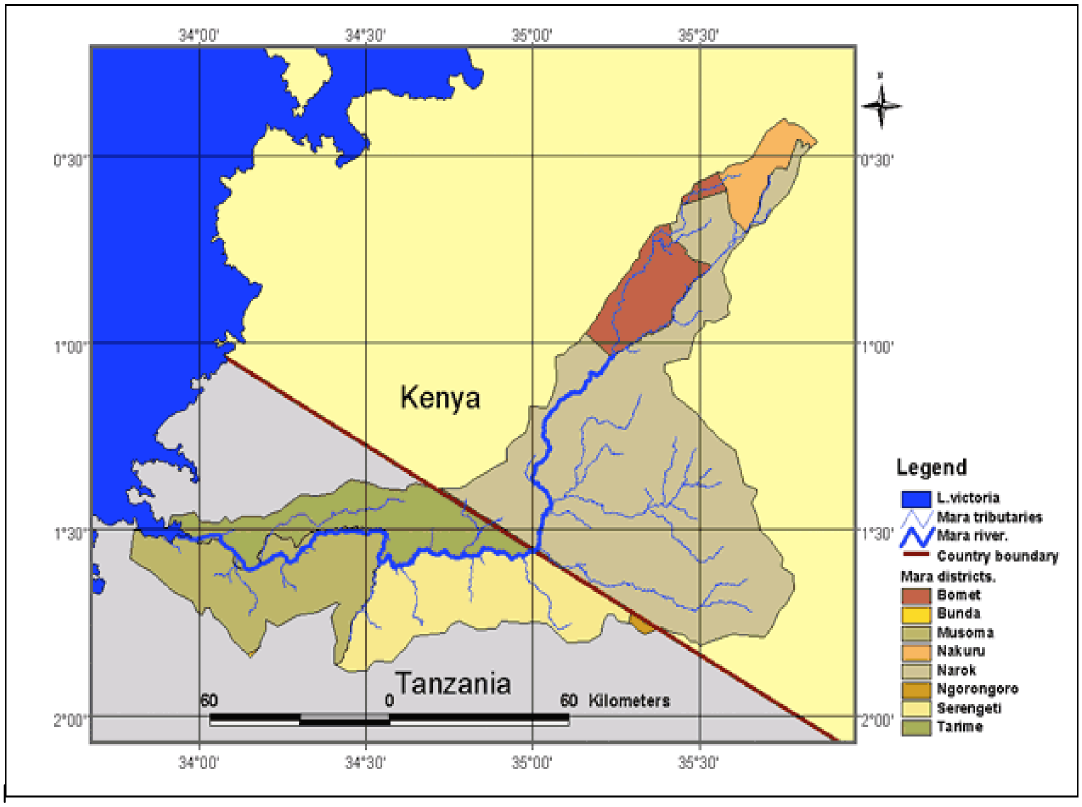


Figure 2.2: The Mara river basin tributaries

Source: Adopted from Alison (2004).

2.3 Household water demand and accessibility

Household water demand comprises issues of water availability, accessibility, usage and quality. Availability is affected to a larger extent by environmental factors from hydrological changes (Osei, 2004). Easy accessibility, reliability and timely availability of adequate safe water to satisfy basic human needs is important in meeting household water demand and security (Ariyabandu, 1999). This enables households to obtain the required quantity of suitable quality water for basic and economic needs.

2.3.1 Household freshwater demand

In almost every region of the world, the demand for freshwater has continued to increase while accesses to the required quantity and quality of the resource has been on the decline (UNEP, 2000). The central role of water is evident in any systematic appraisal of life-sustaining requirements. Even at the most fundamental level of human survival and sustainable development, water not only has life sustaining qualities, but strongly influences economic activity (both production and consumption) and social roles. UN-WATER (2006), estimates that 50% of the world's population lacked access to safe sanitation while 20% lacked access to safe drinking water. Mehretu and Mutambirwa (1992) observed that in Chiduku communal area in Zimbabwe approximately, 91% of the total time devoted to water collection is carried out by women and girls while in Arusha, Tanzania, they account for75 % of this time (Makule, 1997). Bevan, Collier and Gunning (1989) gave more insight by indicating that in the Central and Nyanza provinces in Kenya, younger women spend less time than old women in fetching water from the same distance. In Central Province, women aged 20-29 spend 56 minutes, aged 30-49 (69 minutes) and over 50 years (77 minutes).

2.3.2 Distance and time to improved water sources

Locating improved water supplies within reasonable distances to households saves time and increases total water consumption. The World Health Organization (WHO, 2000) considers 200 metres as a convenient distance for fetching water. Huttly *et al*., (1990), found that improving accessibility by constructing boreholes in villages in Nigeria reduces daily water fetching time from 360 minutes to 45 minutes. Through rain water harvesting, women in SriLanka saved 2 hours (opportunity cost) daily by reducing in the number of trips to dug wells and springs from 8 to 3 hours per day. Such substantial amount of time saved could improve women's welfare through time and energy availability for education, high status work and civic activities. In an earlier study conducted in 12 rural communities in Kenya, Tanzania and Uganda White, Bradley and White (1972) showed that on average water carrier utilizes 240 calories daily in water fetching, this value amounts to 8.5% of the carriers' daily calorie intake.

2.3.3 Scarcity of freshwater supply

Among the world's regions, Sub-Saharan Africa (SSA) faces the greatest problem of water scarcity because the freshwater resources are unevenly distributed over time and space. Africa uses only 4% of its water resources (UNDP, 2007b) yet it faces the greatest problem of water shortage (Hopkins, 1998). Despite the abundant fresh water resources in Africa's lakes and rivers, still a great disparity in water availability and use is experienced. Most freshwater in Africa comes from rain along the equator, specifically around the Congo basin and Niger delta (UN-CSD, 1994).

In the period to 2025, it is expected that the world will need 17% more water to grow food for the increasing population in developing countries, and that total water use will increase by some 40% (UNFPA, 2003). Both the shortage and the uncontrolled excess use of water can be life-threatening, and the essential balance in-between must look to achieve appropriate priorities, equity and economy in the dispensing of this most vital resource. It is with this understanding that world leaders meeting at the Millennium Summit in 2000 set a target of halving by 2015 the proportion of people without sustainable access to safe drinking water.

According to the Population Institute (2010), there has been a widespread failure to recognize that water provides food, energy, sanitation, disaster relief, environmental sustainability and other benefits. This has left hundreds of millions of people suffering from poverty and ill health and exposed to the risks of water-related diseases. Given clean drinking water, fewer children will die from water-borne diseases, more women will have time to engage in productive activities, reducing income poverty and enlarging their social and economic opportunities (UNFPA, 2003).

The most immediate impact of measures to protect water sources and increase access to clean water will be to reduce social and environmental vulnerability (UNWWAP, 2009). By so doing, reductions in child and maternal mortality and improvements in child and maternal health are to be anticipated, as well as reductions in the incidence of malaria and other water-borne diseases (WHO, 2003). The availability of safe drinking water will also help in achieving the goal of gender equality and empowerment of women, as time spent on water collection can be devoted to more productive pursuits. In many localities, this task is undertaken by school-age girls, so this measure should have a positive impact on girls' education (Guisse, 2004).

Water is an essential resource for sustaining health, yet both the quantity and quality of available water supplies are declining in many parts of the world. In developing countries, lack of access to safe water, especially in rural areas and among poor communities, obliges women to spend hours every day collecting water for their families' daily needs, causing enormous drain on their energy, productive potential and health. Largely because of their role in collecting water, washing clothes, cleaning and cooking, and in rural areas, performing day-to-day agricultural tasks, women are constantly exposed to the risks of contracting water-related diseases that affect their reproductive health. Exposure to contaminated water sources is associated with pregnancy failures and with infant and childhood development difficulties, illness and mortality (Carl, 2010). Access to water is a known basic human right, however, Sub-Saharan Africa and other third world countries experience several challenges. This ranges from the water infrastructure to the distance they have to walk to get this precious commodity (UNWWAP, 2009). No such documented information exists for rural communities in Nyangores basin in Kenya. Even if water is available from a source away from home free of charge, its collection involves time to get to the source, to wait at the source (queuing), and time to haul the water back home. One may choose to convert collection time into collection costs using an assumed value of time. However, the value of time may differ widely across households depending on who is responsible for collecting water, and even within a specific household over time of day or day of week. In localities lacking formal labour markets or with high unemployment, estimating an average value of time for a study population is largely guesswork.

Many analysts thus do not attempt to convert the time cost of water collection into a pecuniary collection cost. For example, Larson and others (2006) consider round-trip walking time to water source and waiting time at the source. David and Inocencio (1998), on a sample from Metro Manila in the Philippines, use distance from source in metres as an explanatory variable in their demand model. Strand and Walker (2005) consider hauling time per unit of water consumed. Whittington and others (1990b) are among the only authors to provide some empirical evidence about the pecuniary cost of collecting water from non-tap sources. Using data from Ukunda, a small market town in Kenya, they develop two approaches, based on discrete choice theory, for estimating the value of time spent collecting water. Their results indicate that the value of time for households relying on non-tap sources (kiosks, vendors, or open wells in the village) was at least 50% of the market wage rate and likely to approach the market wage rate for unskilled labour for some households.

2.4 Determining the magnitude of water demand and distribution

The demand for water includes the requirement for water services in agriculture, industry, domestic and other purposes (Jack, 2011), while distribution is the delivery of water to consumers with appropriate quality, quantity and pressure (Bibhabasu, 2010). The distribution system is used to describe collectively the facilities used to supply water from its source to the point of use. Burchi and Andreas (2003) define water distribution as the function of assigning water from a given source to given uses. The spatial demand and distribution of water resources vary depending on a number of factors such as willingness to pay, infrastructural capacity, modern technology, distribution systems and components (Warren, 1998).

An established demand estimate for each major sector is obtained from a conducted abstraction surveys in order to compute water demand and establish the water balance (Musangi, 2009). The amount of water needed for beneficial use is calculated based on a simple per capita taking into account the projected needs of the population, industrial, commercial and other uses supplied by the permit applicant. According to UN-ESCAP (2000), water demands are estimated using population projections, land use information and water production records. Historical population trends and projected growth patterns provide a comprehensive insight into the future water demands determined by the magnitude, direction and characteristic of population growth. Warwick (1997) emphasized the need for an economic efficiency operational criteria requiring the distribution of stream flows until the net marginal utility in per capita water consumption is achieved. The relation between the quantity of water used and the price is illustrated by the demand curve (UNDP, 2007b).

2.4.1 Determinants of water demand

The main variables that determine water demand is discussed with particular attention to water price, household income, weather variables, household size and composition, time for fetching water, education, village population and water accessibility.

Water price: Demand theory states that as the price of a good increases, the demand for that good decreases (Froukh, 2001). Therefore, it is expected that price will negatively influence the quantity of water use from purchased sources. When a price of water exists, then it is quite easy to compute a per unit price for each household and each source. The price of non-piped water has been considered exogenous in all studies except in David and Inocencio (1988). These authors argue that the price of vended water is endogenous because price is determined by demand and supply factors. Due to the fragmented nature of the water vending market, household decisions of water demand are likely to influence its price. Even if free of charge, the collection of water from non- piped sources usually involves costs for hauling water from distant sources.

Household size and composition: Arouna (2009) analysed households' water use behaviour as a function of water availability by explicitly estimating domestic water use for both rainy and dry seasons when water is respectively in surplus and scarce. Domestic water consumption will likely increase with household size, following Keshavarzi *et al*., (2006) and Froukh (2001), both household size and composition affect water use, and more over household size has been found to be the most important factor affecting water consumption. In the analysis, household size and composition involve the ratio of children to adults and gender of the household head respectively.

Time for fetching water: Time used for fetching water and efforts required to carry heavy water buckets has an opportunity cost. This implies that the further away a source is located from the house and the longer one must queue, the less water from the source will be used (Gazzinelli et al., 1998). Sandiford et al., (1990) thus hypothesized that the time for fetching water (that is walking time plus waiting time) will be negatively related to the quantity of water use.

Village population: In some areas, people mainly rely on public water sources, either free or purchased. It is expected that per capita water use will decrease as the population increases (UN-CSD, 1994). In some areas, people can only collect fixed quantities of water in order to allow everybody to have at least a small quantity for basic use only. In a larger population, a household member has to queue several times before obtaining the desired quantity.

Weather variables: The change in weather variables poses risks to water security through altered drought frequency and intensity thus changing water demand. These potentially affect water availability for abstraction, storage and supply (Joanne, 2012). Maidmat and Miaou (1986) suggested that rainfall has a dynamic effect on water demand. It reduces water demand initially, but the effect diminishes over time. Sometimes water users appear to respond to the mere occurrence of rainfall than its amount, therefore, the number of rainy days should be a better explanatory variable than the amount of rainfall in a given period (Martinez-Espineira, 2002b).

Water accessibility**:** It is expected that as with other economic goods, better accessibility will positively affect the quantity of water consumption. Accessibility of water supply points principally supplying adequate and quality water for the wellbeing of human health. Sustainable access to improved and safe drinking water is one of the

MDGs goals. USAID (2006) Ethiopian report estimates percentage coverage of water supply at 40% while NGOs and WHO report the coverage as 22 %.

2.4.2 Determining actual drinking water demand

(i) The per capita use approach

The first stage is to determine the system's current **'per capita use'** in m^3 per day per capita. The following steps show how this is done, for the years between 2007 and 2012. Each step will determine a different number that is entered into a table and spreadsheet, "Water Usage for Small Systems" available on line at **http://www.gadnr.org/cws/**

1) How much water was withdrawn in 2007, expressed in m^3 (annual average)? This number will be referred to as "WD2007" in the calculations below. On the spreadsheet, enter this number in Column 'C'.

2) How much additional water was purchased or derived from other sources in 2007, expressed in M^3 (annual average)? This number will be referred to as "PD2007" in the calculations below. On the spreadsheet, enter this number in Column 'D'.

3) How much water was sold to other systems expressed in M^3 (annual average)? This will be referred to as "SD2007" in the calculations below. On the spreadsheet, enter this number into Column 'E'.

4) How much total system water ("TSW2007") was used? It is the sum of WD2007 +PD2007 minus SD2007. This value is automatically calculated in column 'F' of the spreadsheet.

5) What is the population (POP2007) of your service area in 2007? Use the numbers entered in Table 1.1. Residential population served (see part 3 above). Also, in the spreadsheet “Water Usage Small Systems”, residual population served is entered in Column ‘B’.

6) Determine your Per Capita Usage for the year 2007 (“PCU2007”). To do this, divide Total System Water by Population for that year. That is, PCU2007 = TSW2007 / POP2007. On the spreadsheet, this value is automatically calculated in Column ‘G’.

7) Repeat steps 1 through 5 using the actual numbers for the year 2012 and calculate PCU2012.

8) Calculate the average Per Capita Use (**PCU base)** for 2007 and 2012 by adding them and dividing by two. That is, PCU base = (PCU2007+ PCU2012) / 2. This is your system’s current **per capita use** number. Enter this number in the first line of the table. This value is automatically calculated in Column I, Row 14 of the spreadsheet (EPD, 2007).

(ii) The Goodrich approach

Goodrich formula: Peak water use estimation (Estimation of average daily rate based on a maximum time frame)

The Goodrich formula (Robert, 2007) estimate maximum demand (expressed as daily water demand based on time period for which maximum water demand is desired) for community when given annual average per capita daily water use rates given as:

$$P = 180.\ t^{-0.10} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:

p = percentage of average annual rate (volume/day) use in period of time of interest.

t = length of period for which peak demand is required (valid time period – 2 hours to 360 days).

(iii) The q √ n approach

Another approach is the "q root n" method (James, 2006) used to determine maximum water demand for a number of houses and is adequate for the design of modern distribution networks. This is expressed as:

$$q_{M\,n} = 0.083\sqrt{n} \times {}_{T\,U\ houses} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where:

$q_{M\,n}$ = maximum instantaneous demand of n houses in l/s

n = the number of houses

TU = the number of tapping units house and

(0.083 = the capacity of 1 TU in l/s (300 l/h)

The demand pattern of one house is much more erratical than the demand pattern of 1,000 houses. The pattern of one house will be a number of spikes over the day, while the demand pattern of a cluster of houses will have a much smoother pattern. The method to determine the maximum demand for a number of houses is based on the method used to determine the maximum demand for an in house installation. This is the so-called q√ n – method.

According to Jack (2011), water demands are currently based on three options: Standard water use method, FAO crop requirements approach and direct method. Standard water use method is the simplest case in which the user determines an appropriate activity level such as persons, households, hectares of land for each disaggregated level and multiplied by the annual water use rate for each activity. The FAO crop requirement approach is typically used to represent agricultural demand nodes. This approach assumes for every demand site, a set of simplified hydrological and agro-hydrological processes such as precipitation, evapotranspiration and crop growth emphasizing irrigation and rainfall agriculture. These processes are used to determine the irrigation requirements for each demand site. With the direct method, water demands are directly read from a monthly water use rates and inputted into WEAP (Water Evaluation and Planning).

(iv)The water demand function

The water demand function is a single demand equation for water provided from a tap. The approach assumes that there is no substitute available for water. The water demand function for households is usually specified as an equation linking water consumption (q), the dependent variable to water price (p) and a vector of demand shifters (x) for example, household characteristics, weather conditions and house equipment, to control heterogeneity of preferences and outside variables affecting water demand.

$$q = f\ (p, x) + u$$

Where:

q = quantity of water consumed

f = function

p = price

x = demand shifter

u = error term

The error term u is added to this relationship to account for unobservable or measurement error in variables (Whittington, 2007).

2.4.3 Human and Livestock Water Demand

The per capita domestic water consumption in the rural areas is estimated as 20 litres per day (MoWRD, 2002). This includes water for cooking, bathing and washing. Nearly all the water resources used by livestock are also used by humans, even when visibly turbid and polluted as in rivers, dams and pans. Livestock water demand was estimated based on the drinking requirements of one Tropical Livestock Unit (TLU). According to the Range Management Handbook (Republic of Kenya, 1994), one TLU is equivalent to 250 kg live weight. Thus, an average cow is about 0.9 to 1.0 TLU, while one cow is equivalent to 10 goats or sheep in terms of water per day, because nearly all the animals are crossbreeds and have average body weight. The total demand for human and livestock drinking water in Nyangores sub- catchment (Table 4.9) is 22,695 m^3 per day. This corresponds to about 8.3 million m^3 per year. It excludes water demand for agriculture, pasture and commercial uses. These figures were derived by summing up human and livestock water demands respectively. Human water demand was calculated by multiplying the per capita requirement (60 litres) with the total population, while livestock water demand was calculated using weighted values derive livestock population in terms of TLU, and total TLU multiplied with daily water demand (also 50 litres), (Wairua, 2011). Some water sources are meant only for human consumption; hence they have zero water demand for livestock. Livestock water demand in Nyangores area is affected by long distances to water sources, immigration of pastoralists in dry season, and emigration in the wet season. In most cases, the demand does not match supply which is variable. It has caused a lot of conflicts over water and other resources, especially during dry season, when demand outstrips supply (Biamah, 2004). Apparently two – thirds of the water is utilized for livestock drinking.

Water is an important requirement to livestock as water forms about 50 to 80 per cent of animal's life weight and is an essential nutrient. A good supply of water both quality and quantity is required for animals to maximize feed intake and production. According to David (2006), livestock consume water based on the combination of kind and size of animal, physiological state of animal, for example, lactating cows require an extra 0.8 litre of water per litre of milk while pregnant cows and growing animals require 30-50% increase consumption of water. The type of diet and dry matter intake affects livestock water consumption as dry diets require more water than moist diets. Palatability and salt content together with water temperature, water trough space and air temperature (as hot days increase water consumption than cold days) affect water intake.

2.4.4 The distribution of water supply

Water availability is ensured by its reservoir; however, the distribution is a problem since water demands have increased over time while the supply system has lost its automatic function which has resulted in an on-request system. In most cases, water users have no fixed time schedules for water supply and therefore, experience shortages especially in times of high demands. According to Renate (2007), problems in distribution of water are caused by timing and scheduling and not by too small infrastructure capacities as the water users' claim. The deficiencies of the system lead to unclear, unequal and stressed water distribution. The basic of a modern distribution network is intended to meet the actual water demand, self-cleaning velocities of 0.4 m/s regularly in the network and the unidirectional flow.

The main characteristics of a modern distribution network are a branched system with pipes with a relatively small diameter. In the design process, several steps can be recognized such as to determine the water demand, arrange sections, compose main structure, design sections, check pressure drops and fit in flows. The supply point is the 'end' of the distribution network as far as the water company is concerned. The water meter is the last part of the connection and in unmetered situations; the stopcock is the last part of the connection. Then the actual house installation starts and that is where the water is consumed. For calculation reasons, the pressure at the actual supply point should be at least 200 kPa as the minimum acceptable pressure (Chin, 2000) when no water is abstracted from the installation. Reason behind this is that the pressure at the highest tap point is enough to overcome the hydraulic resistance of the house installation and the tap point itself.

2.5 Factors affecting the rate of water demand and distribution

Many water supply schemes in rural areas are fairly basic; however, the patterns of demand and distribution are more complicated and tend to be dependent on many factors (Wallingford, 2003). Such factors include:

- Population;
- Household occupancy rate;
- Level of service of the water supply for each household;
- Tariff levels;
- Willingness and ability to pay;
- Local knowledge and indigenous practices;
- Cultural values, traditions and religious beliefs;
- Climate;
- Water quality.

The more important of these factors are discussed briefly below.

2.5.1 Population

The growing population increases the demand of water for domestic use, food security and industrial development. The population growth trend has resulted in reduction of per capita water availability (UN-WATER, 2006). Water demand and use are directly related to the population. However, in rural areas, it is often difficult to estimate the population levels accurately due to lack of accurate and up-to-date census data; lack of up-to-date aerial photography or remote sensing data from which to estimate the number of settlements in an area and migratory labour with the male members of households often working in urban areas for long periods of time (Wallingford, 2003). Population growth and economic development have placed stress on water resources (Varma, 2010) which has resulted in a decrease of per capita water availability. The international water management group (UNFPA,2007) asserts that urbanization and industrialization which commonly had high population densities has caused an adverse variability in quantity and quality of water resources therefore retards the demand and distribution of water (WRI, 2007).

2.5.2 Household occupancy rates and level of service

Household occupancy rates and level of service affect water demand and distribution. Studies have shown that low rate occupancy households generally use more water per head than higher rate occupancy ones. The level of service can be defined in terms of water supply based on quantity and quality of water available within a given distance, sanitation in terms of whether there is a pit latrine, pour-flush latrine or piped sewerage and a stipulated measure of reliability.

2.5.3. Tariff levels

Water is often viewed as primarily a social good. Many countries' constitutions enshrine the basic right of every citizen to a safe supply of water; however, water can also be viewed as an economic good. In many circumstances, rural domestic water users have to pay a tariff towards the cost of their water supply. In some cases, consumers are able to choose the level of service for which they are willing to pay. Demand functions and curves can be produced that are related to the following: quantity of water demanded; price or tariff level of the water; price of other related goods or services; household income and other socio-economic factors. The above variables are often known as determinants of demand.

Many researchers agree that different levels of supply and different levels of service will display different functions regarding demand. However, as a rule, water use will generally increase as the level of service increases and decrease as tariff levels increase.

2.5.4 Climate variability

Drought is a recurring phenomenon and its impact on water resources is usually devastating (Mati, 2005). Floods lead to disasters particularly in low-lying areas. Occasionally floods have caused devastating impact on the sector. Both climate variability and environmental degradation have resulted into catchment degradation, drying up of rivers, receding of lake levels, heavy siltation in dams and pans meant for both hydropower generation and water supplies and deterioration of water quality (UN-WATER, 2006). Since the 1970s, serious droughts have occurred e.g. in 1972, 1974/75, 1977, 1980, 1982, 1983/84, 1991/92, 1995/96, 1999/2000, 2004, 2006, 2009 and recently in 2010/2011 *(drought every 2 years).* Crop failures occur in the same areas prone to seasonal flooding. Floods also ravage many areas particularly Lake Victoria region, Tana River, Garissa, Taita Taveta and Nairobi (Bancy, 2012).

2.6 Effectiveness of the current water use management strategies

The development and implementation of water use management strategies are aimed at influencing water demand and distribution in order to achieve adequate level of water consumption and maximum utilization of the finite resource (National Water Policy, 2006).

Water pricing: The price signals provide the information needed to allocate and distribute water more effectively. The water pricing is a major instrument that can be used to resolve inevitable trade-offs (Winpenny, 1994). It forms part of the broad effort that strengthens water use governance and value long-term ecosystem services. Water pricing ensures efficient utilization of water resources in order to achieve a high level of cost recovery. Water conservation measures can be promoted by structuring the system rates and charges to reflect the seasonal variation of water use, the cost of production and distribution during peak hours (American Water Works Association, 2007).

Metering: Water use metering is an essential element for efficiency and conservation management of water resources (Kenny, 2005). Water metering is required for water loss control, accounting and rate making (Perret, 2009). Inaccurate reading leads to inaccurate information about water use and leak detections. Metering is a means of achieving a diurnal demand management in terms of water waste control and detection exercise. The aim is to manage water losses in the network within the economically acceptable levels thereby making better use of the limited resource. Where a water supply is fully metered, the consumption patterns of various categories of consumers can be determined by monitoring the meter readings over a period of time (CMWSP, 1997). All water supplies experience water losses through leakage in the transmission systems, illegal connections, faulty meters and wastage. In general, this is estimated at 20% of the total supply but poorly managed systems may experience losses even greater than 50%.

Restrictions and prohibitions: Water use restrictions and prohibitions are part of command and control tools. Water regulatory agencies and water service providers establish restrictions and bans in water use during droughts for non-essential purposes such as washing cars and watering flowers. Mandatory restrictions are shown to be an effective tool for drought coping as saving measured in expected use per capita range from 18-56% cent compared to 4-12% saving during periods of voluntary restrictions. Mandatory restrictions are effective in reducing water consumption.

Public information initiatives: The customer should understand the water bill which clearly identifies use rates, charges and other pertinent water use information such as home water conservation measures. The water bill provides contacts and phone numbers to report leaks and waste and also proposes initiatives.

Water reuse and recycling: Gray water (waste water) from certain uses is treated and filtered to remove solids are reused for specific purposes such as toilet flush or redistributed for irrigation, helps to reduce water use requirements through efficiency and conservation strategies, a core element of sustainable resource management.

2.7 Gaps identified in literature

Some of the gaps identified in the existing research literature especially the study of Hoffman (2009) on Geospatial Mapping and Analysis of Water Availability, Demand and Use within the Mara River Basin and the study of Alison (2004, 2009) on No Water, No Life-Mara River Basin include challenges arising from low investment and maintenances of existing water infrastructure as a factor of low access to quality water demand and high network losses. Hoffman gave a general conclusion about the growing water demand and unsustainable use of the natural resources without specifying the level of household water demand and the actual population still living without access to safe drinking water supply and how to manage the unsustainable use of the finite resource. What is not clear in the literature is whether the deteriorating access of improved water is the result of physical water shortage, infrastructural constraints, mismanagement or inadequate human and institutional capabilities to tackle the situation. With a view to contributing to such knowledge this study aims to analyse and determined the magnitude of household access to improved water demand and distribution coverage, factors that contribute to deteriorating access to pipe water demand and the effectiveness of the current water use management strategies. But households' level of awareness of the existing health risks associated with the use of contaminated water, the preventive measures to improve the quality of drinking water and the willingness to pay for improved water is beyond the scope of this study.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter gives an overview of the study area, the study design, population of the study, sampling procedures, the sample, instrumentation, data collection, ethical considerations, data preparation and analysis.

3.2 Study design

The study design was qualitative at which Survey research was used to provide numeric description of opinion of population by studying a sample of 300 households using questionnaires and structured interviews with the intent of generalizing from a sample to a population.

3.3 The study area

The research study was carried out in the lower area of Nyangores sub-catchment of Mara Basin of south west Mau in Bomet county, Kenya (Figure 3.1). It lies between Latitudes $0^{0}28^{'}$S and $1^{0}02^{'}$S and Longitudes $35^{0}14^{'}$E and $35^{o}47^{'}$E. It covers an area of $696km^2$. Nyangores and Amala tributaries of Mara River are very important in maintaining the base flow of the Mara mainstream and the only source of water for the Maasai Mara Game Reserve in Kenya and Serengeti National Park in Tanzania. Nyangores sub-catchment covers Bomet and Nakuru counties with a population of 225,458 people. The altitude within the sub-catchment ranges between 2,951m around the source in the Mau Escarpment to 1,706m downstream in Kaboson. The lower catchment has an average annual precipitation of between 1,000 and 1,750 mm and temperature varies from 16^0c to 24^0c (Bomet, 2010). The rainy seasons are bi-modal with the long rains starting in the mid March to June with a peak in April, while the short rains occur between September and December. The Nyangores River has two tributaries, Chepkositonik and Ainop Ngetunyek and runs approximately 94 km before joining Amalo River at Kaboson to form the main Mara River. The Nyangores River has an average flow of 8.6m^3/s (ILAO3, Bomet).

Crop farming remains the dominant economic activity to the majority of the population despite the diversity in spatial extent and land use. About 62% of the households are smallholder farmers (Aboud *et al.*, 2002), with livestock rearing being a second dominant activity, yet agriculture occupies about 28% of the available arable land. The main crops are tea, maize, potatoes, beans, coffee and pyrethrum. Major rock types in the area are dolomite and calcite and major soil type is cambisols with high porosity and good water retention. The river has an average sediment load of 128 tonnes per day (Kiragu, 2009).

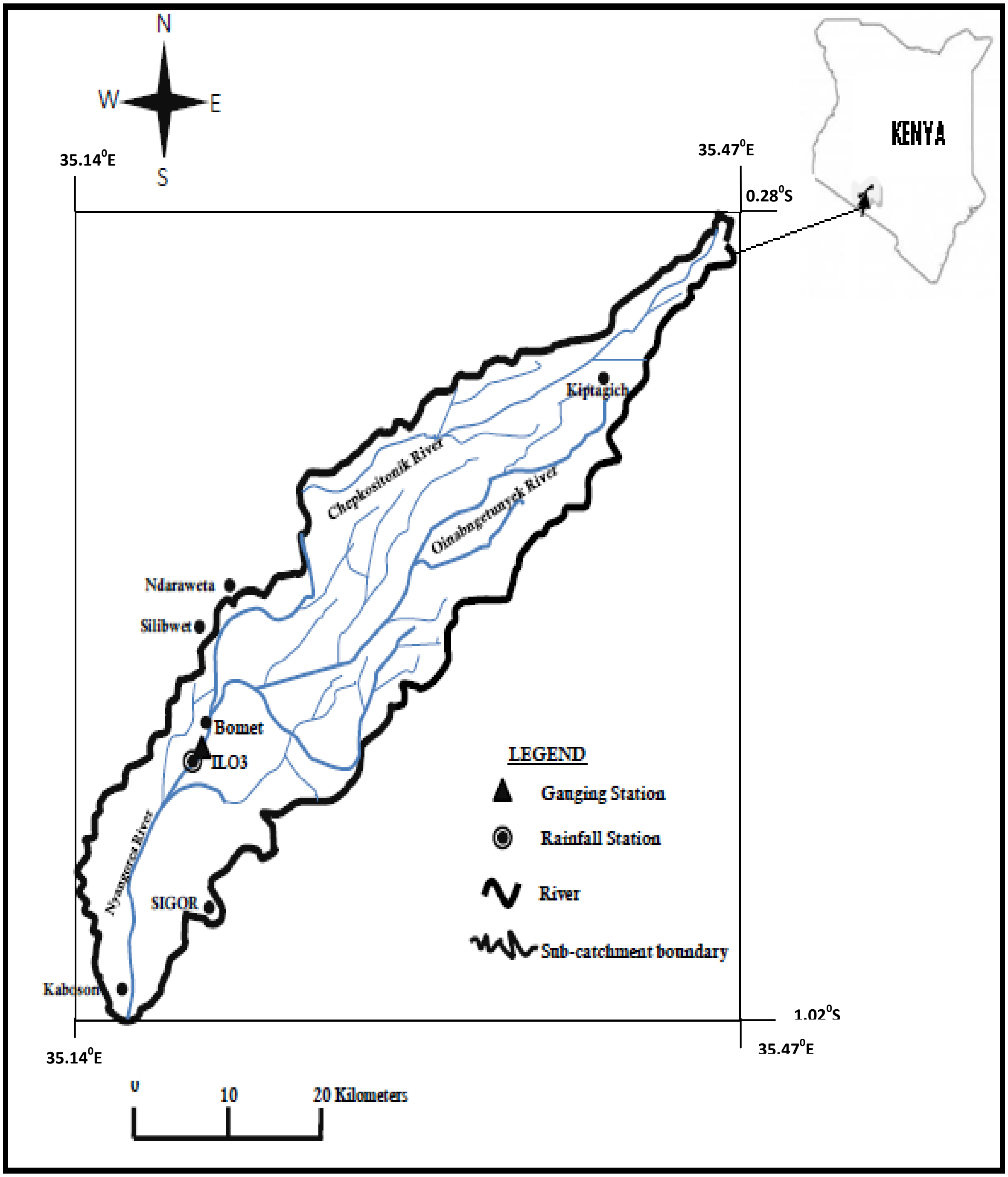


Figure 3.1: Location of Nyangores Basin in Kenya

Source: Nyangores Sub-catchment Management Plan (2011)

3.4 Target population

The research population comprised human beings in urban and rural households and villages within Silibwet, Bomet and Sigor regions in the lower part of Nyangores basin. The target human population of 162,422 residences in 50,832 households (KNBS, 2010) was sampled into 1,984 members of a study population and 300 households in rural and urban areas who access pipe and other sources of water. The demographic and socio-economic information includes household family size, sex, age, village, marital status, educational levels and length of stay, occupation, land acquisition and land use activities.

3.5 Sample size determination

The sample size for the study was based on the total number of households in the study area which is 50,832 (Table 3.1) and was calculated using the following formula adopted from Glenn (1992).

$$\mathbf{n = h/H \times N}$$

Where

n = Sample size for each sampling unit (to be determined)

h =number of households targeted in a sampling unit

H =total number of households in the study area

N =total number of households to be sampled

Table 3.1: Sample size for the study

Major urban centres	**Target Population**	**Target Household**	**Sample size**		**Average**	**Average household size**	**Average Land size**
			Population	**Households**			
SILIBWET	59,555	18,509	727	110	47	3.21	4.6
BOMET	74,714	23,461	913	138	54	3.25	4.5
SIGOR	28,153	8,862	344	52	54	3.17	5.6
TOTAL	**162,422**	**50,832**	**1,984**	**300**	**52**	**3.21**	**4.9**

Source: Fieldwork, 2013

3.5.1 Sampling techniques

Selection of respondents was done through purposive sampling technique to get specific rates of pipe water consumption from household family sizes of 3-5, 6-8 and above 9 (Table 3.2). 300 out of 50,832 households were picked and apportioned based on Glenn's formula into three sampling units (Table 3.1). The peri-urban and rural settings were selected for the reason of comparing the phenomenal situations in each geographical area as shown in Table 3.2 below.

Table 3.2: Geographical areas for the study

Major Urban Centres	Geographical Area							
	Peri-urban	3-5	6-8	> 9	Rural	3-5	6-8	> 9
Silibwet	Mogombet	5.7	1.8	1.1	Kapsoiyo	11.9	4.0	2.0
Bomet	Ririk	8.0	3.0	1.2	Kyokong	0.6	0.2	0.1
Sigor	Oreiyet	10.0	3.3	1.8	Kiplabotwa	5.7	1.9	1.0
Av. Con. M^3/mon.		7.9	2.7	1.4		6.1	2.0	1.0

Source: Fieldwork, 2013

3.6 Pilot study

A pilot study was carried out to ascertain that the questions were precise, understandable and would give relevant information expected. During the pilot survey, ten households were randomly picked for the interview from the study area based on the study variables and the results are given in Table 3.4. The research objectives and the questionnaire were revised after the pilot survey to capture the situation in the field.

3.7 Instruments for data collection

Structured questionnaire, interview schedules and documentary records were designed and used to collect information and data for this study as described below:

Questionnaires

These were used to collect data from different households in the study area especially concerning water distribution and demand. The questionnaires were designed to have both closed and open-ended questions covering areas like availability of water points and whether water demand are always met or not. The questionnaires were administered by the researcher so as to allow for verification of questions that may have not been so easy to understand to some of the respondents.

Interview schedules

The researcher visited Sigor, the headquarters of Chepalungu District and interviewed officials from the Ministry of Water and Irrigation on several issues that were of concern to the study. This shed more light on the capacity of the government to supply clean water to the residents of the study area. This was also important to enable the researcher to verify some of the information received from other sources.

Documentary data

The records that contained the required information for the research were obtained from government offices which included the report on the national housing and population census of 2009, the statements on the water bills, meter readings from the Ministry of Water and Irrigation, daily river discharge for the Nyangores River and climate data from Bomet station (ILA03) and journals. The census report was important in approximating the population of the area and hence demands for water as well as projecting the future water demands by projecting the population. The bills statement was important in the assessment of water management considering that metering is one of the most effective ways of managing water resources.

3.8 Validity and reliability of research instruments

Validity is the ability of the research instruments to collect the information that they were meant to. The questionnaires and interview schedules were prepared with the guidance of experts in the School of Pure and Applied Sciences, Kenyatta University. This guaranteed the content validity of the instruments before they were used for data collection in the field.

The researcher conducted two pilot studies that involved households that were not going to participate in the actual study and the findings of the two studies were correlated using Pearson's Correlation Coefficient. The results yielded a coefficient of 0.85 which was considered high enough and therefore, the questionnaires were adopted for use in the study. Triangulation was also used to ensure that data collected from one source was compared to the others to ensure consistency of the information that has been used in writing the final report of the study.

3.9 Ethical considerations

The study collected some information from the respondents that may be considered confidential but fit for public consumption. This included the family size of the respondents and the information on water bills. This report, has therefore, been compiled with great care and no identity of respondents has been directly referred to in this report. The right of the respondents to privacy was put into consideration by not asking them unnecessary information. The respondents also participated willingly in the study after they were made to understand the intentions of the study and the information received has not and will not be used for any other purposes apart from this report.

3.10 Data processing and analysis procedures

Primary data collected from the field were edited, cleaned and coded to render data usable for empirical analysis. The missing data and outliers have to be dealt with using average method and median. This section describes how some economic variables were processed.

Water quantities

The study revealed that households in Nyangores basin use multiple sources of water for various household chores. Both improved and unimproved sources of water were identified. A distinction was made between household access to these sources during dry and rainy seasons. The quantities of water consumed by households and livestock in this study are based on recall quantities consumed daily. Such quantities indicated could be considered as estimates suggesting that these amounts could be overstated or understated and therefore, subject to errors.

Water price

The price of water used in this study is based on the actual amount of money paid for consuming a unit of water from pipe water sources and imputed prices based on the opportunity cost of time spent in water collection by women and children on unimproved water sources where no actual price per unit was associated to this. Because of long walking distances to fetch water, time devoted to this activity is quite huge and must be accounted for because that time could be potentially devoted to income-generating activities. Appropriate value was placed on household time spent on fetching water. It was the quantity of improved water consumed per unit that was considered for the analysis.

Handling of missing data

Missing data were a challenge in time series data. In some cases, replacements were generated easily while others took time to resolve. One common practice was to replace missing data with the mean or median of the variable in question.

Magnitude of water demand analysis

Data on household water consumption were obtained from the field by the respondents who gave an estimate of water use by type of activity. Per capita water use and per capita water demand across the 300 households were calculated to obtain the quantities of water used by households in the basin. The mean water use and the mean water demand were used to determine the magnitude of household water demand in the study site. Water demand was also determined by the major water abstractors especially from Bomet water supply station. They included schools, hospitals, irrigation projects and domestic users that included livestock farming. Respondents were, therefore, required to indicate their major water uses and this was taken as an approximate amount of water required to meet their needs. The World Health Organization recommended an average of 60 litres per individual person in a day and this was used to estimate the amount of water required to satisfy the demands of water in the area (WHO, 2003).

Population analysis

Data on the population of the study area were obtained from the district planning office by analysing the national housing and population census report of 2009. The population growth rate in the report was used to estimate the population of the study area in the years subsequent to the time the census was conducted to date. This was done with the assumption that the growth rates have remained the same since then. Additional information was obtained from respondents in the study who were requested to indicate the size of their families. This information was then tabulated and a graph of the population trend obtained.

Income level analysis

Respondents in the study area were requested to indicate their average monthly earnings in Kenya shillings. This information was considered important in determining the ability of the residents of the study area to pay for water services. The data were coded and analysed using frequency tables with the help of SPSS.

Water availability analysis

The residents in the study area were required to state their source of water which informed the assessment of whether water is available to them or not. These sources were tabulated and frequency tables produced to indicate which options they had to access water. Additional information on the frequency of water pumping and the amount supplied daily was obtained from Bomet Water Supply Station.

Water Access Analysis

Access to water was determined by the distance walked by the residents to the nearest water point. This was collected using the questionnaire coded and analysed with the help of SPSS to produce frequency tables showing the distances walked by the residents to the nearest water point. Descriptive statistics, particularly the mean, were used to get the average distance walked and hence an estimation of time spent in fetching water.

River flow analysis

Data on the river flows were obtained from among the functional river gauging data station within the sub-catchment, namely; (1LA03) at Bomet. Data regarding the amount of rainfall was obtained from a rainfall station at Bomet Water Supply Station just adjacent. The data were later tabulated and analysed using descriptive statistics like measures of central tendency.

Customer billing records analysis

Water consumption data obtained from customer billing records were tallied for various categories of users. Water consumption subtotals were adjusted to account for unmetered water use and water losses such as leakages and the results were aggregated to determine total water demand and their respective costs in the sub-catchment. Water production reports (Table 4.6) from Bomet Water Supply Station include monthly information on metered water use and arrears as shown in Table 4.13.

SWOT analysis

This review focused on challenges in terms of integrated use of Nyangores River and conducted analysis of strengths, weaknesses, opportunities and threats (SWOT) based on secondary data. The strengths include sharing of water, population that is well-adapted to the environment, presence of political goodwill, strategic location of Nyangores River, and peaceful co-existence of local communities. Weaknesses included insufficient staffing position, inadequate capacity to analyse water resource information, exclusion of the local knowledge of indigenous people, low adherence of water laws and inadequate use of modern technology. Opportunities include more involvement of NGOs, civil society and training opportunities. Among the threats are increased population coupled with poverty and climate change (Table 4.18).

Table 3.3: Study variables

Variable name	Definition
S1Q1	Average household size
S2Q2	Respondents occupation
S3Q3	Average household land holding
S4Q4	Average household livestock holding
S5Q5	Average distance to water source
S6Q7	Average water fetching time per month
S7Q8	Length of stay in years
S8Q14	Major sources of community drinking water
HWC	Household water consumption
WUMS	Water use management strategies
HPWC	Household pipe water coverage
PCHIN	Per capita household income
Rain	Annual average rainfall
Runoff	Annual average runoff

Source: Fieldwork, 2013

Table 3.4: Pilot Study

Variable	Observation	Mean	Standard deviation	Minimum	Maximum
S1Q1	10	3.21	1.7	1	7
S2Q2	10	42.75	28.9	2.2	83.3
S3Q3	10	4.9	1.7	0.1	6.05
S4Q4	10	3	1.2	2	10
S5Q5	10	2.5	0.9	1	4
S6Q7	10	1.0	0.6	0.5	2.0
S7Q8	10	46	27.3	0.5	90
S8Q14	10	82.7	59.4	2	152
HWC	10	55.87	12.6	20	60
WUMS	10	33.3	17.5	10	70
HPWC	10	22.09	0.4	21.8	22.74
PCHIN	10	2735	3510.3	470	10040
Rain	10	51.90	26.8	13	78.04
Runoff	10	21.97	6.6	16.4	33.03

Source: Fieldwork, 2013

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents results of the analysis based on quantitative statistical techniques, indicated and presented in tables, figures, graphs and charts. Answers to research questions and objectives are sought through descriptive analysis of household socio-economic and demographic characteristics, alternative water resources and quantity of water demand and supply. The magnitude of household water demand and distribution in Nyangores basin is discussed and the key factors that influence the rate of water demand and the effectiveness of the current water use management strategies in regard to water consumption, accessibility and costs are explained. The analysis was done on the basis of study objectives and research questions. This chapter further provides a discussion on the study variables and their implication on household water demand, distribution and management. The interpreted data analysis results become the findings of the research study.

4.2 Pilot study

The results of pilot study and the actual study were significantly related. During the pilot study average family size was 3.21, average distance to water source was 2.5 km and average water fetching time was 0.99 hours while during the actual study average family was 3.21, average distance to water source was 2.0 km and average water fetching time was 1 hour. Per capita household water consumption during pilot study was 55.87 m^{3} /d while actual study was 60 m^{3}/d. Therefore the questions were proved precise and will generate relevant information for the study.

4.3 Magnitude of household water demand

The mean annual water use, percentages, averages and daily per capita water consumption are the major measures that demonstrate the feasibility of water demand for specific purposes between different households and provide answers to many long standing questions on how much and where water is used in the rural and urban settings of the entire Nyangores basin. This is discussed under five major variables of water availability status (Table 4.1), household socio-economic Table 4.4), demographic characteristics (Table 4.7), income levels and preferably major water abstractors and the price of water (Table 4.8).

4.3.1 Water availability status

The macro- level data indicates that Nyangores sub-catchment is abundant in unimproved water resources (Table 4.3). However, occasional water scarcities especially in dry seasons have become an always existing problem. This implied the need for a disaggregated analysis to show seasonal and spatial variations in water availability by rural and peri-urban households. This is partly contributed by insufficient water supply points at the community level and high connection costs in household piped water distribution. Considerable walking distances to fetch water are evidence to difficult water accessibility and thus hindrance to meet household water demand. Many households, therefore, depend on multiple water sources for multiple uses. In rural areas, most of the water used was from unimproved sources whose level of quality is uncertain (Table 4.1).

Table 4.1: Percentage of household's water availability per source per season

Piped		**Boreholes**		**Wells**		**River**		**Others**	
Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
4.8%	5.9%	1.4%	0.2%	8.9%	3.3%	27.8%	56.4%	45.1%	46.3%

Source: (Alison, 2004)

Among the people interviewed, 70% hauled water from rivers and other sources mainly dams, ponds and rain water harvesting. Long distances commuted to water source and time devoted to this activity are quite huge and must be accounted for because that time could be apportioned to income-generating activities. Appropriate value is placed on household time spent on water fetching (Table 4.2).

Table 4.2: Average time (hours) spent daily per household collecting water

Geographical region	**Season**	**Number of respondents**	**Average time (hours)**
Peri Urban	Rainy	100	0.17
	Dry	100	0.83
Rural	Rainy	200	0.97
	Dry	200	2.0

Source: Fieldwork, 2013

Water containers having an average capacity of 20 litres are used by women and 10 litre containers by children to carry water thrice a day in the morning, during mid-day and also in the evening hours from source to household. The variation in time taken to collect water in urban and rural households was noted, and it emerged that urban households have access to pipe water connection within the homesteads while rural households collect water from distant sources. Respondents' information further revealed that households devote about 0.99 hours per trip to collect water from available sources. In the context of water collections rural households may not value this time because it is an integral part of their daily activities that must be done at all costs with little option available to them. The upper part of Nyangores catchment is endowed with plenty of rainfall while the lower part experienced semi-arid conditions. This, therefore, creates a suitable condition for rainwater harvesting at the upper catchment and development of water pans in the lower part. Boreholes and shallow wells are mainly used in the mid and lower parts of the catchment. As the demand for water increases, there is need to increase water storage facilities to meet household access to improved water demand. The observed number of alternative water sources and their percentage coverage as shown in Table 4.3 indicates that there is need to protect more springs in the mid and lower catchments. Rainwater harvesting at household level is not widely practiced.

Table 4.3: Alternative water resources in Nyangores basin

Water resource	**Estimate number**	**Percentage coverage**
Unprotected springs	1500	75
Protected springs	23	1.15
Pans	13	0.65
Dams	4	0.2
Boreholes	2	0.1
Roof catchments	58	2.9

Source: Fieldwork, 2013

From observation and survey (Table 4.3), Nyangores sub catchment had limited rain water harvesting due to lack of rain water harvesting structure. The main cause to this problem is low income levels (Figure 4.4) and lack of awareness on existing rain water harvesting technologies.

4.3.2 Household socio-economic and demographic characteristics

In small urban areas, the socio-economic factors such as persons per household, monthly income of households, number of years of education of household head and the household potable water show statistical relationship with household per capita water use.

Household composition and major characteristics

This study conducted a household survey that covered 1,984 persons living in 300 households. The proportion of males to females was almost equal indicating gender balance in the sample (Table 4.4). Based on age structure, the economically active population aged between 18 to 49 years being the dominant group representing 44.4 % of the population. The adolescent age group of 5 to 17 years represents 34.6 % of the population and 50 to 60 years is 3.6 % who are less active.

The level of education in Nyangores basin is low. Those without formal or informal education are about 42.9 %. Approximately, 13.6 % have secondary education and 1.4% has tertiary education (Table 4.4). Christianity is the dominant religion representing

65.8% of the study population and adherence to traditional religion constitutes 20.2% with 0.4% Islamic religious belief and 12.3% non-religious households (Table 4.4).

Table 4.4: Household Socio-Economic Characteristics

Variable	**Mean/frequency**
Population sample	1984
Mean family size	3.2
Sex (%)	**%**
Female	50.4
Male	49.6%
Age composition (%)	**%**
Less than 4 years	17.4
5 to 17 years	34.6
18 to 49 years	44.4
50 to 60 years	3.6
Marital status (%)	**%**
Married	35.3
Divorced	1.5
Separated	0.9
Widow/widower	3.8
Single	58.5
Education	**%**
Non Formal	42.9
Elementary	18.8
Secondary school	13.6
Vocational	0.8
Tertiary	1.4
Still in school	19.6
Others	2.9
Religion	%
Christian	65.8
Traditional	20.2
Non Religion	12.3
Islamic	0.4
Others	1.3

Source: Fieldwork, 2013

Socio-economic factors are significantly related to per capita water use. The quantity of water consumed depends on household characteristics. Household size determined the magnitude of actual water consumption in litres per capita per day (l/c/d) (Table 4.5). The calculated mean household family size of 3.2 persons (Table 4.4) with a mean water consumption of 55.8 litres of water per day and a standard deviation of 12.6. Table 3.4 indicates a wider variation in the rate of household water use, meaning that the magnitude of water use in each household significantly changes from season to season.

Table 4.5: Average household per capita water use in litres per season per day

Region	Households			Quantity use l/s/d		Per capita l/s/d	
	Av/ Hs	Hs/sam	Pop/sam	Wet	Dry	Wet	Dry
Silibwet	3.21	110	727	42,602.2	36,131.9	58.6	49.7
Bomet	3.25	138	913	56,606	43,824	56.0	48.0
Sigor	3.17	52	344	20,812	18,920	60.5	55.0
Total	9.63	300	1984	120,020	98,875.9	175.1	152.7
Average	**3.21**	**100**	**661**	**40,006.7**	**32,958.6**	**58.4**	**50.9**

Source: Fieldwork 2013

Household size positively affects both free and purchased water demand. This implies that the larger the household, the greater is water consumption. These results show that water consumption increases with household size meaning the larger the household, the lower the per capita water consumption. Average per capita water use is higher in wet season than in dry season which is positively related to the availability of the resource. Furthermore, only a few people can afford the higher cost associated with fetching water in the dry season. Well-off households may afford to travel long distances e.g. using transport means such as motorcycles to fetch water and this implies that poverty has a negative effect on water use. Annual per capita domestic water consumption for the period 2000 to 2012 was calculated for each year and the mean annual per capita water use was 0.2884m^3/ year which is equivalent to 288.4 litres per capita per year (l/c/y) (Table 4.6).

Table 4.6: Annual per capita domestic pipe water use

Year	Population	Water use (M^3)	Per capita water use (m^3/y)	Water supply (M^3)	UfW %
2000	120,328	33,880	0.28	66,600	49.13
2001	123,836	33,880	0.27	66,600	49.13
2002	127,334	33,880	0.26	66,600	49.13
2003	130,851	33,880	0.25	66,600	49.13
2004	134,336	32,145	0.24	65,510	50.93
2005	137,826	31,877	0.23	64,400	50.50
2006	141,305	31,261	0.22	65,510	52.28
2007	144,805	43,684	0.3	108,000	59.55
2008	148,264	46,218	0.31	110,005	57.98
2009	151,804	44,745	0.29	105,900	57.74
2010	155,182	43,202	0.28	103,250	58.15
2011	158,883	65,038	0.41	154,800	57.98
2012	162,422	66,624	0.41	156,600	57.45
	Total	540,314	3.75	113,4865	699.08
	Mean	**41,562.615**	**0.2884**	**87,297.308**	**53.77**

Source: Bomet Water Supply, (2013)

The low per capita domestic pipe water use implies that the water demand is not met due to availability of unimproved alternative water sources which are not regulated and therefore, difficult to quantify. The result also shows that rising population has led to a proportionate decrease in per capita water consumption, a reflection that water scarcity is being experienced. The quantity of water consumed per year is less than the quantity supplied for the same population showing that large amount of water is lost an implication that water unaccounted for is high and may be due to commercial losses such as illegal connections, unbilled customers and wastage on unmetered customer's premises (Table 4.16) as well as to technical losses due to leakage. Unaccounted for water (UfW) continue to remain high at an average of 53.77% which is beyond an acceptable benchmark of 25% (Table 4.6).

Demographic characteristics

The average household age is 52 years and the age cohort 18 to 59 years (44.4%) is economically active. Majority of household heads of 42.9 % have no formal education and male-headed households constitute 35.3%. Average net household size is 3.21 persons per household (Table 4.4) with more adults than children. The water use with variables such as number of persons per household, monthly income of households and educational level of household head show strong statistical relationship with household per capita water use. High values of standard deviation indicate a wide variation in demographic characteristics which affect the rate of water use.

Table 4.7: Household demographic characteristics

Variable	Observation	Mean	Std .deviation	Mini	Max
Total households	300	5.28	2.50	1	23
Net household size	300	3.19	2.22	1	23
No.of females	300	2.86	1.70	0	22
No.of males	300	2.81	1.57	0	12
Babies <6 years	300	0.72	0.81	0	5
Children 6-17 years	300	1.67	1.80	0	8
Adults > =18 years	300	3.24	1.91	1	18
Sex	300	1.08	0.24	1	2
Age	300	30.48	9.05	15	100
Formal education (yrs.)	295	3.05	3.20	0	10

Source: Fieldwork, 2013

Household income sources and employment

Majority of household heads are employed in the agricultural sector which constitutes 70.5% of their income sources. Non-agricultural income sources include sale of bricks, teaching and rendering of other services such as car wash generate additional income for households 29.5% (Table 4.8). Income and the number of persons per household are statistically significant determinants of household water consumption.

Table 4.8: Mean annual household income

Source of income	Observation	Mean	Std.Dev.	Mini.	Max.	%(per)
Rural						
Non –agricultural	150	1.8	2.7	0.02	65.0	29.5
Agricultural	150	4.3	6.3	0.01	113.0	70.5
Total Income	**300**	**6.1**	**9.0**	**0.03**	**178.0**	**100**
Peri-urban						
Non-agricultural	150	5.2	4.8	0.03	112	94.9
Agricultural	150	0.8	1.3	0.01	6.0	5.1
Total income	**300**	**6.0**	**6.1**	**0.04**	**118.0**	**100**

Source: Fieldwork, 2013

Agricultural activities contribute 70.5% to household income while the remaining 29.5% comes from non-agricultural sources in the rural area indicating the importance of agriculture in the rural economy. It is also observed that 94.9% of household income in peri-urban area comes from non-agricultural activities while agricultural activities contribute 5.1% showing that agricultural sources least contribute to household income in urban economy. Sources of non-agricultural income include brick-making, car wash, teaching and entrepreneurship.

Major water abstractors

The magnitude of water demand and distribution in Nyangores sub-catchment was determined using the following major water abstractors with their respective water quantity consumption per day, domestic water use 18000m^3, learning institutions use 140m^3, dispensaries consumes 55m^3, livestock 4,500m^3, irrigation 24,000m^3 and industrial/ commercial 5,000m^3 (Table 4.9). The analysis indicated that the quantity of domestic water consumed depends on household characteristics like family size, and gender composition. A majority of the respondents indicated that water is used for domestic (34.8 %), livestock (8.7 %) and irrigation (46.43%) as shown in Table 4.9. This can be explained by the fact that the proposed irrigation will only be done by large-scale horticulture projects in the study area while the rest are practicing rain-fed agriculture mainly on small scale. Regardless of the season, a lot of water is used in households for bathing, dish washing, cooking and general cleanliness. However, a majority of people wash their clothes from the river as seen in plate 4.5. Similarly, livestock in the area are mainly watered at the river which also supplies water for other domestic functions. Other major water abstractors in the study area are schools, hospitals, irrigation projects and commercial enterprises (Table 4.9).

Table 4.9: Major water abstractors in Nyangores sub-catchment

Water use	Number	Rate	Estimated Qty	%
Domestic	300,000	60 liters/c/day	18,000	34.8
5 secondary schools	400 students	50litres/c/day	100	0.19
10 primary schools	800 pupils	5 liters/c/day	40	0.08
Dispensaries	11	5,000litres/day	55	0.1
Livestock	0.3 LU per capita	50litres/LU/day	4,500	8.7
Irrigation	300 ha		24,000	46.43
Industrial/commercial			5,000	9.7
Total			51,695	100

Source: Fieldwork, 2013

There are no large scale irrigation farms or major industries along the study area; hence the amount of water that goes into these sectors is limited.

4.4 Key factors that influence the rate of water demand

The key factors that influence the rate of water demand in the study area were ascertained using the following determinants: population growth, family size and land use activities, price of water, household income levels, climate change, water accessibility and availability. The information is presented in form of tables, charts, graphs and plates.

4.4.1 Population growth

A comprehensive water demand and distribution begins with evaluating the areas' historical population trends and projected growth patterns. According to data from the national housing and population census report of 2009, the study area had a population of 155,182 with a population growth rate of 2.3 per cent. If this growth rate is sustained, the population was approximately 162,422 by the end of 2012 and is projected to increase to 194,851 by the year 2020. This is shown in Figure 4.1.

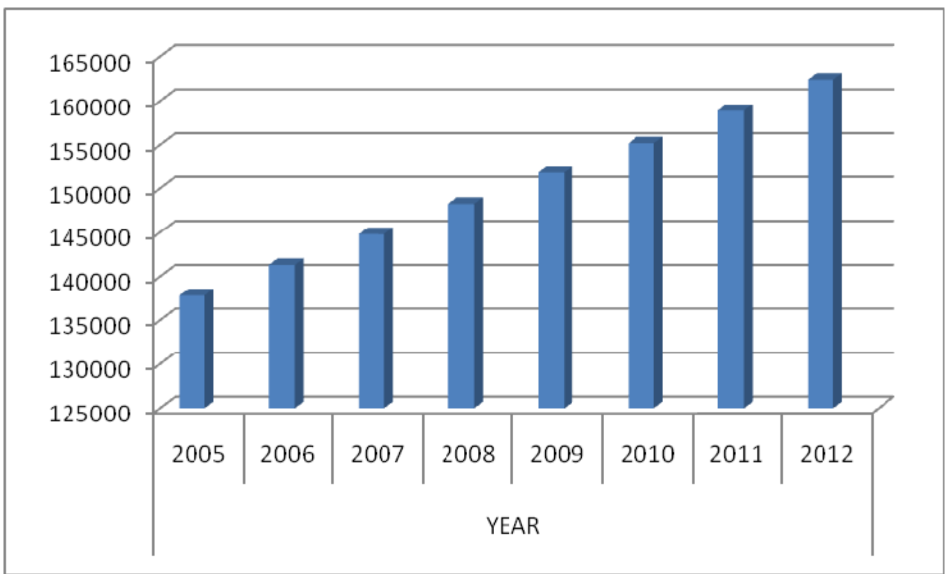


Figure 4.1: Annual population increase

Population is and will remain a major determinant of water demand and a major consideration of any water supply system. If every member of any household uses an average of 60 litres of water daily, then the current water demand by the human population alone is approximately 9,745 m^3 per day but this may change with the climatic conditions and modern lifestyles. This demand is likely to increase to 116,922

m^3 daily by the year 2020. Due to population growth, it has been estimated that by the year 2025, Kenya's per capita water availability will be 235 cubic meters per year, about two thirds less than the current 650 cubic meters (World Bank, 2010).

The study respondents were majorly people who have been in the area for long enough and are in a position to give a true and clear position of water demand and supply in the area. About 1.6% of the respondents have lived in the area for 20 to 30 years, 54.9% for 31 to 40 years, 21.9% for 41 to 50 years while 15.6% of them have lived there for 51 to 60 years and 6.0% for over 61 years (Table 4.10).

Table 4.10: Respondents' duration of stay in years

Duration of stay in years	Percentage
Between 20 – 30 years	1.6
Between 31 – 40 years	54.9
Between 41 – 50 years	21.9
Between 51 – 60 years	15.6
Over 61 years	6.0

4.4.2 Family size

The respondents were also required to provide information on the size of their families and the findings indicate that a majority of the households have between 3 and 6 members at 61.1 percent. These findings replicate those of the national housing and population census report that put the average family size at five members. These findings are shown in Figure 4.2.

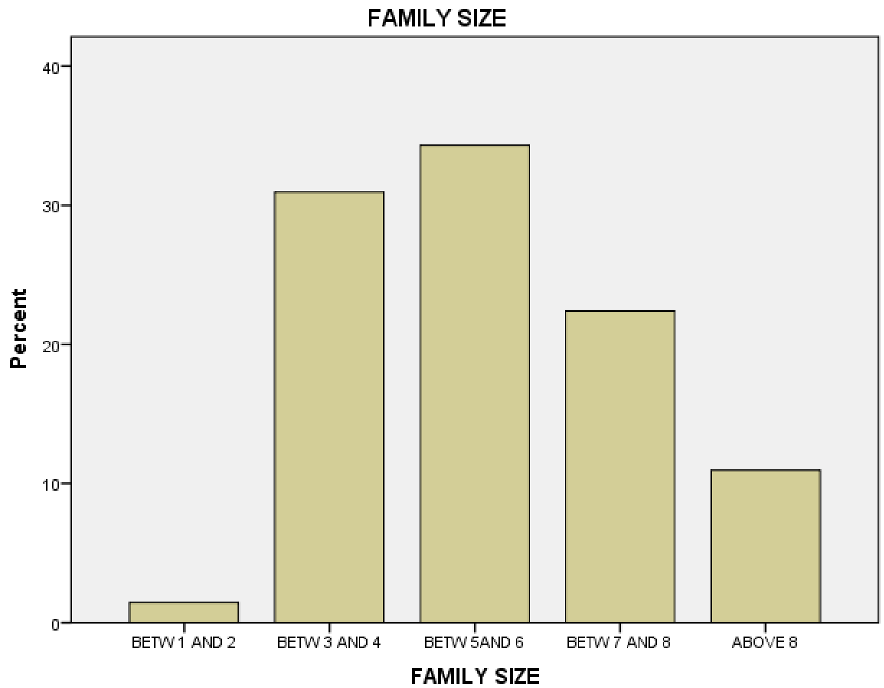


Figure 4.2: Family size

Pipe water use rates varied significantly from one household to another depending on household family sizes of 3-5, 6-8 and above 9 in urban and rural set up (Table 3.2). Family size influences water consumption as there is a household water demand of 38.1% per month according to the study (Table 4.13) and an average water consumption of 60 liters per day per household (Table 4.9) which is in line with UN water consumption per day.

4.4.3 Land use activities

The major land use types in Nyangores sub-basin are forest, mixed farming, bush land, water, cropland and livestock. The existing land use –based water demand characteristics in the study area include irrigation, livestock, residential, institutions commercial and industrial. Crop farming remains a dominant economic activity in the study area. A majority of the residents are small scale farmers that rely on rainfall with very little irrigation being practiced.

According to USAID (2011), up to 62% of the residents are small-scale farmers compared to 86.6% of the respondents who indicated that they were farmers. The increase should not be misconstrued to mean profitability of farming in the region even though the land is fertile. Any agricultural activity dependent on the vagaries of the weather is likely to be unprofitable (Osei, 2004).

The dependency of majority of the rural population on agriculture for their livelihoods suggests the lack of opportunities in the non-agricultural sectors and the absence of an enabling environment necessary for agricultural and rural development. The high dependency on agriculture may not be very healthy for the sub-catchment. High population increase is already pushing residents to clear more land for agriculture and pasture. The sub-catchment management plan indicates that land use change and the intensification of human activities both at the catchment and local levels have a great influence on the rate of water demand and remain a major challenge to the ecology of the Nyangores River.

Longitudinal changes in water quality parameters and nutrient levels are already clear. Increased sediment levels are likely to reduce primary production and reduce benthic and spawning habitats for macro invertebrates and fish (Minaya, 2010). Increasing nitrogen and phosphorous levels could lead to declining dissolved oxygen in the water, with negative impacts on aquatic organisms. High nutrient levels will also lead to water fouling which will make it unfit for human use. The findings show that the major soil types in the area are the cambisols which are characterized by structural stability, high porosity, good water retention and moderate to high fertility, all of which make them suitable for agricultural activities evidenced by plates 4.1 and 4.2.

Plate 4.1: Sorghum growing in Sigor Division along Nyangores sub-catchment
Source: Author, 2013

Livestock farming is the second major agricultural activity in the study area. Averagely, every household has 4 animals mainly cows, goats and donkeys.

Table 4.11: Ownership of cows in Nyangores sub-catchment

	Range	Frequency	Percent	Valid Percent	Cumulative Percent
	<2	66	29.5	31.4	31.4
	3-4	91	40.6	43.4	74.8
	5- 6	33	14.7	15.7	90.5
	7 – 8	18	8.0	8.5	99.0
	>8	2	.9	1.0	100.0
	Total	210	93.7	100.0	
Missing	System	14	6.3		
	Total	224	100.0		

Source: Fieldwork, 2013

Daily water requirements for various livestock are shown in Table 4.12

Table 4.12: Estimated average daily water consumption for livestock

Type of animal	Description	Litres per day
BEEF		
Lactating cow	520kg	45.4
Dry cow	520kg	37.8
Calf	112.5kg	11.3
Feeder-growing	180-360kg	24-36
Feeder- finishing	270-540kg	34.1
Bull	----------	45.4
DAIRY		
Milking	Friesian (Holstein)	136.2
Dry cow	Friesian(Holstein)	45.4
Calf	247.5kg	13.2
SHEEP AND GOATS		
Ewe/ Doe	----------------------	9.5
Milking ewe/ doe	----------------------	13.2
Feeder lamb/ kid	---------------------	7.6
POULTRY		
Broiler	Per 100	15.9
Roaster/ pullet	Per 100	18.2
Layers	Per 100	24.6
Breeder	Per 100	32.2

Source: Livestock watering fact sheet (2006)

Intensive agriculture in the upper part of Nyangores River has led to high discharge of nutrients especially nitrogen and phosphorus into the river leading to water fouling as shown below (Plate 4.2).

Plate 4.2: Intensified agricultural activities in upper Nyangores River
Source: Veronica, 2010

Generally, intensive mixed farming on small scale level is common. However, other activities in the region include brick making, quarrying and some are employed mainly as teachers and in the health sector.

4.4.4 Customer billing records

Customer billing reports for 2012 were obtained from water supply units in Bomet and Silibwet water projects. The data list included monthly billed water use by customer category. An analysis of the data shows that the institutional, commercial and industrial uses are stabilized. Water use by customer category is shown in Table 4.13. By computing the percentage total of water use, it is seen that irrigation is the major water demand sector with 50.9 % followed by households with 38.1 %. The expansion of piped water supply has been quite slow for some time as out of the 696 square kilometers in the study area, only 36.9% has been covered with piped water system since 2003. This, according to the water officials, is mainly due to non-payment of water bills which as at January 2013, stood at shillings 4,171,949. The arrears are said to be increasing at a rate of 18.3% every four months, approximately 4% every month. This denies the supply company capital to run its daily activities and even maintain the system or even expand it. This may also be attributed to the fact that the residents have several other sources of water mainly river Nyangores and the numerous springs in the area.

Table 4.13: Water bill - February 2013

Customer	Water sup m^3/ month	Water demand m^3/ month	% water demand	Connections	Unit cost/ (M^3)	Monthly water bill (SH)	Monthly arrears (SH.)
Households	6,070	540,000	38.1	906	33.30	202131	2,977,697
Irrigation	Nil	720,000	50.9	Nil	Nil	Nil	Nil
Industrial	Nil	4,230	0.3	21	33.30	Nil	Nil
Commercial	74	5,160	0.4	11	33.30	2,464	96,440
Institutional	195	11,460	0.8	23	33.30	6,494	1,097,812
Livestock	Nil	135,000	9.5	Nil	Nil	nil	nil
TOTAL	6,339	141,5850	100%	961	33.30	211,089	4,171,949

Source: Fieldwork 2013

4.4.5 Income levels

The study also sought to find out the income level of the respondents and their responses are shown below.

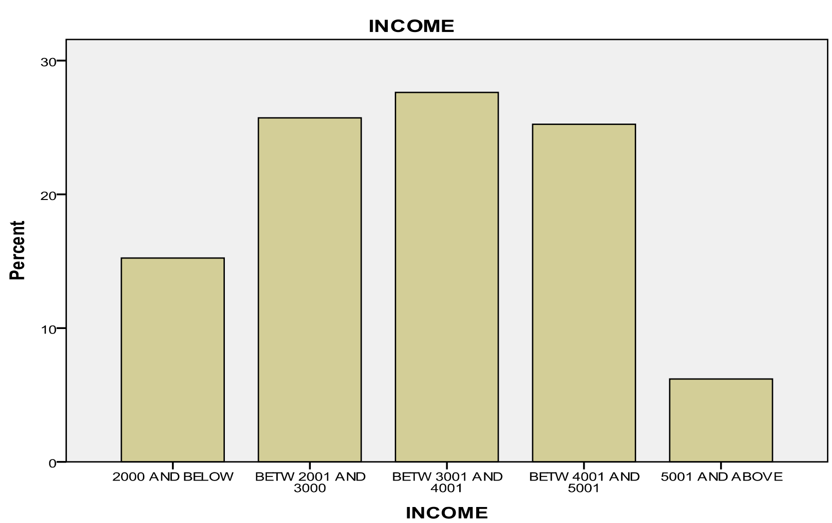


Figure 4.3: Respondents' income levels

Majority of them earn between 2,001 and 5,000 shillings a month. Considering that a higher percentage of them are farmers and may not quantify their farming output in monetary terms, these are not to be considered poor. This consideration is important especially in determining whether or not they are capable of paying for water and sanitation services.

4.4.6 Climate change

The study area receives plenty of rainfall annually except for short dry spells between January and April. This is shown in Figure 4.4.

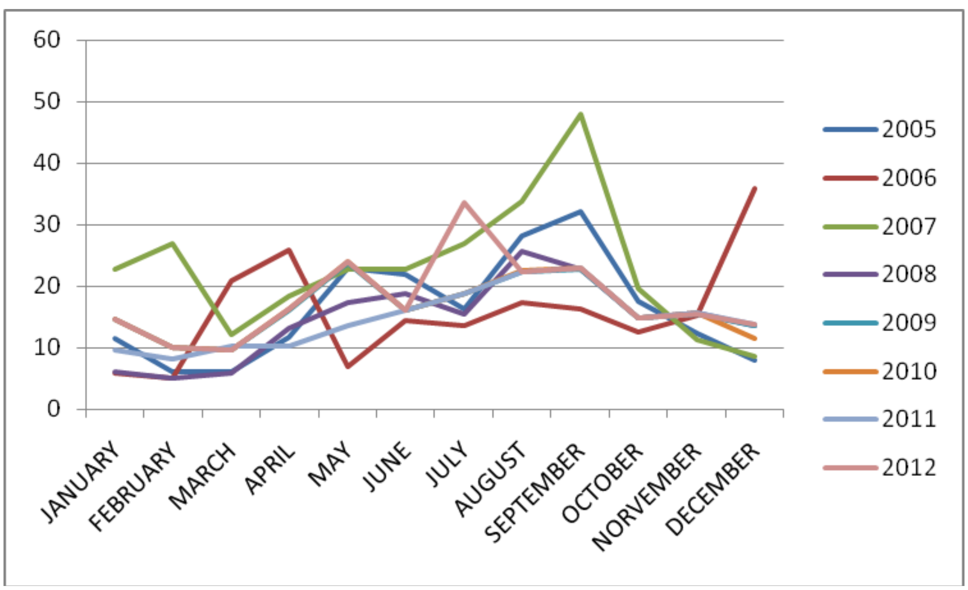


Figure 4.4: Average annual rainfall patterns – Nyangores basin

This rain water if harvested and stored properly could be of great importance to the people of the study area and they could not be experiencing water shortages. However, when asked if they have ever experienced any water shortage, all respondents confirmed that indeed at one time or another, they have experienced shortage of water. This is mainly due to drought as shown in Figure (4.5). Residents of the area also blame the high demand and inadequate supply of water as other major causes of water shortage. This should not be the case though in a place that receives so much rainfall; measures should be put in place to harvest rain water and store it for use during the dry seasons.

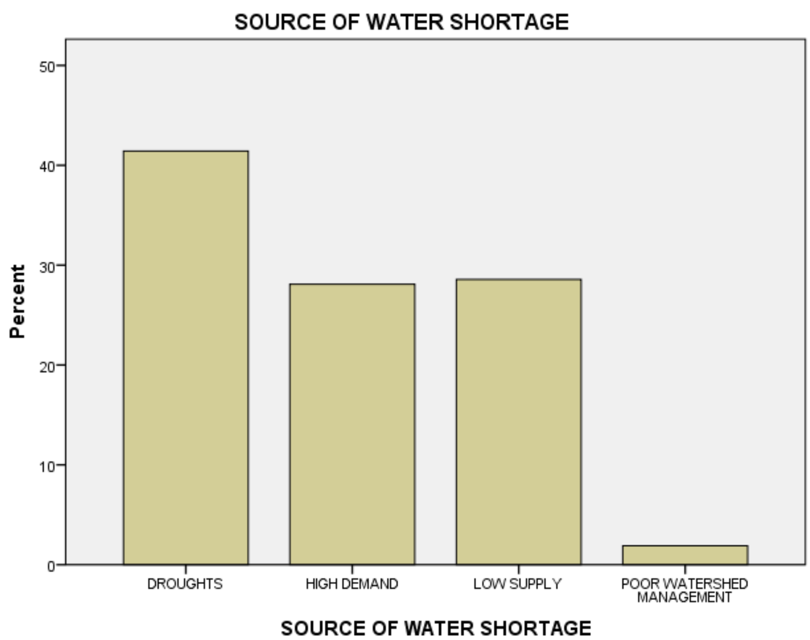


Figure 4.5: Determinants of water shortage

4.4.7 Water accessibility

Water is a basic human right and access to it should be a basic human right as well. The right of access to water resources is enshrined in the National Constitution and in the Water Act 2002. Access to water is an equally important factor in demand for water. Timely and easy access to water should be considered as a basic right that should be guaranteed for all. The study, therefore, sought to find out the average walking distance to the nearest water point for every household and the findings are shown in Table 4.14 and Fig. 4.6).

Table 4.14: Percentage of households with access to water source by distance and season

Less than 1km		**2km**		**Above 2km**		**3-4km**		**Above 4km**	
Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
4.1%	4.2%	47.9%	70.8%	16%	10%	8.3%	2%	4.2%	0.3%

Source: Fieldwork, 2013

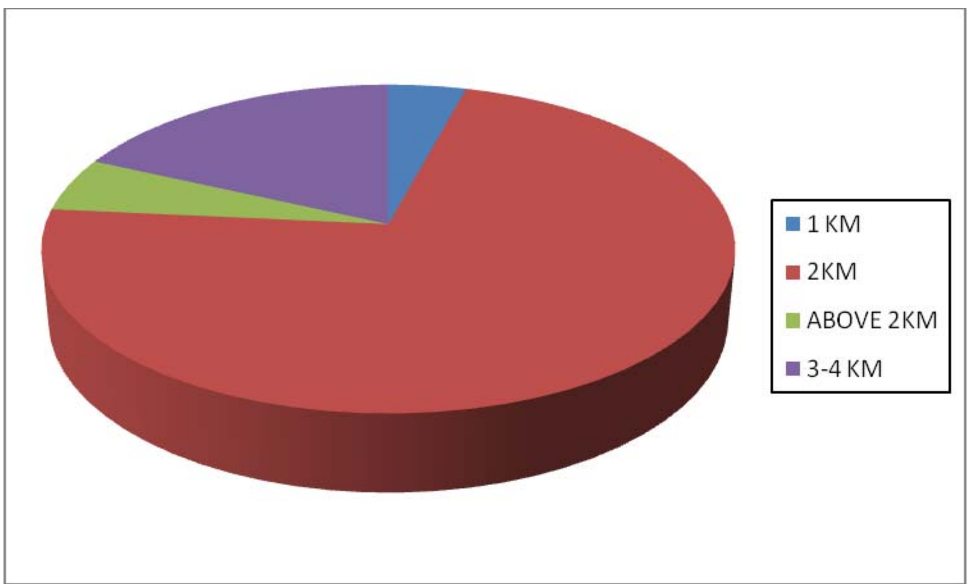


Figure 4.6: Average household walking distance to nearest portable water point

The results indicate that 4.1% of household's access water from less than 1km during the dry seasons compared to 4.2% during the wet seasons. The percentage of households accessing water within 2-3 km during the dry and wet season is 16% and 10%

respectively. However, households that access water within 3-4 km during the dry and wet seasons accounts for 8.3% and 2% respectively. Majority of households (47.9% and 70.8%) in Nyangores basin spend less than one hour to get water during the dry and wet seasons respectively with an average walking distance of 2 km. Given the average family size of five and some livestock that need water daily, then a lot of time could be used to get enough water for a family in a day. Majority of the respondents fetch water in the morning and in the evening and with a water point density of 400 persons, this time may be more. If this time is quantified economically, the population in the study area could be wasting valuable time that can be utilized in alternative economically viable activities. Time spent on fetching water can be used to do business, clean the house, work in the farm or even take care of the livestock. If time is thought of as an economic resource and even quantified in monetary terms, then inaccessibility to water can be a cause of poverty and other social problems.

According to the respondents, inadequate water can be associated with poverty, food shortage, waste of time and poor health. One of the respondents was quick to comment that "during dry periods, we have to walk for long distances to get clean water and even what we get is not so clean and so we get water-borne diseases on which we spend a lot of money to treat." The most affected are women and children who traditionally are charged with the role of fetching water. It is even worse that at times, school going children have to take part of their school time to fetch water for their families and some don't even attend school as they take responsibilities in their families early in life. The catchment area is at risk of being trapped in poverty due to low investment in human capital. UNFPA (2003) notes that stabilizing global population at a level that will permit the achievement of sustainable development will be attainable only if efforts to expand and improve the quality of reproductive health programmes are maintained, and only if these are combined with greater empowerment of women and increased investments in human capital, particularly in the education of girls. This may not be the case for Nyangores sub-catchment as an area if girls are to continue doing the traditional roles of taking care of young siblings and fetching water even during school times as seen in the Plates 4.3 and 4.4 respectively. Long distances and time taken by women and children to haul water from various water sources reduce household water consumption and has a negative impact on water demand.

Plate 4.3: School children fetching water from unprotected spring within Nyangores basin

Source: Author, 2013

Plate 4.4: Hauling water by school going children and women in Nyangores River
Source: Author, 2013

The quality of water the residents of the area get is an equally important consideration. Access to clean water is important for human health, not only in the study area but the whole of humanity. Contaminated water is a source of diseases and is associated with pregnancy failures. Water from protected springs and piped water are considered to be safest options. However, only 36% of the respondents have access to piped water and the rest get their water from the river or springs which in most cases are unprotected (Table 4.15 and Plate 4.5).

Table 4.15: Sources of water

	Source of water	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SPRING	82	36.6	39.0	39.0
	RIVER	53	23.7	25.2	64.2
	PIPPED WATER	75	33.5	35.8	100.0
	Total	210	93.8	100.0	
Missing	System	14	6.3		
Total		224	100.0		

Source: Fieldwork, 2013

Plate 4.5: Effects of human activities on water quality along Nyangores Stream

Source: Author, 2013

The piped water supply currently covers 5.3 per cent of the study area and its expansion has been quite slow for some time now. Out of the 696 square kilometers in the study area, only 36.9 have been covered by piped water system since 2003. This gives an average of 0.4 square kilometers per year. This, according to the water officials, is contributed mainly by non-payment of water bills which as at January 2013, stood at shillings 4,171,949. The spatial distribution of piped water is shown in Figure (4.7). The municipal water distribution systems represent a major portion of the investment in urban infrastructure. The goal is to design water distribution systems to deliver potable water over spatially extensive areas in required quantities under satisfactory pressure. Cost-effectiveness and reliability in system design are also important.

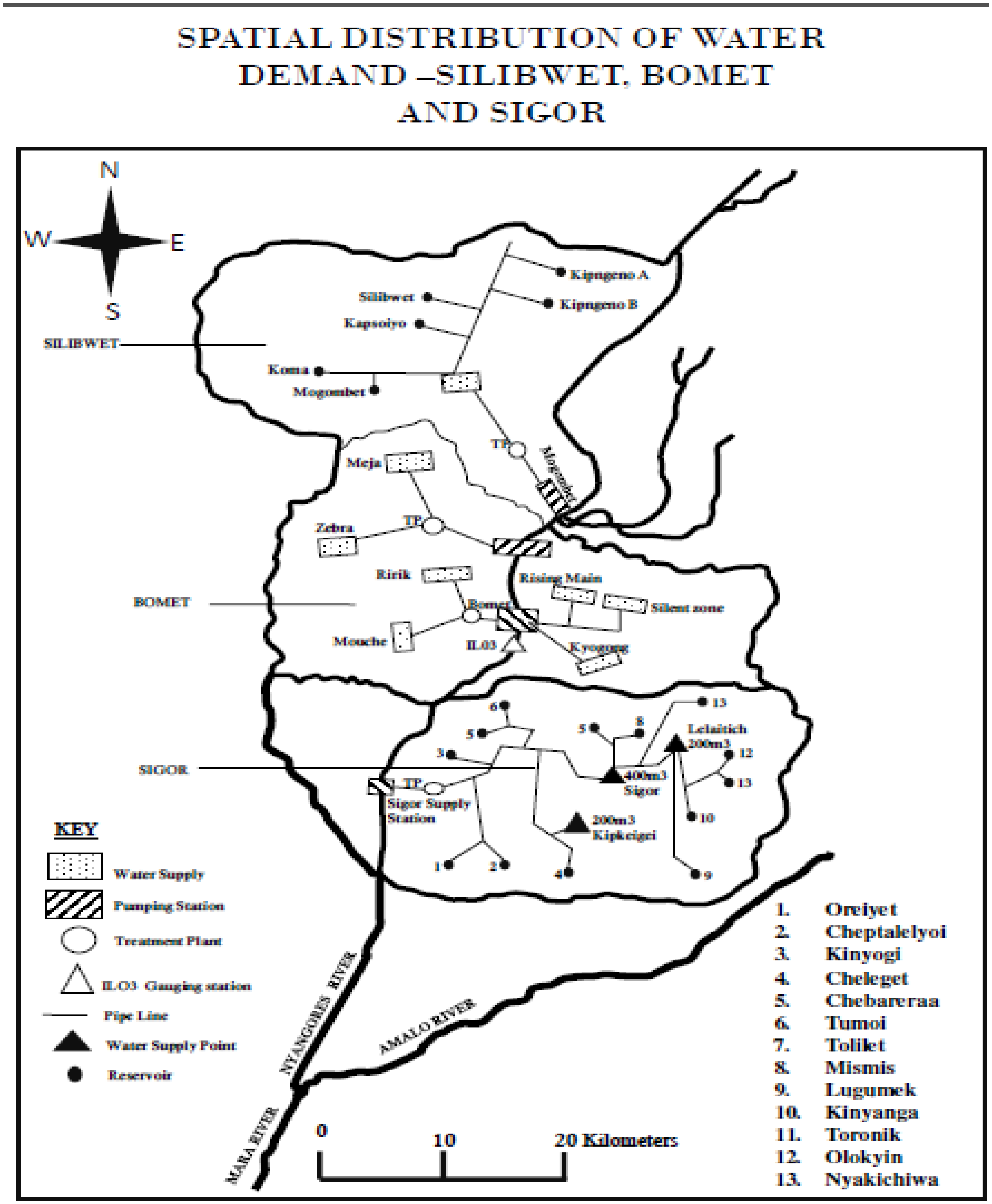


Figure 4.7: Piped water distribution network

Source: Fieldwork, 2013

Water fetched from rivers may not be of good quality considering that the river serves many purposes. The most affected groups are those in the downstream, who have to fetch contaminated water. Contamination may be as a result of farm chemicals like fertilizers, animal waste having in mind that most livestock farmers water their livestock directly from the river or even from people washing clothes, a few meters from the point where others are fetching domestic water.

Plate 4.6: Nyangores River supports a wider range of human activities
Source: Author, 2013

Surface water sources are unsafe because of their potential for contamination with human activities.

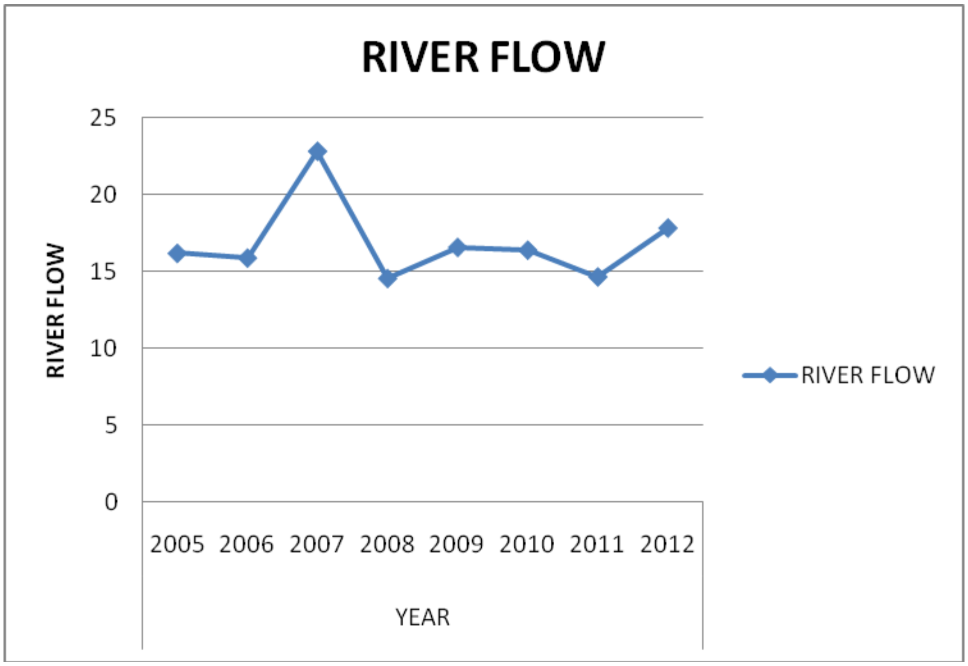


Figure 4.8: Nyangores River flow trend

The available river flows are important considerations for planners in determining among other things the water quality management strategies. Data obtained from the river gauging station at Bomet indicate a general decline in the amount of water flowing daily in the river. This is even worse during the dry periods of the year when more water is drawn to support agriculture. However, at an average flow of 16.7 m3 /y, this is adequate to serve the needs of the sub-catchment population in the present but as a resource use practices change, coupled with population increase, this may change for worse in the future and measures have to be put in place to manage such a challenge. Figure 4.8 shows the average annual river flows for the period 2005-2012.

4.5 The Effectiveness of the current water use management strategies

The applicability and effectiveness of current water use management strategies was calculated based on the perception of respondents interviewed during field study. A total of 290 household respondents generate information on applicability and effectiveness of 9 water use management strategies. The percentage frequencies are given in table 4.15 and 4.16 respectively.

Water is an important life sustaining resource necessary for economic development and general wellbeing of the society. It is, therefore, in the best interests of every member of the community that it be used efficiently to serve the interests of all indiscriminately. It is for this reason that the study sought to establish the strategies currently being employed by the community in the study area to manage this very important resource.

4.5.1 Permits

The officer in charge at Sigor observed that since the area has sufficient water for the moment, there have not been very strict rules imposed on the amount of water drawn by an individual or groups from the river. However, large water consumers abstract water by permits. These permits are processed at the WRMA-LVSCA regional and sub-regional in Kisumu and Kericho respectively. Large water abstractors include water supply units, institutions, hospitals, factories and irrigation projects. Among them are Bomet water Supply, Tenwek Mission Hospital, Tenwek, Mogombet Water supply, Tirgaga Tea Factory, Ndaraweta Secondary School, Kaboson Mission, Kaboson secondary school, Chepalungu Water Supply, Sigor water supply, Chebara irrigation project , Kaboson irrigation project and Tumoi Community water supply. They get their right to abstract water by permits. The consumers who use buckets without application of pumps do not need abstraction permits.

4.5.2 Rationing

Water service providers like Bomet water supply, Sigor, Chepalungu and Silibwet use water rationing as a tool to manage water use. Those served by the company noted that "we have to discipline ourselves because we are aware that water will only be available to us at certain times, we therefore use water for the basic needs only and this reduces wastage". The officer in charge of Sigor water supply observed that they have a schedule assigned to every line from Monday to Sunday. Rationing, according to him, is set for effective supply of the demanded volume of water to every zone. At Sigor, for example, low lift water pumps receives 50 m^3 in 24 hours while high lift receives 75 m^3, 11 hours per night.

4.5.3 Community involvement

Members of staff in the water supply companies have made available their mobile phone numbers to the public in their respective areas of work. This has helped them to quickly get information on leakages in the pipeline or even pipe bursts whenever they occur. This has not only improved service delivery and customer relations; it has improved on the flow of water and reduced losses incurred. Community provides unskilled labour and locally available materials in the integration of community water resource management.

4.5.4 Sensitization on effective use of water

Workshops in schools and churches by water officials are the major means of public education being used in the study area. Such sensitization events are also done by water supply staff at market places in their respective areas of operation. Among the topics covered in the public education forums are water use management practices like reporting leaking taps, burst water pipes, water recycling and control of free flow of water from taps.

Table 4.16: Applicability of water use management strategies

Strategy	Applicability	Percentage	Description
Water use restrictions	-Essential uses - Discretionary uses	45 55	-Hygiene, cooking and basic living -Linked to lifestyles (swimming pools)
Metering	-Unmetered -Metered not billed -Metered and billed	80 15 0.5	-Hydrant flushing and fire fighting -Leaks, theft, failed meters and readings -Domestic use
Public education initiative	-School programmes -Community programs -Workshop programs -Workgroups	10 45 30 15	-Pertinent water use information -Home water conservation measures -Rates and charges -Report leaks and waste initiatives
Pricing/Cost	-Flat rate charge -Short run marginal cost (SRMC) -Long run marginal cost (LRMC)	75 20 5	-Convincing where water is plentiful -Prices fluctuate through time Cost of expanding capacity to cater for increase in demand
Legislation	-Pricing oversight -Utilities -Customer service level -Water trading oversight -Bulk water management	10 30 15 20 25	-Provide universal priority right to water -Enhanced members livelihoods fairly and equitably

Source: Fieldwork, 2013

In the category of metering strategy, unmetered water applicability is the highest with a frequency of 80% which almost correspond with flat rate charges of 75%, an indication that a large percentage of piped water in the study area has no meters to regulate water use and control wastage (Table 4.16). Community involvement as compared with other water use management strategies was found to be the second most effective approach with 20.7% effectiveness. Restriction came third, but a poor long-term policy tool for balancing demand with supply because of costs imposed on water users according to water analysts (Table 4.17). The perception of respondents ranked pricing as the best water use strategy with a percentage frequency of 24.2%. They supported their argument with the fact that water prices provide an efficient means of balancing water demand with supply. Consumers can decide on how much they consume based on the price offered by the producers. Additional information was that prices generate sufficient revenues for water companies to cover their efficient cost of supply and a signal to the scarcity value of water to consumers and investors. Table 4.17 summarizes the effectiveness of the current water use management strategies by the community in the study area.

Table 4.17: Effectiveness of the current water management strategies

Strategy	**Household Respondents**	**Percentage effectiveness**
Water pricing	70	24.2
Community involvement	60	20.7
Water use restriction	40	13.8
Leak detection (monitoring)	35	12.1
Public initiative	30	10.3
Water permit	25	8.6
Metering	15	5.2
Water recycling	10	3.4
Rationing	5	1.7

Source: Fieldwork, 2013

4.6 Challenges on efficient water use and resource management in Nyangores Basin

The results of the review revealed that for many years, the Nyangores basin people have been facing many complex environmental and socio-economic challenges that have made it difficult for the proper management and sustainability of the Nyangores water. The environmental concerns include deforestation leading to losses of biologically important habitats and water catchment degradation. High rates of soil erosion leading to sedimentation of rivers and dams; however, localized water pollution arising from agriculture, mining and domestic effluent are symptoms of big underlying causes of Nyangores water quality. Poverty and population growth were singled out to cause additional pressures on natural resources and has been compounded by lack of awareness of land-water interaction. On the same note, climate change especially droughts arouses serious threats to freshwater recharge leading to low flows and drying up of the river course which poses a big threat to aquatic ecosystem. The issue of local participation in water resource management in Nyangores basin is still scanty which reflects an aspect of knowledge disintegration on efficient use of water. The SWOT analysis technique (Table 4.18) summarizes the most basic aspects of water use challenges and resource management.

Table 4.18: SWOT analysis on inefficient water use and resource management

Strengths	**Weaknesses**	**Opportunities**	**Threats**
• Existence of a perennial river • Population is well adopted to the environment • Availability of rainfall • Presents of political goodwill • Existence of water laws (Water Act 2002) • Peaceful co-existence of local communities • Strategic location of Nyangores River	-Low literacy rate -Inadequate capacity building and institutional strengthening -The planning did not incorporate the local knowledge of indigenous people -Inadequate donor funding -Lack of sufficient staff to respond to increasing water demand -Low adherence of water laws -Lacks equipment with more robust institutional infrastructure and critical skills -Insufficient capacity to handle database and analyse water resource information -Inadequate input of modern technology -Inadequate water infrastructure	-More involvement of NGO's and civil society will improve effectiveness and efficiency of water resource -On-going catchment rehabilitation by the government through a forestation will improve the quality of the resource -Training opportunities for community water use management -Availability of alternative sources of water -Current water research undertaking will increase availability of data	-Deforestation -Localized water pollution -Increasing poverty levels -Increasing population growth -Increasing food insecurity -Increasing water demand -Climate change -Low flows -Urbanization -Immigrations -Encroachment of water catchments -Low freshwater recharge -No sewerage system

Source: Fieldwork 2013

Nyangores Sub-Catchment is facing formidable weaknesses and threats as can be clearly noticed in the SWOT analysis. Nyangores basin should capitalize on its strengths and opportunities to work out the challenges it faces, promote accelerated growth and sustainable use of the resource. There is need to incorporate the issue of shared local knowledge to eradicate widespread poverty and change long standing traditions and practices.

CHAPTER FIVE
SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

Deteriorating access to quality and quantity household water demand, inefficient water distribution systems and inadequate measures to make changes in the water use rates has the potential to stifle agriculture, human health, development and ecosystem in Nyangores basin. In this case, to avert the scarcity of improved water for drinking and domestic use to attain recommended quality and quantity standards of WHO requires huge expenditure on the part of government and households in providing efficient water systems, treatment plants and storage facilities. At the household level access to water demand is of great concern because of frequent periodic and seasonal water scarcities mainly resulting from the use and abuse of the available water resources by the growing population, development and the escalating vagaries of weather. The dynamic nature of the quantity and quality of water demand as a function of price, distance to water source and inconsistent distribution traverse issues of accessibility, availability and usage of the resource over time and space of which it has remained a major concern to both water users and water providers in Nyangores basin.

5.2 Summary of findings

The major outcomes of the study are exhaustively discussed based on empirical evidence, opinions and theories highlighted in the literature and advance reasons that support the findings underlying the problem under consideration.

5.2.1: The magnitude of water demand and distribution

The magnitude of water demand as determined by measures of per capita water demand and use, mean water use, quantity and percentage of major water abstractors in Nyangores basin was found to be ever increasing. Daily mean household water use of 55.8 litres with household water availability per source of 5.3% from improved sources and 94.7% from traditional sources, indicate majority of households resort to alternative sources of water. Agriculture and domestic water demand has the highest percentage of 46.43% and 34.8 % of the total water sector demand respectively and others represent 18.77% with high unaccounted for water (UfW) of 53.77% as compared with UN recommended benchmark of 25%. The water demand outstrips supply in Nyangores basin and per capita water use has declined to as low as 0.2884 m^3/c/y. However the projected water demand will increase to 13,998.72 m^3/d from 9,745.32 m^3 /d by the year 2032 with a projected population of 233,312 people, leading to an increase in daily water demand by 43.65%, with a water demand deficit of 48.02% showing that the magnitude of water demand is high and can only be overcome through gradual implementation of public intervention on the economic use of water.

The current distribution coverage of household pipe water demand is 5.3 %, equivalent to 36.9 km^2 over a period of ten years to 2,695 households of the total 50,832 with an average family size of 3.2 and a mean household income level of 4,000 shillings per month. The actual daily water demand of 3,248 m^3 in comparison to actual average daily water supply of 239.17 m^3 is a reflection of inadequate and inconsistent rural and urban water supply coverage hence the gap between the haves and the have-nots has widened resulting in frequent water demand conflicts in the basin.

5.2.2: Key factors that influence the rate of water demand and distribution

Growing population and development

Water demand is being driven mainly by the growing population and development. The increasing population growth rate of 2.3% and an average household family size of between 3.2 and 4.2 in the sub-catchment and 7% growth rate per year in the entire Mara basin is an indication of an increasing water stress in Nyangores basin. Limited supply of water demand to support the intensive land use activities such as horticulture and dairy farming, irrigation, industrial supplies, growth of towns and market centres impacted negatively on water availability for food production and other investments in the study area.

The price and cost of water

A slight change in the marginal and average cost of water leads to an adverse effect in the quantity and quality of water demand. The short run marginal cost of 20% and the long run marginal cost of 5% applicability rates in price of water use as a management strategy lead to a shift of 75% of water users to unimproved sources. Non payment of the water bills per month stand at shillings 4,171,949 with a monthly increase of 4%, an indication that most customers cannot afford the cost of water and unwillingness to pay for water services is still high. This greatly depends on the low socio-economic ability of the local community, unreliable access to quality water and inefficient water service operators to motivate the consumers.

Climate change

Extreme events related to climate change such as heat waves, droughts and increased precipitation has lead to an increasing water scarcity and water quality degradation within the sub-catchment posing a significant seasonal water demand variability of 4.82% between the dry and wet seasons. Water short regions especially Sigor experience long standing dry seasons from January to mid March and September to October at which rainfall is below 10 mm, drastically affecting water availability. However, rainy seasons in the months of August, November and December increase the volume to match the demands of users.

Distance and time to water source

Household water demand per source indicates a high demand of 56.4% from the highly contaminated river water during dry season compared with 45.1% from unprotected springs, a replicate of high consumption of unsafe water. Considerable daily walking distances of over 3 kilometres commuted to fetch water and an average time taken of 1-2 hours daily are evidence to difficulty in water accessibility and a hindrance to meet adequate household water demand. A lot of valuable time is wasted by households' members in hauling water from distant sources. There is no clear distinction between water source and the intended purpose as majority of households depend on unimproved water sources among other alternatives to supplement their water needs for drinking, cooking and washing as well as for livestock. This means the same sources of water provide water for human and livestock use, suggesting that water resources play complementary roles.

Socio-economic factors

The level of household education in Nyangores sub-catchment depends on the household head. The age cohort of 18-49 years represent 44.4% of the population and out of this, 42.9% has no formal education. Agricultural sector contribute 70.9% of the total household income and 29.5% from non agricultural sector. Average number of persons per household is 3.2 and household per capita water use per day is 58.4 and 50.9 litres during wet and dry seasons respectively. Household income and the number of persons per household are statistically significant determinants of household per capita water use; therefore the quantity of household water consumed depends on household socio-economic factors such as level of education, income and family size.

5.2.3: Effectiveness of the current water use management strategies

Based on the applicability and effectiveness of current water use management strategies, water restriction was found to be the most applied at 50% applicability rate but its effectiveness was low at 13.3%. The applicability of water metering and pricing was 33.3% with an effective rate of 23.3% followed by community involvement at 20% effective rate. The use of legislations and the recommended policy implementation was the least applied at 20% level. Unaccounted for water of 53.77% of the total water supply is more than twice the recommended UN benchmark of 25%, illustrate inefficiency in water transmission systems and faulty meters. Unmetered water applicability was found to be 80% showing that large percentage of piped water has no meters to regulate water use and control wastage. The percentage of effectiveness of all water use management strategies in Nyangores basin are below 30% which is the main cause of high water loss and an increase in water demand which outstrips water supply. This is mainly contributed by inefficient water infrastructure, low implementation of water use management strategies, legislations and policies.

5.3 Conclusions

Development and Population growth alongside climate and land use changes have posed the risk of water shortage in Nyangores sub-catchment. From the findings of the study, the rate of water demand is increasing which is a reflection of an increasing population, land use activities and climate change. The results reveal that despite the availability of adequate water resources, water shortage remains a great challenge to water sector demands. Demographic, land use and climate change which is not reversed to some degree by policy intervention may be difficult to adjust to a manageable level in future. Policies and programmes to reduce water demand and wastage depend on efficient water use systems and conservation strategies. The right of the people to access adequate quality water from improved water sources for their livelihood is a priority concern in the basin however this is limited by lack of regulatory framework to measure water sector performance by the water service providers. Water strategic plans and policies towards improving access to household water demand and distribution are affected by political differences, limited funding by the government and dilapidated infrastructure.

Household water consumers comprise the largest percentage of debtors whose monthly water bill is 95 per cent and water arrears have increased to 2.9 million shillings per month. The distribution of the available water is skewed with the rural and those living in the informal settlements getting less of the share. Low rate of water supply coverage is attributed to less developed infrastructure and inadequate-autonomous rural water service providers. It was also clear from the study that with the current expansion rate of piped water coverage of 3.31% to an area of 23.05 km2 out of 696km2 is an indication that the distribution of this vital resource may not get to all households in the near future. However, stern measures and strategies need to be put in place to ascertain and enhance equitable water coverage to meet an annual threshold of 139.2 km^2 in the next five years.

Nyangores basin is facing formidable challenges, weaknesses and threats as can be clearly noticed in the SWOT analysis and therefore should capitalize on its strengths and opportunities to work out the challenges it faces. There is need to promote accelerated growth and sustainable use of the resource to eradicate widespread and severe poverty through shared visions and incorporate issues of shared local knowledge.

5.4 Recommendations

(i) Magnitude of water demand and distribution

The magnitude of water demand is ever increasing while the distribution of water to end users is diminishing. Therefore there is need to increase water availability by supporting the construction of more underground water resources such as boreholes and protected springs. The local community should be encouraged to invest more on rain water harvesting infrastructure in order to increase access to safe water and reduce water bills. Local authorities should enforce the legislation and regulation to protect water resources and catchment areas from contamination.

(ii) Factors that influence the rate of water demand and distribution

To overcome some of the factors that hinder access to improved household water supply there is need to locate safe water close to homes within a maximum radius of 200 metres. This will reduce health risks, increase water consumption and poverty alleviation. More non-agricultural income generating activities need to be created in Nyangores to enable households pay for accepted rates of safe water. Increase water coverage in rural areas by expanding and developing new water storage facilities to serve more people.

(iii) Effectiveness of the current water use management strategies

The water services regulatory board should ensure that effective water use systems for allocation, control and management are applied to reduce loss of water. The local community should be made to understand the importance of economic use of water through aggressive awareness campaigns to promote effective and measurable social change. All water connections should be metered and frequent replacement of aged and weak water infrastructure be made through proper monitoring and evaluation.

5.5 Suggestions for Further Research

This study could not answer some relevant questions and overcoming some methodological limitations met during the study. The following are suggestions to enrich the results of future research on household access to water demand and distribution.

- Identify reliable estimates of water demand and time allocated to access water from improved sources.
- Establish basic daily minimum water requirements for various household activities upon rural and urban communities.
- Determine the impact of infrastructure on the quality and management of pipe water distribution.
- Establish the effectiveness of rain water harvesting techniques to improve safe water accessibility among the rural communities.

References

Aboud E. A., (2002). Effects of Land use type on the level of Microbial Contamination based on total Caliform and Escherischia Coli count on the Mara River, EA.

Al Radif A. (1999). Integrated water resources management (IWRM): An approach to face the challenges of the next century and avert future crises.

Alison M. J. (2004). No Water No Life, Watersheds of Africa and North America, IRC 501(c) (3).

America Water Works Association, (1999). Water Statistics, Michigan.

American Water Works Association, (2007). Water use efficiency and conservation management strategies, Michigan. An Economic Analysis, Oxford Clarendon Press.

Arbués, F., Garcıa-Valiñas, M.Á. and Martınez-Espiñeira, R. (2003). Estimation of residential water demand: a state-of-the-art review. *Journal of Socio-Economics,* 32, pp. 81-102.

Ariyabandu R.De.S. (1999). Household water security using rainwater harvesting RWH, Conference, New Delhi.

Arouna, A; Dabbert, S. (2009). Determinants of domestic water use by rural households without access to private improved water sources in Benin.

Babel, M.S.; das Gupta, A.; Nayak, D.K. (2005). A Model for Optimal Allocation of Water to Competing Demands. *Water Resour. Manag. 19*, 693–712.

Bancy, M. M. (2012). Annual Water Sector Conference Research and Resource Centre (WARREC). Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi.

Bevan, D., Collier, P., and Gunning, J.W. (1989) .Village labour markets in Kenya and food processing, grain, fetching wood and water and caring for children.

Bhutta, M.N and Van der Velde E.J. (1992). Equity of water distribution along secondary canals, Punjab.

Biamah, E. K; Gichuki F. (2004). Land and Water Management for Poverty Alleviation: Experiences from Iiuni Watershed, Machakos District, Kenya.

Bibhabasu M (2010). Water distribution system, Department of Civil Engineering.

Bomet County Development Plan (2010). *Planning and natural development, vision 2030.*

Brown, L.R. (2001). How water scarcity will shape the new century, *Water Science and Technology*, 43(4), pp. 17-22. Water Security for the 21st Century-Innovative Approaches, the 10th Stockholm Water Symposium, August 14-17, 2000.

Bruns, B.R (2004). *Pro-poor people lack water rights.* Paper presented at the ADB water week, Manila, 26^{th} -30^{th} August.

Burchi, S. And Andrea A.D (2003). Preparing national regulations for water resources management, Principles and practices, Rome.
Carl, B. (2010). *Journal for contemporary water research and education* vol. 144 Issue 1, USA.

Cave, R.R, Ledoux, (2003). The Humber Catchment and Coastal Area, from U.K to European perspectives, the science of the total environment, 314pp.31-52.

Chin D.A. (2000). Performance criteria for water use distribution, USA.

Conradie B. (2002). The value of water in the South African Economy: The opportunity for efficient allocation through price, an extensive study on domestic water demand in low income communities.

CMWSP (Community Management of Water Supplies Project, 1997). Guidelines, Modalities and Selection Criteria for Handing over Water Supply Schemes vol.II.

DAAD – German Academic Exchange Programme (2008). Sub-catchment Management Plan – Keuyaritha – Ngaciuma Watershed Kenya.

Dale W. (1990). Calculating the value of time spent collecting water. Some Estimates for Ukunda, Kenya, University of North Carolina, Washington DC.

David, C.C., and A.B. Inocencio, (1998). Understanding Household Demand for Water: The Metro Manila Case, Research Report, EEPSEA, Economy and Environment Program for South East Asia, available at http://web.idrc.ca/en/ev-8441-201-1-

David S. (2006). Water we drink beyond 2006, Managing Uncertainty in the Provision of Safe drinking water, Alberta Research Institute and the Ontario Centres.

DFID (2002). Mara River Basin wide Water Allocation Plan, Nyangores sub-catchment Village report.

Dinar A. (1990). Economics of Water Resources allocation mechanisms: The effects of pricing policies on water conservation and drainage. *American Journal of Agricultural Economics, 55:77-82*

EPD (Environmental Development Plan). Guidance Document (2007). *Methods for determining future water demand,* Georgia.

FAO (Food and Agriculture Organization, 2008). Coping with water scarcity, water Report 38.

Froukh LM (2001). Decision-support system for domestic water demand forecasting and management. *Water Resource Management*, 15(6):363-382

Fürst, J; Herrnegger, M; Olang, L O.(2014): MaMa-Hydro: Exploring Water Resources Planning and Management of Options in Nyangores Headwater Catchment of the Vulnerable Maasai Mara River Basin in Kenya. MID-TERM PROJECT REPORT KEF Project p196.

Gakubia, M. (2009). *.Impact: A performance report of Kenya's water service sub-sector (Issue2).* Ministry of Water and Irrigation: Annual Water Sector Review, pp. 32 –34.

Gazzinelli A, Souza MCC, Nascimento I et al (1998) Domestic water use in a rural village in Minas Gerais, Brazil, with an emphasis on spatial patterns, sharing of water, and factors in water use. *Cad Sauda Publica 14:265-277.*

Gichana Z.M., Njiru M., Raburu P.O., Masese F.O. (2014).Effects of Human Activities on Microbial Water Quality in Nyangores stream Mara River Basin, Kenya.

Gleick, P.H (1986). Methods of Evaluating the Regional Hydrological Impacts of Global Climatic Changes, *Journal of Hydrology*, 8: 99-116.

Glenn, D. I, (1992). Sampling the Evidence of extension program Impact. Programme Evaluation and Organizational Development, IFAS, University of Florida.

GoK (Government of Kenya), (2002). An Act of Parliament to provide for the Management, Conservation, Use and Control of Water Resources and Acquisition.

Guisse, E.H (2004). Final report on human rights commission on the promotion and Protection of human rights to water, South Africa.

GWP, (2000). TAC background paper No 4. Integrated Water Resource Management, GWP, Stockholm, Sweden.

Government of Western Australia (2009). *Operational policy no.1.02 – Policy on water Conservation /efficiency gains through water licensing,* Department of Water, Perth.

Herrnegger, M. Senoner, (2014). Climate change scenarios for the assessment of future Drinking water availability in the Alps, Australia.

Hinrichsen D, Robey B, Upadhyay UD (1997). Solutions for a water-short world. Population Reports 14. Johns Hopkins School of Public Health, Population Information Program, Baltimore, Maryland.

Hoffman, C. M. (2009). Geospatial mapping and analysis of water availability-demand-use within the Mara River Basin. MSC. Thesis. Florida International University, Miami, FL, USA. pp 114 - 2007.

Hopkins J. (1998). Solutions for a Water- Short World. Population Informed Program, Baltiware, Maryland, USA.

Huttly, S., et al. (1990) “The Imo State (Nigeria) drinking water supply and sanitation project, 2. Impact on dracunculiasis, diarrhea, and nutritional status.” Transactions of the Royal Society of Tropical Medicine and Hygiene 84, pp. 316- 321.

Jack S. (2011). Water systems modeller, Stockholm Environmental Institute (Hydrologic Engineering Centre).

James, (2006). The ‘Q’ root ‘ n’ approach in determining household water demand.

Jerald L. (2008). Technologies for clean water: Living with changing water environment, National Academy of Engineering, Annual Report vol. 38 No.3, Bangladesh.

Joanne M. Parker and Robert L. Wilby (2012). Quantify household water demand: A review of Theory and Practice in the U.K

Keller A. & Seckler D. (2000). Water scarcity and the role of storage in development: International water management institute (IWMI), vii 20p, Research Report 39.

Keller, J., Keller, J. & Davis, G. (1998). River basin development phases and implementations of closure, *Journal of applied irrigation science,* 33(2): 145-164.

Kenny, D. (2005). Prior allocation of water right reform journal Vol. 1 US.

Kenya and UNICEF (1998). Access to improved water resources.

Keshavarzi AR, Sharifzadeh M, Haghighi AAK et al (2006) Rural domestic water consumption behaviour: a case study in Ramjerd, Fars province, I.R. Iran. *Water Res* 40(6):1173-1178.

Kiragu, D. (2009). Daily sediment load in relation to flow level at Bomet Bridge on Nyangores River, Kenya.

KNBS (Kenya National Bureau of Statistics), Nekessa (2009). *Population and Housing Census,* Vol.1c, Kenya.

Larson E. A. (2006). Combating Water Scarcity in Southern Africa: A case study in Namibia; Water use patterns.

London School of Hygiene and Tropical Medicine; (2009). Indicators of Access to Household Water Demand.

Maidment, D.R., Miaou, S.P.,(1986). Daily water use in nine cities. Water Resources Research 22 (6), 845–885.

Makule, D. E. (1997). "Water and sanitation—gender perspective." Proceedings of the 23rd WEDC Conference. Online. *http://www.iboro.ac.uk/departments/cv/wedc/23 conts.htm.*

Mati, B.M.S Mutie, P Home, F Mtalo and H Gadain (2005). Land use changes in the Transboundary Mara Basin, 8th International River Symposium, Brisbane, Australia.

Mati, B. M., Mutie, S., Gadain, H., Home, P., and Mtalo, F. (2008). Impacts of land use / cover changes on the hydrology of the transboundary Mara River, Kenya / Tanzania, Lake. Reserv. Manage., 13: 169 – 177.

Mart´ınez-Espiñeira, R., (2002b). Residential water demand in the Northwest of Spain. *Environmental and Resource Economics* 21 (2), 161–187.

Mehretu, A. and C. Mutambirwa (1992) "Time and energy costs of distance in rural life space of Zimbabwe: case study of the Chiduku Communal Area." *Social Science and Medicine* 34(1), pp. 17-24.

Melesse, A.M, MMcClain, M Abira, W Mutayoba (2008). Hydrometerological Analysis of the Mara River Basin, World Environmental Resources Congress.

MCKinney, D.C, Cai, X, Rosegrant MW, Ringler C (1999). Modelling water resources management at the basin level, Colombo, Sri Lanka.

Minaya . V (2010). land use influence on the benthic macro invertebrate communities of streams in the Nyangores and Amala tributaries of Mara river, Kenya. UNESCO, Paris.

Ministry of Water and Irrigation, (1998). Water Quality Improvement and Conservation Project, Ruseifa Area, Water quality study training model, 1998.4.

Ministry of Water and Lands, (2006) Livestock Watering requirement requirements, quality and quantity, British Columbia.

Molden, D., Sakthivadivel, R.& Keller J. (2007). *Hydronomic Zones for developing basin water conservation strategies. Research Report No.56. International Water Management Institute, Colombo, SriLanka p30.*

Molden E.A (2010). Improving Agricultural Water productivity and Land management, p528-535.

Moor J.W (1989). Balancing the need for water use. Springer-Verlag, New York.

MOWRD (Ministry of Water Resource Management and Development, 2002). Unpublished records at the district water office, Isiolo.

Musangi, R.S. (2009). Water Resources Management Authority, Athi River, Kenya.

Nalenga, D.W. (2010). Water allocation challenges in rural basins: report, South Africa.

Nyong A. O, Kinarogbu P. S, (1999). Domestic water demand in rural and semiarid North eastern Nigeria: Identification of determinants and implementation for domestic water demand.

National Housing and Population (1999). Kenya Population and Housing Census, Ministry of Planning and National Development and Vision 2030.

National Water Policy (2006). Kenya National Water Development Report, 2nd UN World Water Development Report Water: A shared Responsibility.

Newzealand, (2004). *Water allocation and use: Technical working paper, Ministry for environment, Newzealand.*

Ogallo L.A. (1996): *Human induced climate changes: Myths or reality;* Kenya National Academy of Science (Ed.): Environment and Development in Kenya, pp.169-194, Nairobi.

Orie K.K. (1995): *Legal regime of water allocation and the conservation of aquatic environmental values in Kenya:* Journal of Eastern African Research and Development No. 25, pp 76-114.

Osei A.Y. (2004). *Household water security and water demand in the Volta Basin, Ghana.*

Perret, S. Farroli S. & Hassan R. (2009*). Water Governance for sustainable Development* Part III Pg 169, London.

Peter, G. (2004). Poverty Reduction Strategy Paper, Bomet District Consultative Forum Report.

Pieter Van der Zaag and D. Kammer (2003). Assessment of catchment water demand use (DFID- Department for International Development) U.K.

Population Institute (2010) population and water. New York

Radhika de Silva, David Seckler and Upali Amarasinghe (1998). Wold Water Supply and Demand, 1990 to 2025: Scenario and Issues. Research Report 19, Colombo Sri Lanka: International Water Management Institute.

Renate, V.B. (2007). An analysis of current water distribution and rights system of an irrigation system, Bolivia.

Republic of Kenya (1994). Range management Handbook of Kenya Volume 1. Introduction to Rangeland Development in Kenya. Ministry of Agriculture, Livestock, Development and Marketing, Nairobi.

Robert, P. & Shirley C. (2007). Water demand module 4a, University of Alabama.

Rose, A.D. (2009). Domestic water supply an evaluation of the impacts challenges and prospect on women in rural house hold, Uganda. LUMES, Lund University.

Sandiford P, Gorter AC, Orozco JG, Pauw JP (1990). Determinants of domestic water use in rural Nicaragua. J Trop Med Hyg 93(6):383-389.

SCMP (Sub-catchment management plan, 2011). Nyangores River basin sub-plan, Bomet.

Seckler, D.; Amarasinghe, U.; Molden, D.; de Silva, R.; Barker, R. (1998). *World water demand and supply, 1990 to 2025: Scenarios and issues. Research Report 19. Colombo, Sri Lanka: International Water Management Institute (IWMI).*

Sharma NP, Damhaug T, Gilgan-Hunt E et al (1996) African water resources: challenges and opportunity for sustainable development. World Bank Technical paper 331. The World Bank, Washington, DC.

Sieber, J, Yates, D., Huber- Lee, A, and Purkey, D. (2005). WEAP, A Demand Priority and Preference Driven Water Planning Model Part 1, Model Characteristics, Water International, 30 (4) pp 489-500.

Stephenson, D. (1998). Theory of water demand management, water systems research Group, University of Witwatersrand South Africa.

Strand & Walker, (2005). Estimation of Water Demand in Developing Countries: Hauling time per unit of water consumed.

Sungai, L. (2005). *Integrated River Basin Management Study, Final Report, Vol.3, Technical Studies Part 1 of 4.*

Swaminathan, M.S. (2001). Ecology and Equity: Key Determinants of Sustainable Water Security, *Water Science and Technology*, 43 (4), pp. 35-44. Water Security for the 21st Century-Innovative Approaches, the 10th Stockholm Water Symposium, August 14-17, 2000.

Trivedi, G. (1963). Measurement and analysis of socio-economic status of rural families. New Delhi.

Tue, K.N. (2004). *Water Demand Management Report*, Nigeria.

UN-CSD, (United Nations Commission on Sustainable Development 1994*). Human Settlements and Freshwater Resources, Report of the Secretary General of the UN.*

UNDP, (United Nations Development Program (2006). *The human development report for 2006.* New York.

UNDP, (2007b). Effective Water governance, the key to sustainable water management and poverty eradication, New York.

UNEP, (1999). Freshwater use by sector at the beginning of 2000, vital water graphics, Water use and management.

UNEP, (2000). Global Environmental Outlook 2000, UNEP Earth Scan 1997, UK.

UN-ESCAP, (United Nations Economic and Social Commission for Asia and Pacific, 2000). Principles and Practices of Water Allocation among water use sectors, Bangkok, Thailand.

UNESCO (2010). Institute for water Education: Water footprint network.

UNFPA (2003). Global Population and Water- Access and Sustainability *New York*

UNFPA, (2007). Measuring Water use in a Green Economy. International Resource Panel working group on water efficiency.

UN-WATER/ Africa (2003). Improving the Quantity, Quality and Use of Africa's water.

UN-WATER, (2006). Water for wealth creation and health environment.

UNWWAP (United Nations World Water Assessment Programme 2009). UN world water development report: Water for life. UNESCO and Berghahn Books, Paris and New York.

USAID (2006). A Rapid Assessment of Kenya's Water, Sanitation and Sewerage framework, Nairobi.

USAID (2011). Land Use and Climate Change Impacts on the Hydrology of the Upper Mara River basin, Nyangores sub-basin, Kenya.

Varma, S. and Charles C. (2010). Out of water: From abundance to scarcity and how to solve the worlds water problems, USA.

Veronica G. Minaya M. (2010). Land use influence on the benthic macro vertebrate communities of streams in Nyangores and Amalo tributaries of Mara River, Kenya.

Wairua M. (2011). Water requirement for beef cattle reflects the amount needed for Growth, (Extension Publication).

Walker I. (2005). Pricing Subsidies and the Poor: Demand for Improved Water Services.

Wallingford, H.R. (2003). Assessment of Catchment Water Demand and Use, DFID, U.K.

Wang, E.A (2007). Basin wide cooperative resources allocation, *European journal of operation research* vol.2 (1).

Warren, V., Mark J. and Addison W. (1998). Trend in water withdrawals per water use category.

Warwick, J. J. (1997). *Oriental model for efficient allocation in river basin Journal* vol.2 issue 5, Australia.

Water and River Commission (2000a). State wide policy no.3- Policy on water sharing, Perth.

Water Act (2002). Water Resources Management Authority (WRMA): Management, Conservation, use and control of water resources, Kenya.

Website http://www/epnrm.sa.gov.au/water all. Plan saps.

White, G.F., Bradley, D.J., and White, A.U. (1972) Drawers of water: domestic water use in East Africa. Chicago: University of Chicago Press.

Whittington D. (2007). Estimation of water Demand in Developing Countries. USA.

WHO, (World Health Organization, 2000). Global Water Supply and Assessment Report.

WHO, (World Health Organization, (2003). The right to water. New York.

WHO, (Wold Health, Organization, (2004). The global burden of diseases, 2004 update.

Winpenny, J.T. (1994). Managing Water as an economic resource, Routledge, London, UK.

World Bank, (2010). Kenya Briefing: IWRM & Transboundary Water Resources Management in Kenya.

WRI (World Resource Institute, 2007). Department of Resource Survey and Remote Sensing, Ministry of Environment and Natural Resources, Kenya.

WWAP, (World Water Assessment Programme, 2009).*World Water Development Report 3: Water in changing world, Paris/ London, UNESCO/ Earth scan P.S.*

APPENDICES

Appendix 7.1: Questionnaire

Good morning/afternoon. My name is Koech John Cheruiyot, a post graduate student of Kenyatta University undertaking the study of the analysis of water demand, distribution and community management strategies on water use in Nyangores sub-catchment in Bomet County. This study is basically on academic purposes and I promise to treat the information you provide with the confidentiality it deserves. Your name will not be used in any report but your ideas and suggestions will be used to inform policy makers and service providers to improve on their services to you.

Respondent's information

Name.....................................sex....................age.................village............

Zone.....................marital status...............educational level: (primary..........secondary....... University..................non................).

(Tick the highest level).

Occupation: (Farmer..............Teacher............Nurse............Others specify................) Tick

Instructions: Tick the appropriate choice

(I): Socio-Economic Information and Water Resources

1. How many people live in this household? ....

2. How long have you lived here?

Less than 5 years ☐ 5 – 10 years ☐ 11- 15 years ☐

16-20 years ☐ over 20 years ☐

3. How did you obtain the land you are living on now? Bought ☐ Inherited ☐

Acquired ☐ Encroached ☐

4. What is the main source of water for this household? River ☐ Tap ☐

Borehole ☐ Dam ☐ Others ☐

5. What is the approximate distance from your household to the source of water?

6. What is your livelihood? Farming ☐ Break making ☐ Tree planting ☐

Business ☐

7. At what time of the day do you draw water? .... Morning ☐ Lunch ☐

Evening ☐

8. How many water points are available in this area?...........................

9. How many people are served by one water point?.........................

10. What are some of the water challenges experienced in this area?____ __ ____ __

____

____

____

11. Have you ever experienced any water shortage?

Yes ☐

No ☐

12. If yes, how often?

(a) Regularly ☐

(b) Sometimes ☐

(c) Always ☐

(d) Frequently ☐

13. What causes these shortages?

(a) Persistent droughts ☐

(b) High demand for water ☐

(c) Low water supply ☐

(d) Poor management of watersheds ☐

Any other (specify) ____________________

14. Is the shortage of water related to inequitable distribution?

Yes ☐

No ☐

15. If yes, state other factors that contribute to inequitable distribution of water in the area?

(a)..........................(b)................................(c)..............................(d)............................

(II) Water Demand

16. How much water do you need for household use per day?.....................................

17. How much water do you need for livestock use per day?.......................................

18. Name major uses of water in this area (Tick the applicable).

(a) domestic ☐

(b) Industrial ☐

(c) Irrigation ☐

(d) Livestock ☐

(e) Hydro-power ☐

(f) Recreation ☐

(g) Environmental ☐

(h) Cultural ☐

Any other (Specify) ____

19. From the uses above, which sectors demand the highest allocation of water?

....

20. What are the main determinants of:

a) Domestic water demand? Size of households Number of households ☐

Family income ☐ Cost of water ☐ Connection charges ☐

Quality of service ☐ Availability of alternative water sources ☐

Population density ☐ Cultural ☐ Influence ☐

b) Agricultural water demand? Cost of water ☐ Alternative sources of water ☐

Reliability of supply ☐ Crop water requirement ☐ No of livestock ☐

Legal requirements ☐

c. **Industrial and commercial water demand?** Cost of water ☐

Type of industry ☐ Reliability of water supply ☐

Cost of treatment and waste water disposal ☐

Legal requirements☐ working hours ☐ Cost of water using appliances☐

21. What are the major sources of water? (**Tick**) Rivers ☐ Springs☐ Boreholes ☐

Dams ☐ Rain ☐ others (specify)..

22. How is the water demand allocated?..

23. Which sector is given the least consideration in the allocation of water? ____________

What is your opinion? ____

24. What are the impacts of inequitable distribution of water? _______________

____

____

Water coverage

25. (a) Is there any water supply in this area? **Yes** ☐ **No** ☐

(b) What can you say about water supply infrastructure in the sub-catchment?..........

26. How many households are **connected to piped water (**...................), **not connected to piped water (**...................) in this area

27. How many water operating water points are here? (................) and how many are dormant (.................)

28. Are you willing to be connected to pipe water? **Yes** ☐ **No** ☐

29. Which service level do you prefer? (Tick the applicable) **House connection** ☐

Public tap ☐

30. Are you willing and able to pay for the cost of water? **Yes** ☐ **No** ☐

31. If yes, how much are you willing to pay per **1m**^{3} of water use ....

32. From your own opinion what can you say about water coverage in the sub-catchment?

....

Income levels

33. What is your occupation? Farming ☐ Business ☐ Teaching ☐

Entrepreneurship ☐ Others (Specify)..

34. How much do you earn per month? < 1000 ☐ 1000-2000 ☐

2500-5000 ☐ >10,000 ☐

35. Do you pay for water services? **Yes** ☐ **No** ☐

36. If yes, how much do you pay per **1m**^{3} of water?............................

37. What can you say about the cost of water? Costly ☐ Cheaper ☐ Affordable ☐

38. How often do you pay for water bill? Daily ☐ Weekly ☐ Monthly ☐ Yearly ☐

39. Do you have any water balance? **Yes** ☐ **No** ☐

40. If yes, how much is the balance? **Ksh.**..............................

41. What do you think is the cause of huge water bill balances? Unwillingness to pay for water ☐

High cost of water ☐ Low income levels ☐ unmetered water supply ☐

Poor method of paying for water services

42. How much do you get in return?..

43. What is the best way of controlling water use at the utility?........................

44. Identify some of the water conservation strategies in the Nyangores basin. (i).....................

(ii)............................(iii)...............................(iv).............................(v)............................

45. What can you say about water use efficiency in the sub-catchment?............................

46. Is there any illegal water abstraction? **Yes...............No....................**

48. How often do you experience drought and flooding in this area?................................

49. What effect does drought and flooding have on water demand and distribution?..........

50. What can you say about the population of Nyangores sub-catchment?........................

51. How does an increasing population affect:

i. Water resources?.........................

ii. Water demand?.............................

iii. Water distribution?........................

iv Water conservation?........................

52. What are the major land use activities in Nyangores basin?..........................

53. How does these land use activities allocated water?....................................

54. How does the available water utilized to meet the demand?.........................

55. In what ways does the available water improved your economic status?...................

56. How has it reduced the poverty level to the local community?................................

Appendix: 7.2 Interview Schedule

Hallo Sir/Madam, I am Koech J. Cheruiyot, masters' student at Kenyatta University Ref. No. 156/CE/14352/09. I would appreciate your contribution based on water demand, distribution and community management strategies on water use. Any answer given will be strictly confidential. Thank you for your willingness.

Respondent's Information

Name ………………………ID No...............Sex..........Age.................Marital..............

Family size.......................Residential.......................Educational level........................

Occupation ………………………………… Signature...............................

1(a) For how long have you served in this area?............................

(b) How do people acquire land?.......................................

(c) What are the current uses of water in Nyangores sub-catchment?

i. Livestock [ ]

ii. Domestic [ ]

iii. Gardening [ ]

iv. Brick making [ ]

v. Building and construction [ ]

vi. Tree nursery [ ]

vii. Irrigation [ ]

viii. Car wash [ ]

Others ……………………………………………………………………………..

2. Name other sources of water that serve the local communities in Nyangares area?

3(i) How does people access safe drinking water? …………………… ……… …

(ii) What is the average distance and time taken to water source?......................

4. Is there shortage of water in terms of quantity in Bomet County?

a) Yes [ ]

b) No [ ]

5. If yes, what contributed to these shortages?

a) Drought [ ]

b) High demand [ ]

c) Low supply [ ]

d) Inadequate water resources [ ]

e) High wastage [ ]

f) Inadequate distribution systems [ ]

g) Poor adoption of conservation measures [ ]

Others ………………………………………………………………………………

6. What can you say about the distribution of water resources over time and space in Bomet County (Nyangores sub-catchment)?

a) Poor [ ]

b) Fair [ ]

c) Good [ ]

d) Excellent [ ]

7. How many public and private water points are available in Nyangores sub-catchment?

………… … … ……… ……………………… ………………………………

8. What are the peak hours of water withdrawal?

a) Morning [ ]

b) Lunch [ ]

c) Evening [ ]

d) Morning and evening [ ]

9. What is the estimate water consumption per day for the following water sector demands in m^3 in the sub-catchment? :

(i) Domestic............. (ii) Agriculture................ (ii) Livestock........... (iii) Industrial.......

(iv) Entrepreneurship....................

10. What is the average production of water per day in Nyangores basin..............................

11. What is the estimate number of households in this area?..........................

12. Out of this number, how many are connected to pipe water?....................

13. How many members are active and how many are dormant? **Active..........**

Dormant..........

14. How many connections are **Metered?.......................** **Unmetered?.............**

15. Do you experience any water loss in the distribution systems? **Yes ......** **No.......**

16. What measures have you taken to reduce water loss? (i).................(ii).................

(iii)...................... (.iv)..........................(v)...........................

17. Which steps have you put in place to regulate water demand? (a)....................(b)............... (c)..................... (c)........................ (d)...............................

18. How is water use managed at the community level?

(a)................... (b).........................(c)......................... (d)................................

(e)......................... (f).........................

19. What are the major challenges faced in the distribution of water resources in Nyangores Sub-catchment?

(i)......................(ii)......................(iii)......................(iv).......................(v)......................

20. From your own opinion what can you say about water demand?

High.........Moderate........Low..........

21. Identify major factors that contribute to this situation **(Tick)**

a) Growing population ☐
b) Rapid urbanization ☐
c) Drought and flooding ☐
d) Inadequate water storage facilities ☐
e) Inadequate water resources ☐
f) Upland watershed destruction ☐
g) Non-equitable distribution of water resources ☐
h) Wasteful and inefficient water management ☐

22. What are some of the strategies taken to reduce water usage under control of utility in Nyangores basin? (**Tick)**

a) Metering ☐
b) Water calibration and replacement ☐
c) System audit ☐

d) Leak detection and repair programs ☐

e) Full cost pricing ☐

f) Water use restrictions ☐

23. What are some of the public information initiatives on water bill?

(i) Usage ☐ (ii) Rates ☐ (iii) Charges ☐

24. What information do you have about home water conservation measures in Nyangores sub-catchment?...

25. Identify some of the methods the water supplier can utilize to educate the public about water efficiency and conservation strategies in Nyangores basin.

- School programmes ☐
- Community programmes ☐
- Work groups ☐
- Advisory committee ☐

26. Tick some of strategies for promoting new technology and mitigations for reducing water use requirements in Nyangores

i. Recycling ☐
ii. Waste water treatment ☐
iii. Grey water (Filtered waste water) ☐
iv. Catchment systems (collecting and storing water) ☐

27. In what ways does the income level of the local community affect water demand and distribution?

(i)..................................(ii)................................(iii).............................(iv).....................

28. How is water allocated to the legitimate claimants?...................................

29. Do you experience any illegal abstraction of water in the sub-catchment? **Yes**........**No**......

If **Yes,** give percentage estimate...............................

30. Which months of the year are prone to drought and flooding?.......................

31. What impact does climate change have on water demand and distribution?...................

32. What can you say about the relationship between the population increase and water Demand and distribution in Nyangores basin?...................................

33. What are the major land use activities in Nyangores sub-catchment?........................

34. How is water allocated to water sector demands?...................................

35. How is the available water utilized to meet the demands?............................

36. In what ways does the available water improved the economic status and livelihoods of the local community?..

37. Is the water supply infrastructure efficient enough to meet the required water demand and distribution?...

38. What can you say about the spatial and temporal distribution of water in Nyangores basin?...

39. Are people willing to pay for the cost of water?................................

40. Give an estimate of the annual water bill arrears in the sub-catchment........................

Appendix 7.3 Background information of the study area

Source: Fieldwork- 2013

Year	Total rainfall	Total average rainfall	Average water flows	Total runoff	Average runoff water flows	Human population	Total water consumption (m3)	Total water supply	Available storage capacity	Water supply coverage (km2)
2000	468.12	39.01	10.11	198.12	16.51	120328	33880	66600		
2001	548.76	45.73	21.02	232.20	19.35	123836	34868	66600		
2002	611.4	50.95	17.51	258.72	21.56	127334	35853	66600		
2003	593.64	49.47	18.56	251.28	20.94	130851	36843	66600	200	2.60
2004	831.48	69.29	14.92	351.96	29.33	134336	37824	65505	200	2.65
2005	466.2	38.85	16.20	197.28	16.44	137826	38807	64400	200	2.75
2006	672	56	15.90	284.40	23.70	141305	39787	65510	200	2.80
2007	509.16	42.43	22.80	215.52	17.96	144805	40772	108000	200	3.03
2008	472.68	39.39	14.58	200.04	16.67	148264	41746	110005	200	3.20
2009	463.8	38.65	16.59	196.32	16.36	151804	44745	105900	200	3.60
2010	693.12	57.76	16.41	293.40	24.45	155182	47870	103250	200	4.20
2011	589.56	49.13	14.68	249.48	20.79	158883	71135	154800	400	5.80
2012	936.48	78.04	17.84	396.36	33.03	162442	75667	156600	400	6.25

Appendix 7.4: Summary of Household Respondents

VARIABLE	RESPONDENTS		
	Rural	**Peri-Urban**	**Total**
Land Acquisition			
(I) Inherit	150	10	160
(II)Bought	75	35	110
(III) Gift	25	5	30
(IV) Encroached	0	0	0
Total	**250**	**50**	**300**
Length of stay			
20-30 Years	10	30	40
31-40Years	25	10	35
41-50Years	50	7	57
51-60Years	35	3	38
>60Years	130	0	130
Total	**250**	**50**	**300**
Family size			
1-2	15	31	46
3-4	32	15	47
5-6	76	4	80
7-8	67	0	67
>8	60	0	60
Total	**250**	**50**	**300**
Sources of water			
Spring : No-prot:23 Unprotected: 1500	80	12	92
River:-NO- 1	53	10	63
Rain	30	4	34
Dams: NO-4 Pans: No-13	42	0	42
Boreholes:No-2	20	4	24
Pipe water: con-906	25	20	45
Total	**250**	**50**	**300**
Water points			
<2	172	13	185
3-4	75	30	105
5-6	3	7	10
7-8	0	0	0
Total	**250**	**50**	**300**

Water withdrawal time			
Morning	112	35	147
Lunch	77	5	82
Evening	61	10	71
Total	**250**	**50**	**300**
Livestock			
<2	34	20	54
3-4	109	30	139
5-6	31	0	31
7-8	36	0	36
>8	40	0	40
Total	**250**	**50**	**300**
Walking distance to water source in (km)			
<1	51	27	78
2-3	115	23	138
4-5	84	0	84
Occupation			
Farming	165	10	175
Mining	65	2	67
Brick making	13	5	18
Teaching	4	15	19
Others	3	18	21
Total	**250**	**50**	**300**
Water billing			
Residential.....83%	135	19	154
Industrial.........7%	35	17	52
Institutions.......1%	33	2	35
Commercial......1%	32	2	34
Others...............6%	15	10	25
Total	**250**	**50**	**300**

Appendix 7.5: Respondent's information on water challenges, shortage and major users

Water challenges	Respondents	Causes of water shortage	Respondents	Water users	Respondents
Pollution	64	Population pressure	66	Domestic	83
Encroachment	42	Poor watershed management	23	Irrigation	27
Flooding	31	Slow implementation of water policies	20	Livestock	75
Drought	66	Inadequate storage facilities	56	Environment	53
Conflict	18	Inefficient distribution systems	45	Fishing	24
Water use control	22	Lack of modern technology	27	Recreation	12
Access	57	Climate change	63	Fire output	26

Source: Field work 2013

Appendix 7.6: Respondents' average time, distance and Income

Household range	Average time taken to water source (minutes)	Average distance taken to water source (km)	Average household income per month (ksh)
<50	0-9	0-0.5	3000-5000
50-100	10-19	0.5-1	2500-4500
100-150	20-29	1-1.5	2000-4000
150-200	30-39	1.5-2.5	1500-3500
200-250	40-49	2.5-3.5	1000-2000
250-300	50-59	3.5-4.5	<1000

Source: Fieldwork, 2013

Appendix 7.7: Alternative sources of water within Nyangores basin

Water source	Estimate number	Percentage coverage
Shallow wells	1500	35.7
Unprotected springs	270	6.4
Protected springs	23	0.5
Dams	4	0.1
Boreholes	2	0.05
Roof catchments	2400	57.2

Source: Fieldwork, 2013

Appendix 7.8: Domestic annual water production in M^3

Yr	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total	Ave.
2007	3557	3665	3645	3880	4010	4105	3940	3880	3776	3485	3875	4008	**45826**	3819
2008	3475	3540	3882	3468	3275	3370	3490	3415	3551	3325	3425	3520	**41746**	3479
2009	3347	3420	3395	3482	3841	3669	3743	3842	3874	3992	4125	4015	**44745**	3729
2010	3745	3642	3575	3840	3980	4009	3822	3975	4039	4128	4430	4685	**47870**	3889
2011	5992	5765	5891	6288	6432	5910	5420	5716	5921	5845	6010	5945	**71130**	5928
2012	5725	5841	5667	5995	6005	6408	6103	6205	6570	7049	7168	6941	**75677**	6306
TOTAL	**25841**	**25873**	**26055**	**26953**	**27543**	**27471**	**27036**	**27033**	**27731**	**27824**	**29043**	**29114**	**327517**	**27150**

Source: Bomet water supply.

Appendix 7.9: Household pipe Water Distribution coverage over Time

Year	Available water storage capacity (m^3)	Household water distribution over time (m^3)	Area covered over time (km^2)	Percentage coverage of total area ($696km^2$)
2008	200	41776	3.20	0.46
2009	200	44745	3.60	0.52
2010	200	47930	4.20	0.60
2011	400	71135	5.80	0.83
2012	400	75670	6.25	0.90
TOTAL	600	281256	23.05	3.31

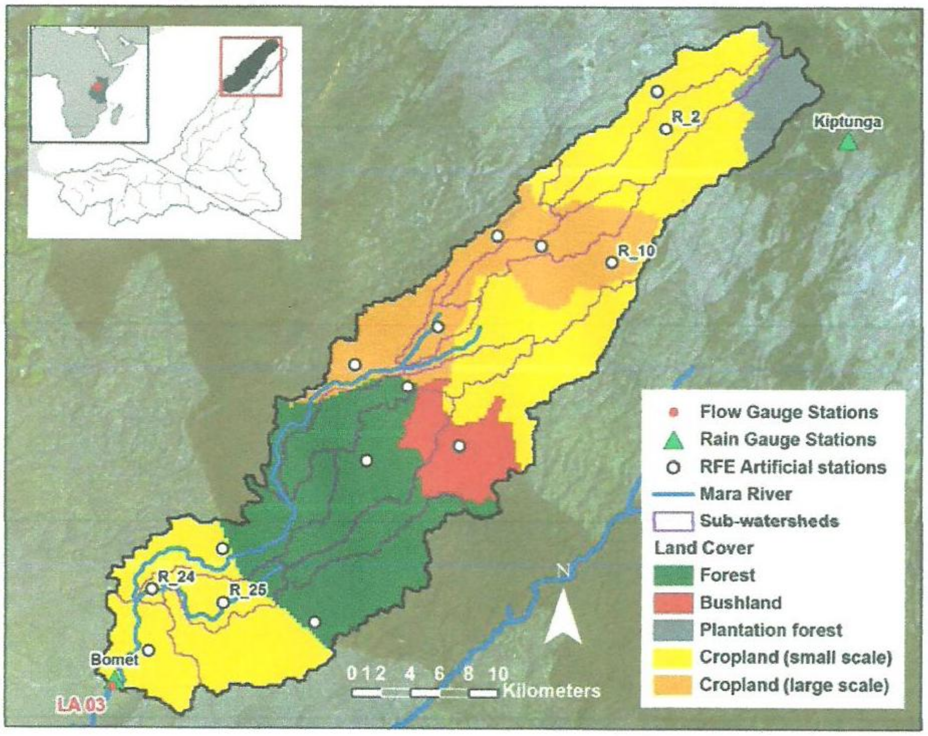
Source: Fieldwork, 2013

Appendix 7.10: Per Capita Water Demand

year	population in water area	water demand/day(m^3)	water demand (m^3)/yr	per capita water demand (m^3)/yr	Average water production(m^3) /yr
2008	148264	8896	3247040	21.90	41745.05
2012	162422	9735	3553453	21.88	75675.45
2017	180120	10897	3977444	22.08	109642.35
2022	197817	12014	4384965	22.17	143536.25
2027	215515	13128	4791723	22.23	177466.65
2032	233312	14240	5197746	22.28	211397.05

Source: Author, 2013

Appendix 7.11: Land Use Activities in Nyangores Sub-Catchment



Source: Adopted from Alison, 2004

Appendix 7.12: Summary of Respondents, information

Variable name	Interview schedule	Questionnaire
(i) Background information		
Name, sex, age, village, marital, educational level, occupation	Respondent's information	Respondent's information
(ii)Demographic and Socio-Economic variables		
Family size	Respondent's information	1,2,3,6
Length of stay	1(a)	2
Land acquisition	1(b)	3
Land use activities	1(c)	6
(iii)Water availability		
Sources of water	2	14, 21
Distance to water source	3(ii)	5
Time taken to water source	3(ii)	7
Water point density	7	8,9
Water shortage	4	11,12,13,14
Water challenges	5,15,16,19	10
(iv)Water demand		
Water consumption	9,10,11,13,14,20	16,17,8
Demand determinants	1(b)	20(a,b,c)
Demand management strategies	17,18,25,26	22, 43
(v)Water distribution		
Water allocation	6	15,19,22,23
Water coverage	38	24,25,26,28,29,32
Water cost	39, 40	30,31,35,36,37,38
Water access	3(i)	40
(vi)Water use management		
Under control of utility	22,16	43

Water bill information	23	38,39,40,41
conservation strategies	24	44
Water use efficiency	25	45
Illegal abstractions	29	46
(vii)Factors affecting water demand and distribution		
Climate change	21(c), 30, 31	48, 49
Population increase	21(a), 32	50, 51
Income levels	27	33, 34, 35
Land use activities	33, 34	52, 53
Supply infrastructure	37	25(a), (b),
Availability of water	35, 36	54, 55, 56

Source: Fieldwork, 2013

Appendix 8.1: Research Authorization Letter

REPUBLIC OF KENYA

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Telephone: 254-020-2213471, 2241349, 254-020-2673550
Mobile: 0713 788 787 , 0735 404 245
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secretary@ncst.go.ke

P.O. Box 30623-00100
NAIROBI-KENYA
Website: www.ncst.go.ke

Our Ref: **NCST/RCD/17/013/12**

Date: **17th May, 2013**

John Cheruiyot Koech
Kenyatta University
P.O Box 43844-00100
Nairobi

RE: RESEARCH AUTHORIZATION

Following your application dated **2nd May, 2013** for authority to carry out research on "***Analysis of water demand, distribution and community management strategies in Nyangares sub-catchment in Bomet County, Kenya.***" I am pleased to inform you that you have been authorized to undertake research in **Bomet District** for a period ending **31st July, 2013.**

You are advised to report to **the District Commissioner and District Education Officer, Bomet District** before embarking on the research project.

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

SAID HUSSEIN
FOR: SECRETARY/CEO

Copy to:

The District Commissioner
The District Education Officer
Bomet District

"The National Council for Science and Technology is Committed to the Promotion of Science and Technology for National Development".

Appendix 8.2: Research Permit

PAGE 2

THIS IS TO CERTIFY THAT:
Prof./Dr./Mr./Mrs./Miss/Institution
John Cheruiyot Koech
of (Address) Kenyatta University
P.O Box 43844-00100, Nairobi
has been permitted to conduct research in

	Location
Bomet	District
Rift Valley	*Province*

on the topic: Analysis of water demand, distribution and community management strategies in Nyangares sub-catchment in Bomet County, Kenya.

for a period ending: 31st July, 2013.

PAGE 3

Research Permit No. *NCST/RCD/17/013/12*
Date of issue *17th May, 2013*
Fee received *KSH. 1,000*

Applicant's Signature

For: Secretary
National Council for
Science &Technology

CONDITIONS

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

GPK6055t3mt10/2011

REPUBLIC OF KENYA

RESEARCH CLEARANCE PERMIT

(CONDITIONS—see back page)