UNIVERSITY OF NAIROBI
COLLEGE OF ARCHITECTURE AND ENGINEERING
SCHOOL OF ENGINEERING
DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

MAPPING THE SUPPLY OF PIPED WATER IN KILIFI COUNTY

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Declaration

I, Julius Katana Kahindi, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

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Name of student Signature Date

This project has been submitted for examination with my approval as a university supervisor.

Dr.-Ing. David. N. Siriba

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Name of supervisor Signature Date

Dedication

This project is dedicated to all the inhabitants of Kilifi County who have no access to adequate quantities of piped water.

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First and foremost I would like to thank my supervisor, Dr. David. N. Siriba for his instrumental support throughout my research. He was always available for consultation and advice.

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Finally, I would like to thank my classmates of the MSc (GIS) 2014 class for their support and encouragement throughout the course.

Abstract

Piped water supply refers to the distribution of water through pressurized pipe networks. Studies done by the World Health Organization (WHO) have indicated that pressurized pipe networks provide the best protection against water contamination. However, due to limited water resources worldwide and the growing human populations, water service providers are facing challenges in the provision of adequate quantities of piped water for human use. The problem of inadequate supply of piped water to meet basic human needs forces people to resort to open channel water supply networks like rivers, dams and boreholes. This leads to many water-related diseases which impact negatively on human health and development.

One of the approaches of ensuring equity and fairness in the distribution of the scarce water resource is to base the supply of water on the available water volumes and existing population figures. Such a water per capita supply model can be mapped by use of GIS to visualise the fairness and adequacy of supply.

This research used water supply and population data for each sub county in Kilifi to generate choropleth maps for the water per capita supplied to the inhabitants over a three year period of 2012, 2013 and 2014. The Basic Water Requirements (BWR) index of 18.3 m^3 of annual water per capita which has been adopted as a benchmark indicator by the WHO was used to gauge the adequacy of the water supplied. Using graduated colour symbology, these maps gave an indication of the inequality of water supply among the sub counties. The inadequacy of the supply was illustrated using bar chart symbology.

The maps generated from the collected data indicate that there is inequality of water per capita supply among the seven sub counties. The water supplied does not meet the basic water requirements of the inhabitants in all the seven sub counties. The maps also indicate that there has not been any significant increase in the per capita water supply over the three year period.

From the results, it is recommended that the Coast Water Services Board increases the supply of water to at least meet the basic water requirements of the residents of Kilifi County. At the same time the water service providers need to address the existing inequality of water supply among the sub counties.

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List of Abbreviations and Acronyms

BW	Billed water
BWR	Basic Water Requirements
CAAC	Catchment Area Advisory Committee
CWSB	Coast Water Services Board
GIS	Geographic Information System
IEBC	Independent Electoral and Boundaries Commission
IWMI	International Water Management Institute
KIMAWASCO	Kilifi and Mariakani Water and Sewerage Company
KNBS	Kenya National Bureau of Statistics
MAWASCO	Malindi Water and Sewerage Company
MWI	Ministry of Water and Irrigation
NRW	Non-Revenue Water
SOK	Survey of Kenya
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WAB	Water Appeals Board
WASREB	Water Services Regulatory Board
WHO	World Health Organisation
WRMA	Water Resources Management Authority
WRUA	Water Resources Users Association
WSB	Water Services Board
WSP	Water Service Provider
WSTF	Water Services Trust Fund

CHAPTER 1: INTRODUCTION

1.1 Background

Piped water supply refers to the distribution of water through pressurized pipe networks. The pressurized networks are fed by either gravity or pumps. Such networks provide a means of supplying water to individual dwellings, buildings and communal taps. The networks are managed by public bodies, commercial organisations, community groups or individuals.

According to a report by the World Health Organization, pressurized pipe networks provide the best protection against water contamination as opposed to open channel networks , (WHO, 2004).This contributes significantly to both the reduction and control of water-related diseases and therefore greatly improving human health and development. They also reduce the inconvenience of water collection, which is borne especially by women and children, and is itself associated with much disease and injury.

Piped water supply provides a cherished service to users as most people highly value the opportuneness of a household tap. A joint study conducted in rural Vietnam by USAID and EastMeetsWest Foundation on behalf of Water SHED (Sanitation, Hygiene Enterprise Development) concluded that households connected to piped water supply systems benefit from improved water quality, greater water quantity, and lower costs of water, (USAID, 2010).

Piped water is ordinarily treated before being distributed. The water treatment steps include purification, disinfection through chlorination and sometimes fluoridation. Treated water then flows either by gravity or is pumped to reservoirs, which can be elevated like water towers or on the ground. Water supply systems get water from a multiplicity of sources such as groundwater aquifers, surface water (lakes and rivers) and sea water through desalination.

An adequate water supply is a prerequisite for human and economic development. However, water resources are limited worldwide and this impacts negatively on productivity and advancement of individuals, communities and governments globally. With growing human populations, the water consumption per capita is also likely to rise, creating an increasing demand for water.

Addressing this water scarcity calls for a sustainable methodology to water management and an equitable and sensitive strategy of water allocation and supply mechanism. One of the tactics of ensuring equity and fairness in supplying water is to base the distribution on available water volumes and existing population figures. Agencies responsible for water supply have faced challenges in managing the demand and supply of piped water to meet domestic requirements. This is more so given that domestic water requirements compete for the scarce resource with agricultural and industrial needs.

The scarcity of the piped water resource coupled with escalating demand due to population increase have posed major challenges in the supply of adequate quantities of water for human use. This calls for a more effective geographic targeting of water supply. This targeting requires decisions to be made and priorities to be assessed so that water can be supplied to where it is most needed to meet the needs of human populations. The proper application of GIS technology can go a long way in achieving the targeted supply of piped water. Based on the water volumes available for distribution against area populations, agencies responsible for water supply can apply GIS technology to ensure unbiased distribution of piped water for domestic use. This can be applied either at the national, regional or county level.

The objective of this research paper was to map the quantities of piped water supplied to the residents of Kilifi County. The volumes of water per capita supplied by the Water Service Providers in the county were used in this research. This was compared against the basic water requirements (BWR) index for human needs as adopted by WHO. This index which is independent of climate, technology and culture caps the basic water requirement for human hygiene at 50 litres per day per person or an annual per capita water usage of 18.3 m^3.
This index was adopted against other indices because its threshold is considered by the World Health Organisation as a human right, below which a person's wellbeing is adversely affected. The per capita water supply in each sub county was visualised through the creation of choropleth maps so as to appreciate the spatial distribution of piped water supply within the county.

Water supply agencies would find such maps useful in re-planning their water supply infrastructure to achieve a just, equitable and targeted distribution of the scarce water resource.

1.2 Problem Statement

On 28th July 2010, the UN General Assembly recognized that access to safe and clean drinking water is a human right, essential to the full enjoyment of life, (UNICEF and WHO, 2012). This was consequently ratified at its 15th session in September 2010, when the UN Human Rights Council asserted that the right to clean water is derived from the right to an adequate standard of living. Such a right was deemed to be inextricably related to:

- The right to life and human dignity.
- The right to the highest attainable standard of physical and mental health.

The ratification made it legally binding for nations to strive and fulfil the right to water by its citizens, just like any other right inscribed in the UN treaties. Fundamentally, governments use the concept of progressive realization to comply with the provision of human rights. Thus, while the provision of clean and safe water in adequate quantities to every Kenyan may not be achieved overnight, the government must be seen to be taking tangible steps towards the realisation of this right.

This position is also reinforced by section 43.(1)(d) of the Constitution of Kenya 2010 which states that every person in Kenya has the right to clean and safe water in adequate quantities and to reasonable standards of sanitation. Therefore, all water service providers (WSP) in Kenya have a constitutional responsibility to meet this constitutional provision. This calls for water service providers to focus on taking their services to all citizens wherever they reside irrespective of the geographic locality. However, due to the scarcity of the piped water resource and increasing population, the provision of adequate quantities of water as per the constitution remains a major challenge.

The problem of inadequate supply of piped water can be best visualised and addressed by mapping the quantities of water being currently supplied. Since a distinguishing feature of the human rights framework is the principle of non-discrimination, such mapping will help appraise the fairness of the distribution of the scarce water resource among the citizenry. The mapping can also be used to determine the extent to which the supply meets the basic human water requirements. This will go a long way to ensure equitable distribution of the scarce resource among different societal segments and population assemblages.

1.3 Objective

The objective of this study was to combine water supply statistics, population data and GIS-based choropleth mapping in a way that provides a simple, practical, yet powerful tool that gives a spatial demonstration of water supply in the county of Kilifi. The maps are to depict the quantities of water supplied and areas where people are getting less than the basic minimum amount of water required for a healthy lifestyle. The study will help the water service providers to identify the geographic areas in which to focus their water supply efforts in a more equitable manner. The research aimed at achieving two specific objectives, namely:

1. Mapping the annual water per capita water supply to the residents of Kilifi County during a three year period of 2012-2014.
2. Mapping the adequacy of the quantities of water supplied during the period in terms of the basic human water requirements as adopted by WHO.

These specific objectives involved collection of the appropriate data and the application of thematic mapping techniques. These techniques involved the use of choropleth maps for mapping the annual water per capita supply while bar chart symbology was used to compare the actual water supply against the basic water requirements.

1.4 Justification for the Study

The research will go a long way in assisting the water service providers to gauge the fairness of existing water distribution systems in the County. Sub counties suffering from inadequate water supply can easily be visualised and appropriate remedial measures planned and also guard against discrimination.

It can also facilitate planning of equitable distribution of the scarce water resource among different societal sectors and population groups. The maps generated can be used for the development of policies aimed at achieving universal water supply.

Since the provision of adequate quantities of good quality water is now a constitutional requirement, this research will contribute in a small but significant way towards the implementation of the 2010 Kenya constitution as regards to the provision of water.

1.5 Scope of Work

The project investigated the quantities of water supplied to the inhabitants of the County in terms of water per capita. The quality of the water supplied was not considered in this research. The assumption made in the research is that the water supplied by the service water providers in the County has been properly treated and that it meets the required quality and sanitation standards and that it is safe for human consumption.

The research covered the water supply over a three year period from 2012 to 2014. The trend of supply over this period was analysed to detect any improvements, stagnation or deterioration. From this analysis conclusions were drawn and appropriate recommendations made. Due to time constraints, the sub county was used as the unit of analysis although the county sub location would have yielded a better result. This is because the disparities of water quantities supplied to individual water consumers; i.e. water per capita within a small geographic area are likely to be less significant compared to those within a large area. The impact of the water pipe distribution network within the county, though significant was not incorporated in the study due to the time factor.

1.6 Organization of the Report

This report is organized into five chapters. Chapter one gives a background information of the research, including the importance of accessing adequate quantities of piped water for human development. The objective and justification for the study is also presented.

Chapter two gives a review of relevant literature in the supply of piped water. Institutions responsible for water distribution in Kenya and in particular the area of study are identified. Established water indices for measuring water scarcity are highlighted .The impact of water scarcity on human development is also discussed.

Chapter three deals with the methodology used .The data sets used for the study are identified. Processing of the data and how the water supply maps were generated is discussed.

Chapter four presents the results of the study, including the maps generated. It also covers an analysis of the generated maps and a discussion of the results.

In Chapter five conclusions from the study are drawn and appropriate recommendations made.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

According to the Human Development Report of 2006 titled 'Coping with water scarcity: Challenge of the twenty-first century', water scarcity is among the main problems to be faced by many societies and the world in the 21st century, (UNDP, 2006) .The report states that water use has been growing at more than twice the rate of population increase in the last century and as such, an increasing number of regions are chronically short of water.
In the report a person is deemed as water insecure when that individual does not have access to safe and affordable water to satisfy his or her needs for drinking, washing and livelihood. When a large number of people in an area are water insecure for a significant period of time, then that area is said to be experiencing water scarcity.

It can be argued that people lack access to water because the water service provision is poor and that water shortages and scarcity situations are often made worse due to problems of uneven distribution and also mismanagement of existing supplies. Any severe asymmetrical distribution of the scarce water resources in relation to population concentrations makes it almost impossible to meet the demands of rapidly expanding economic undertakings.
It can therefore be concluded that there is a large room for efficiency enhancement in the distribution of piped water. Mapping the quantities of supplied piped water can greatly assist water service providers improve on the fairness of water dissemination and work towards the universal attainment of the right to accessing adequate water for all the areas they are mandated to serve. Such thematic mapping should bring together data on the spatial distribution of piped water as well as the population of administrative units in a given region.

2.2 The History of Piped Water Supply

Earlier humans had to carry their water from the source to the point of utilisation. The conveniences of present day piped water distribution systems took a large number of incremental innovations in science and technology.

The earliest piped water supply dates back to two millennia before Christ, (Walski .T.M, 2006). Vestiges of wooden water pipes were discovered in Minoan cities on the Mediterranean island of Crete which were used to supply water for irrigation in 1400 BC. Through gradual technological advancements, the materials used for water pipes have evolved into the currently used cast iron, ductile iron, galvanised iron, cement, polyvinyl chloride (PVC) and poly propylene (PP). These materials make the pipes long-lasting and hard to damage.

When designing a piped system, the aim is to ensure that there is sufficient pressure at the point of supply to provide an adequate flow to the consumer. If gravity is insufficient to supply water at an adequate pressure, then pumps need to be installed to boost the pressure. Pumps can be either permanently operational or intermittent. They can be controlled by a time-switch, pressure or a water level in a tank or reservoir. A back-up system (e.g. a standby pump) may be needed.

In Kenya, the history of piped water supply can be traced back to the period of the East African Protectorate, (Nyanchaga and Ombongi, 2007). At that time water supply was fixated on the needs of colonial settlements. The organisation of water supply was carried out by the Hydraulic Branch of the Public Works Department, which started operating in the coastal city of Mombasa. The construction of the Kenya-Uganda Railway in 1896 provided an important stimulus for the development of water pipelines in the interior of the country along the railway line.

Between 1920 and independence in 1963, the first attempts were made at policing water supply in the colony and protectorate of Kenya, while responsibility was shared by many institutions. In the 1950s and early 1960s, accountability for the administration of water supply was split between three institutions:

1. Ministry of Works operating in urban centres with centralised water service provision.
2. Local Authorities that were deemed capable of managing water supply.
3. Water Development Department, which was responsible for developing new water supplies for urban and rural areas.

As Kenya gained independence in 1963, efforts at simplifying the administration of water supply resulted in the transfer of all structures responsible for water to the Ministry of Agriculture in 1964

In order to improve operations and efficiency and to reduce the financial burden of the water sector, the National Water Conservation and Pipeline Corporation (NWCPC) was formed in June, 1988. Its responsibility was to run water supply systems under state control on a commercial foundation. This centralised approach to water supply failed to achieve the improvements that had been projected. Thus the idea of creating local-government owned and commercially viable utilities emerged. It was hoped that the de-centralised organisations would best manage the water supply systems.

2.3 Institutional Responsibilities of Water Supply in Kenya

At present, several institutions play different roles in the water supply chain in Kenya. The basic principle is that there is distinction between institutions responsible for policy and regulation on the one hand; and those in charge of providing services on the other.

The prevailing legal framework for the Kenyan water and sanitation sector is based on the Water Act No. 8 of 2002 which became effective in March 2003. The 2002 Water Act introduced far reaching reforms based on the following principles:

i. The separation of the management of water resources from the provision of water services;
ii. The separation of policy making from day-to-day administration and regulation;
iii. Decentralisation of functions to lower level state organs;
iv. The involvement of non-governmental entities in the management of water resources and in the provision of water services.

The implementation of these principles triggered a wide-ranging restructuring of the water sector and led to the creation of new institutions. The Ministry of Water and Irrigation (MWI) is the key institution responsible for the water sector in Kenya. The Ministry is also in charge of overall water sector policies, investments, planning and resource mobilisation. The role of other institutions is indicated in Table 2.1:

Table 2.1: Water institutions and their mandate

INSTITUTION	MANDATE
Ministry of Water and Irrigation (MWI)	Policy formulation, sector coordination, monitoring, financing and supervision
Water Resources Management Authority (WRMA)	Water resources management regulation
Catchment Area Advisory Committees (CAACs)	Provide water resources management advisory functions at water catchment level
Water Resources Users Association (WRUAs)	Co-operative management of water resources and conflict resolution at sub-catchment level.
Water Services Regulatory Board (WASREB)	Regulation of water and sewerage services
Water Services Boards (WSBs)	Water and Sewerage services planning and provision at regional level asset management, development and rehabilitation of water and sewerage facilities, investment planning and implementation
Water services providers (WSPs)	Direct provision of water and sewerage services as agents of the WSBs
Water Services Trust Fund (WSTF)	Support financing of water services for underserved rural areas
Water Appeal Board (WAB)	Handle disputes in the water sector
National Water conservation and pipeline Corporation (NWCPC)	Dam construction, flood control, land drainage, ground water development

The responsibility for water and sanitation service provision is currently devolved to eight regional Water Services Boards (WSBs) .The boards, their head offices and the counties they serve are shown in Table 2.2:

Table 2.2: Water service boards and counties served

S/No	**Water Services Board**	**Head Office**	**Counties served**
1	Rift Valley WSB	Nakuru	Lodwar, Nakuru, Narok, Nyandarua, Elgeyo Marakwet, West Pokot
2	Northern WSB	Garissa	Garissa, Mandera, Wajir, Isiolo, Marsabit, Laikipia, Samburu
3	Coast WSB	Mombasa	Mombasa, Kilifi, Kwale, Taita-Taveta, Lamu and Tana River.
4	Athi WSB	Nairobi	Kiambu,Nairobi
5	Lake Victoria North WSB	Kakamega	UasinGishu, Transnzioa, Kakamega, Busia, Nandi,Bungoma,Baringo,Vihiga
6	Lake Victoria South WSB	Kisumu	Kisumu,Siaya,Migori,HomaBay,Bomet,Kericho,Nyamira,Kisii
7	Tana WSB	Nyeri	Nyeri,Muranga,Kirinyaga,Embu,Tharaka Nthi,Meru
8	Tanathi WSB	Machakos	Kitui, Machakos, Makueni and Kajiado counties.

The coverage of the eight water service boards is illustrated in Figure 2.1.

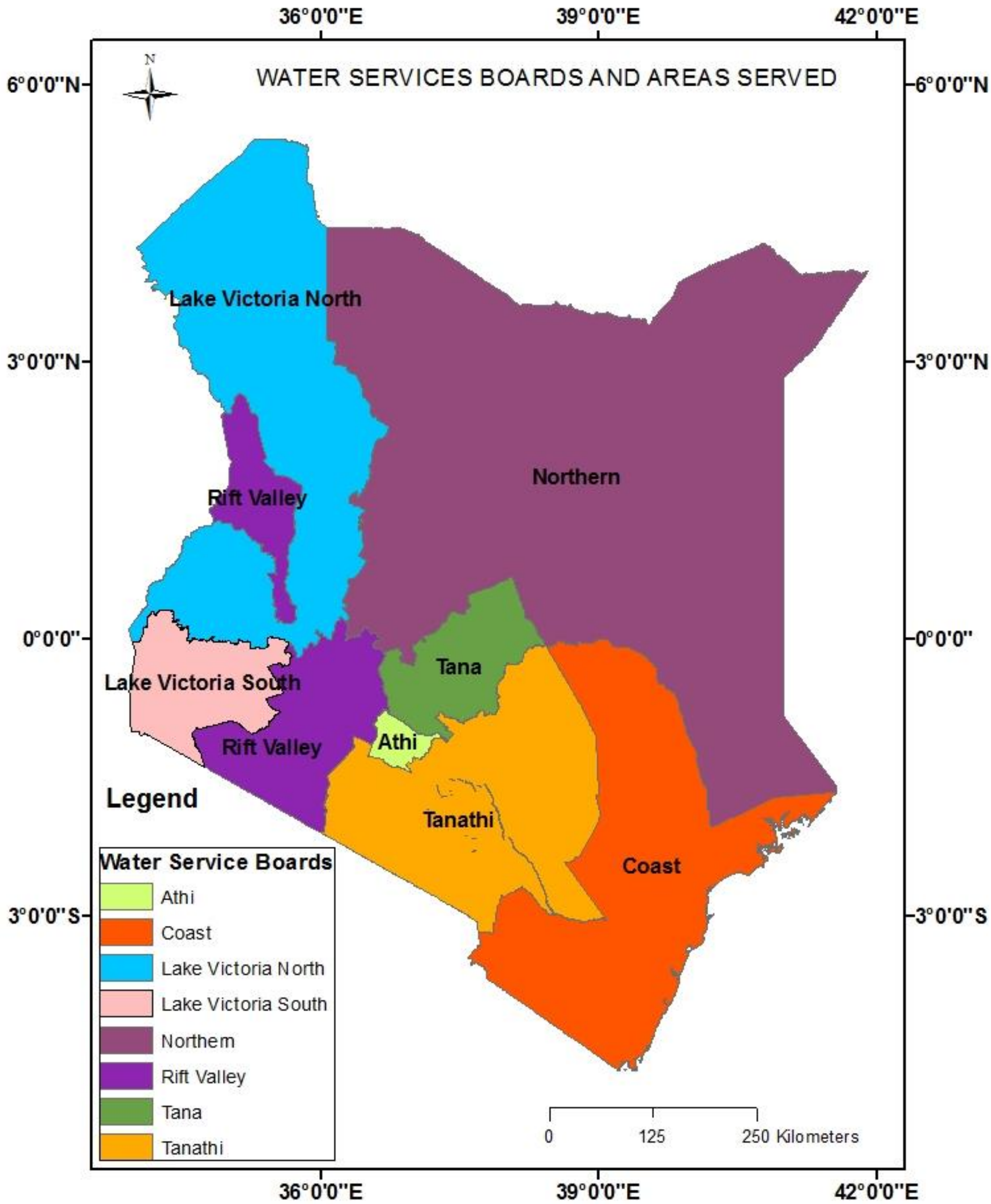

Figure 2.1: Coverage of water service boards

The 2010 Kenya Constitution obliged Parliament to revise the Water Act of 2002 to make it conform to the Constitution. This would ensure that the water supply services are fully devolved to the counties. The Water Service Providers would take charge of developing county water assets that can be used for the provision of water services. Currently county water assets are managed by the Water Services Boards which are parastatals of the national government in the Ministry of Water and Irrigation. Towards the realisation of this requirement, a new water bill 2014 is currently undergoing the legislative process in parliament, although the current Water Act remains in force until the bill is passed by Parliament.

If voted into law, the bill would transform the eight Water Services Boards (Asset Holding Companies) in the country into forty seven Water Works Development Boards, one for each of the counties in Kenya. The Bill is meant to be an improved version of the Water Act of 2002 and is meant to further improve the water supply mechanism in the counties.

The proposed institutions and their functions in the proposed water bill 2014 are as indicated in Table 2.3:

Table 2.3: Proposed water institutions and their functions in the water bill, 2014

Proposed Institution	**Proposed function**
(a)Water Resources Regulatory Authority	i. Formulate and enforce standards, procedures and regulations for the management and use of water resources and flood mitigation; ii. Regulate the management and use of water resources in consultation with the National Land Commission;
(b)National Water Harvesting and Storage Authority	i. undertake on behalf of the national government, the development of national public water works for water resources storage;
(c)Water Services Regulatory Authority	i. Protect the interests and rights of consumers in the provision of water services. ii. Maintain the register of all accredited water services providers.
(d)Water Services Provider	i. the provision of water services within the area specified in the licence ii. The development of county assets for water service provision.
(e)Water Sector Trust Fund	i. Provide conditional and unconditional grants to counties ii. Assist in financing the development and management of water services in marginalized areas or any area which is considered by the Board of Trustees to be underserved
(f)A Water Tribunal which shall be a subordinate court	i. Exercise the powers and functions set out in this Act and in particular shall hear and determine appeals at the instance of any person or institution directly affected by the decision or order of the Cabinet Secretary or by any of the proposed Authorities in the Act.

2.4 Coast Water Services Board

The Coast Water Services Board (CWSB) is a parastatal under the Ministry of Water and Irrigation responsible for the provision of Water and Sewerage Services in the Coast Region. It is one of the eight Water Services Boards in Kenya, formed during the implementation of the Water Sector Reforms. Coast Water Services Board was gazetted on the 27th February, 2004, (http://www.afriwater.org/articles/125, accessed on 18/03/2016).

Its area of jurisdiction coincides with the administrative boundaries of the Coast Region covering six counties namely Mombasa, Kilifi, Kwale, Taita-Taveta, Lamu and Tana River.

Coast Water Services Board operates a bulk water supply system which supplies water in bulk to the six counties in the Coast region.

The Coast Bulk Water Supply comprises of four independent Water supply Schemes namely:

1. Baricho Water Supply,
2. Mzima Pipeline,
3. Marere Pipeline
4. Tiwi Bore Holes.

The current arrangement is that the CWSB collects water from sources and supplies in bulk to various Water Service Providers (WSP) that supply the counties in the Coast Region.

The County of Kilifi is served by two WSP namely KIMASCO and MAWASCO. The coverage of water supply by the two providers in illustrated in Figure 2.2.

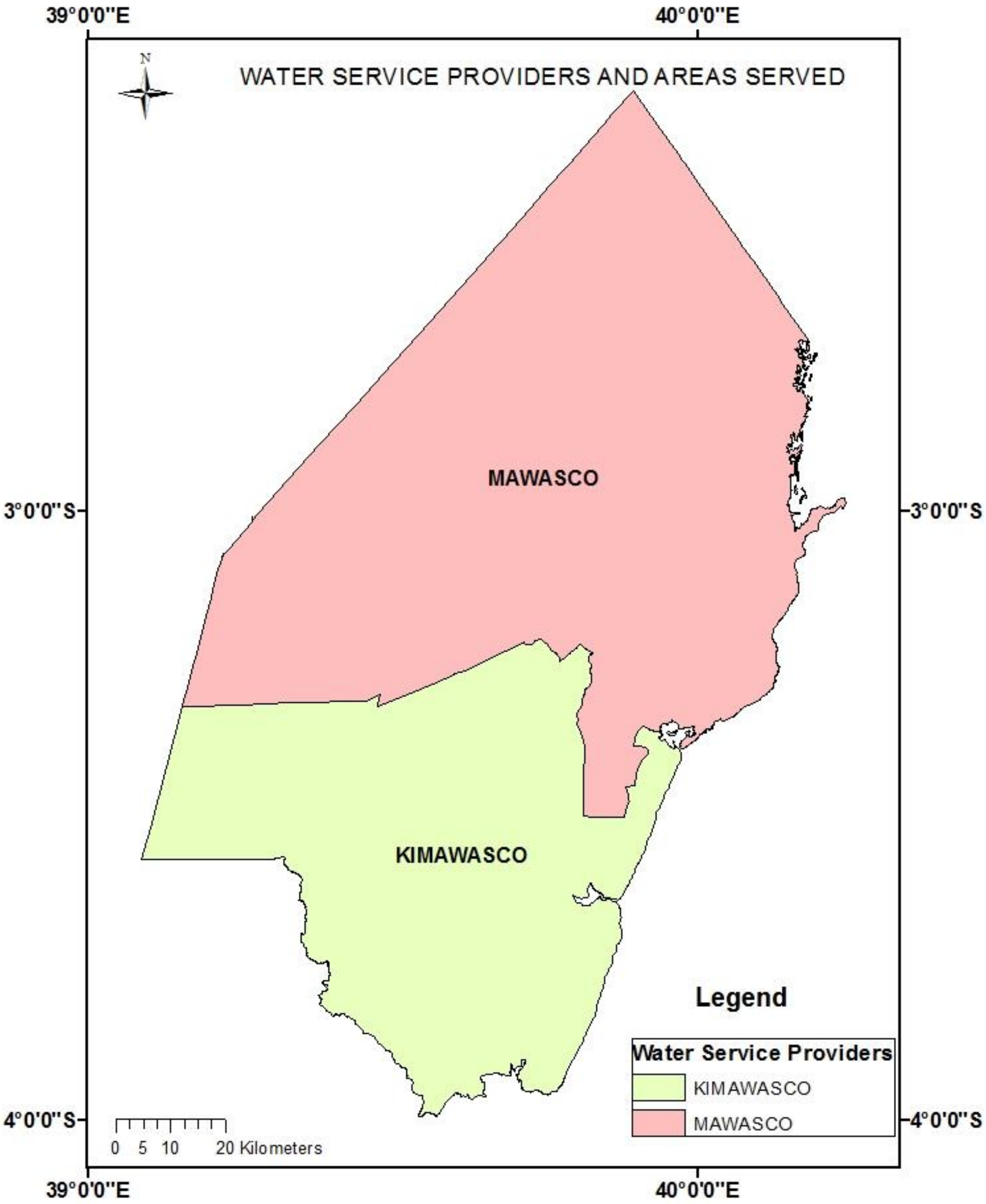

Figure 2.2: Areas served by the Kilifi water service providers

2.5 Water Scarcity Indices

Water scarcity refers to a situation of diminishing water resources coupled with an increasing demand of the available water resource. The scarcity is experienced at the point when the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors cannot be satisfied fully. Water scarcity of a region can be due to low water supply, high demand or both. Hydrologists, more often than not assess water scarcity by looking at the population-water equation. (Brown and Matlock, 2011). In the past 20 years, many indices have been developed to quantitatively evaluate water scarcity. Fresh water scarcity is commonly described as a function of available water resources and human population. These figures are therefore generally expressed in terms of annual per capita. The logic behind this is simply that if one knows how much water is necessary to meet human demands, then the water that is available to each person can serve as a measure of scarcity.

Four of the most commonly used indicators for water scarcity are listed hereunder:

1. Basic Water Requirements(BWR) Index
2. Falkenmark Indicator
3. The Water Resources Vulnerability Index(WRVI)
4. Water Poverty Index

2.5.1 Basic Water Requirements (BWR) Index

In a report titled 'Basic water requirements for human activities', Gleick. P.H, (1996) developed the BWR index as a measurement of the ability to meet all water requirements for basic human needs. The basic human needs were identified as follows:

- Drinking water for survival,
- Water for human hygiene,
- Water for sanitation services
- Water for modest household needs for preparing food.

Using data from the National Research Council of the National Academy of Sciences, the proposed minimum amount of water needed to sustain each of the basic human needs was worked out as follows:

1. Minimum Drinking Water Requirement: - Under typical temperate climates with normal activity, minimum drinking water requirement was found to be about 5 litres per person per day.

2. Basic Requirements for Sanitation:-Taking into account various technologies for sanitation worldwide and to account for the maximum benefits of combining waste disposal and related hygiene as well as to allow for cultural and societal preferences, a minimum of 20 litres per person per day was recommended for human hygiene.
3. Basic Water Requirements for Bathing: - The study suggested that the minimum amount of water needed for adequate bathing is 15 litres per person per day.
4. Basic Requirement for Food Preparation: Taking into consideration both developed and under-developed countries, the water use for food preparation to satisfy most regional standards and to meet basic needs was found to be 10 litres per person per day.

On averaging the above needs, the proposed water requirements for meeting basic human needs gave a total demand of about 50 litres per person per day or an annual water per capita of $18.3m^3$. Since then, international organizations and water providers have adopted this overall basic water requirement as the threshold for meeting the basic human needs. This is independent of climate, technology, and culture. The fulfilment of this basic water requirement is currently considered as a human right. The basic water requirements are illustrated in Table 2.4.

Table 2.4: Gleick's basic water requirements

Basic human need	**Daily minimum amount of water needed(litres)**
Drinking water for survival	5
Waste disposal and related hygiene	20
Water for bathing	15
Water for modest household needs for preparing food	10
Total	**50**

The BWR index does not include the quality of the water into the concept. It is therefore prudent to apply it only on properly treated piped water. The needs of other water users such as industrial, agricultural and commercial uses are not included into the index. The assumption is that these other uses are deemed secondary to the basic domestic human needs of water.

2.5.2 The Falkenmark Indicator

The Falkenmark Indicator is one of the most widely used measure of water scarcity.
It was developed by Falkenmark Malin, Jan Lundqvist and Carl Windstrand in 1989, (Rijsberman.F.R,2005). The indicator uses the total volumes of water available annually for various human uses including both domestic and non-domestic uses. It is also based on per capita usage and is normally applied at a national scale. Its popularity is due to the fact that it is easy to apply and understand.

Multiple countries were surveyed and the water usage per person in each economy was calculated. Based on the per capita usage, the Falkenmark indicator classifies the water scarcity levels for a country into four categories as shown in Table 2.5:

Table 2.5: The Falkenmark water scarcity levels

Scarcity Level	**Annual Water Per Capita**
Severe Scarcity(S)	$<500m^3$
Medium to Severe Scarcity(MS)	$500m^3$-$1000m^3$
Moderate Scarcity(M)	$1000m^3$-$1700m^3$
Little or No Scarcity(N)	$>1700m^3$

These thresholds are based on estimates of water requirements in the household, agricultural, industrial and energy sectors, and the needs of the environment. According to the Falkenmark Indicator, countries should strive to ensure that their renewable water supplies do not fall below the $1{,}000m^3$ annual per capita level when a country starts experiencing water scarcity.

The major advantages that make this simple indicator almost unbeatable are that:
a) The data are readily available; and

b) Its meaning is intuitive and easy to understand. As a result the indicator dominates most discussions of water scarcity fora.

However, the Falkenmark indicator also has the following shortcomings:

- Only the renewable surface and groundwater flows in a country are considered.
- The water availability per person is calculated as an average with regard to both the temporal and the spatial scale and thereby neglects water shortages in dry seasons or in certain regions within a country.
- It does not take the water quality into account at all
- It does not consider a country's ability to use the available water resources. This is because a country may have sufficient water resources as per Falkenmark indicator, but be unable to use the same due to pollution or insufficient access to the sources of water.
- The annual, national averages hide important scarcity at smaller scales;
- The indicator does not take into account the availability of infrastructure that modifies the availability of water to users; and
- The simple thresholds do not reflect important variations in demand among countries due to, for instance, lifestyle and climate.

Ohlsson. L, (1999) modified the Falkenmark indicator by accounting for a society's 'adaptive capacity', meaning the capacity to adapt to water stress through economic, technological or other means. He used UNDP's Human Development Index to improve the Falkenmark indicator, and called it a 'Social Water Stress Index'.

Despite these limitations, scholars agree that the Falkenmark indicator will not be replaced by other indices any time soon. The attraction of a simple, easy-to-understand indicator such as the Falkenmark indicator is simply too important to be replaced by other more complex dimensionless indices. The use of population data and water supply data has the advantage that one avoids the expenses of having to conduct detailed individual household surveys.

2.5.3 The Water Resources Vulnerability Index (WRVI)

This indicator was first developed by Raskin .P, et. al, (1997) for the United Nations Committee on Sustainable Development. It uses the volumes of water withdrawn from different sources as a percentage of total water supply. A year later in 1998,an improved version of the indicator was developed by the International Water Management Institute(IWMI) based in Sri Lanka to incorporate an estimate of future water withdrawals as a percentage of current withdrawals. The improved version came to be referred to as the IWMI indicator. It focusses on the assessment of water demand on a national scale by analysing a country's annual renewable water supply against water withdrawals rather than per capita water supply. The water demand covers the sectors of agricultural, industrial and domestic sectors.

Water scarcity is then computed as the total annual withdrawals as a percentage of available water resources. This index suggests that a country is water scarce if annual withdrawals are between 20-40% of annual supply, and severely water scarce if this figure exceeds 40%.The index also considers a country's water infrastructure, such as water in desalination plants, into the measure of water availability, recycled water and the adaptive capacity of a country to address water scarcity such as improving efficiencyin water usage.

Using this approach, the IWMI indicator classifies countries that are predicted to be unable to meet their future water demand without investment in water infrastructure and efficiency as economically water scarce; and countries predicted to be unable to meet their future demand, even with such investment, as physically water scarce

While the IWMI measure of water scarcity is more sophisticated, its complexity means that it requires significant amounts of time and resources to estimate. This approach also fails to consider the ability of people within countries to adapt to reduced water availability by importing food grown in other countries, or by using water saving devices. The ability to adapt also depends on the economic resources available in countries as a whole, as well as to individuals within a country. For instance, wealthy residents in rich countries are more likely to be able to adapt to reduced water availability than poor people in developing countries.

The disadvantage of the IWMI model, however, is its intricacy and resulting complexity of assessment. Unlike the per capita indicators and even the simpler supply-demand models, it is not perceptive, and hence relatively inaccessible to the wider public. It also relies on considerable expert judgement because data are not available to assess all components of the indicators.

2.5.4 Water Poverty Index (WPI)

This was developed by Sullivan .C, (2002) who was a hydrologist based at the centre of Ecology and Hydrology at Wallington, UK .In this index, water scarcity analysis in-cooperates the following factors:

a. Total amount of water available
b. Accessibility of available water for human use
c. People's ability to manage water
d. Different uses of the water like domestic, agricultural, industrial and other productive purposes
e. Environmental impact of the aquatic habitats in the area
f. Water quantity, quality, and variability;
g. Capacity for water management

The index attempts to reflect both the physical availability of water, the degree to which humans are served by that water and the maintenance of ecological integrity. It thus takes into account the role of income and wealth in determining water scarcity.

The advantage of this indicator is in its comprehensiveness. It is however hampered by its complexity and lack of discerning understanding.

A summary of the indices, their applications and data requirements is shown in Table 2.6.

Table 2.6: Spatial scales of water scarcity indices and data requirements

S/No	Indicator/ Index	Reference	Spatial Scale	Required Data
1	Basic Water Requirements Index(BWRI)	Gleick, 1996	Country, region	Domestic water use per capita, population
2	Falkenmark Water Stress Indicator	Falkenmark, 1989	Country	Total annual renewable water resources, population
3	Water Resources Vulnerability Index (WRVI)	Raskin, 1997 IWMI,1998	Country	Annual water withdrawals, total renewable water resources, GDP per capita, national reservoir storage volume, time-series of precipitation and percentage of external water resources
4	Water Poverty Index (WPI)	Sullivan, 2002	Country, region	Internal renewable water resources, external renewable water resources, access to safe water, access to sanitation, irrigated land, total arable land, total area, GDP per capita,under-5 mortality rate, UNDP education index, Gini coefficient, domestic water use per capita, GDP per sector, Water quality variables, use of pesticides, Environmental data (ESI)

2.6 Index Adopted for the Research and Justification

The research adopted Gleick's Basic Water Requirements (BWR) index for the analysis .This is because this index has been adopted by the World Health Organisation as the bench mark indicator for the bare minimum water requirements for human survival. The threshold in this index is now considered as a human right.

The adequate quantities of water referred to in section 43(1) (d) of the Kenya Constitution 2010 are deemed to refer to the basic water requirements.

Some of the most recent studies have postulated that no single definition of water scarcity can capture all possible scenarios and that different water scarcity indices capture different aspects of the pressures on water resources,(White .C, 2012). For instance, an intermittent piped water network where water does not flow continuously to customer homes or public taps can cause water scarcity. Intermittent water supplies are caused primarily by lack of sufficient water to serve all customers and keep the piped networks fully pressurized at all times, (Lee and Schwab, 2005). Other causes of intermittent water supply include scarcity of source water, scarcity of treatment capacity, and interruptions of electricity to run water pumps, high leakage rates, high population growth, or some combination of these conditions.

The emerging trends is that access to present water technologies like water recycling will have a great impact on the earlier perceived water scarcity levels. It is also envisaged that investment in technological development will have a big impact on improving water security.Future water sarcity indices will therefore need to incooperate the emerging water technologies and the ability of individual countries to invest in such technologies.

2.7 Water Scarcity and Economic Poverty

Economists have established that there is a direct correlation between accessibility to piped water and economic poverty, (Toure. N.M, et. al, 2011).This has led to the emergency of what has come to known as the ‘water poverty trap’ concept.

In shanty towns of developing countries, people without access to piped water were typically found to be paying five to ten times more per unit of water than do people with access to piped water. This compounds the problem of economic poverty of the people living in such slums and thus creating the water poverty trap. Chances of breaking out of such a poverty trap are extremely slim especially when deliberate measures are not taken to target water supply in such areas.

This calls for extending the piped water infrastructure to these areas. Thus the social and economic consequences of lack of piped water penetrate deep into the spheres of overall productive potential of individuals, communities and nations.

2.8 Geographic Targeting of Piped Water Supply

Geographic targeting is the focusing of efforts in particular areas. The argument for geographic targeting stems from the observation that poverty tends to exist in pockets caused by a combination of individual and structural factors, (Cullis and O’Regan, 2003). These pockets can be fairly and easily identified in both urban and rural areas. Intuitively, water poverty will tend to have a more obvious geographic nature owing to the importance of environmental factors and the level of local infrastructure development in defining both the availability of the water resource and people’s ability to access it.

The use of poverty maps to facilitate geographic targeting of policy initiatives has been identified as the most cost-effective use of scarce resources for stimulating the development of the poor. Geographic location is more important in identifying target groups than other characteristics. The reduction in poverty that can be achieved through geographic targeting of piped water supply is greater than that achieved through an equally expensive universal water distribution programme, (ibid).

2.9 Thematic Mapping

A thematic map is a type of map especially designed to show a particular theme connected with a specific geographic area.

The use of maps to portray the complex nature of general water supply and in particular water poverty and scarcity, as well as the ability to visualize different water supply policy scenarios, are just two ways of applying thematic mapping.

A thematic map in which areas are shaded, patterned or coloured in proportion to the measurement of a statistical variable being displayed on the map, such as population density or a per capita variable is called a choropleth map.

A choropleth map provides an easy way to visualize how a measurement varies across a geographic area. The variable being depicted should have numerical attributes which can be used to display layers of different quantities.

The numerical measures used in the layer display could represent the following:

1) Range
2) Count
3) Ratio or percentage
4) Rank, such as high, medium, or low.

The use of such maps offers the following advantages:

a) It is easier to integrate data from different sources and allows the switch to new units of analysis from, for example, sub county boundaries to smaller units like sub locations when the relevant data is available.

b) Maps are a powerful visual tool and are more easily understood by a wider audience of stakeholders, particularly in developing countries. This can improve decision making and strategy planning of international development organizations.
c) Water supply maps can not only help in our understanding of the spatial nature of water poverty, but the use of layering can also be useful in identifying the underlying causes of water poverty and scarcity in an area.

When features are drawn with graduated colours, the quantitative values are grouped into classes and each class is identified by a particular colour. These choropleth maps can be used to provide a visual summary of the information on the water scarcity situation in a given area. The resultant map can then be used not only to show the current situation, but also to identify key areas to be targeted for the efficient allocation and implementation of water supply. It can also be used for the development of policies resulting in a list of priority projects required. In addition, the choropleth maps can also be used to display the results of water policy scenario simulations.

The maps should be of an appropriate resolution so as to meet the objectives of the study and correctly display the required information. A map at too coarse a resolution may not adequately reflect the heterogeneity within each unit. This is because within a given region, patterns and scenarios are often more visible when rendered at smaller geographic units.

When using choropleth maps, emphasis should be made on the need to have a balance between the assumptions of homogeneity of a phenomena with the additional costs and logistics of producing a more detailed map. This balance should take into consideration the following applications of choropleth mapping:

- Choropleth maps should support a comparison of phenomena in geographic space and help in representing regional differences.
- Choropleth maps should be used for phenomena that have spatial variation that coincide with the boundaries of the spatial area used for mapping.

It should however be acknowledge that this is seldom the reality as most often choropleth maps are representing a typical value for a region when that value or phenomena is not spread uniformly within the region. This does not negate the fact that choropleth maps supports easy understanding of a spatial pattern as they provide an easy way to visualize how a measurement varies across a geographic area or the level of variability within a region.

CHAPTER 3: MATERIALS AND METHODOLOGY

3.1 Research Design

The research was designed to identify and collect relevant data that was used to generate GIS based choropleth maps depicting the supply of piped water in Kilifi County. The maps were then analysed to gauge the adequacy or otherwise of the quantities of piped water supplied to the residents of Kilifi County.

3.2 Area of Study

The study was carried out in the County of Kilifi which is one of the 47 counties in the Republic of Kenya. The County lies between latitude 2° 20’ and 4° 0’ South of the Equator and between longitude 39° 05’ and 40° 14’ East of the Greenwich Meridian, (SOK, 2012).

The County is located in Kenya’s Coast region and borders Kwale County to the south west, Taita Taveta County to the west, Tana River County to the north, Mombasa County to the south and Indian Ocean to the east.

It covers an area of 12,609.7 km^2 . Kilifi town is the County headquarters.

The location of Kilifi County within the republic of Kenya is shown in Figure 3.1.

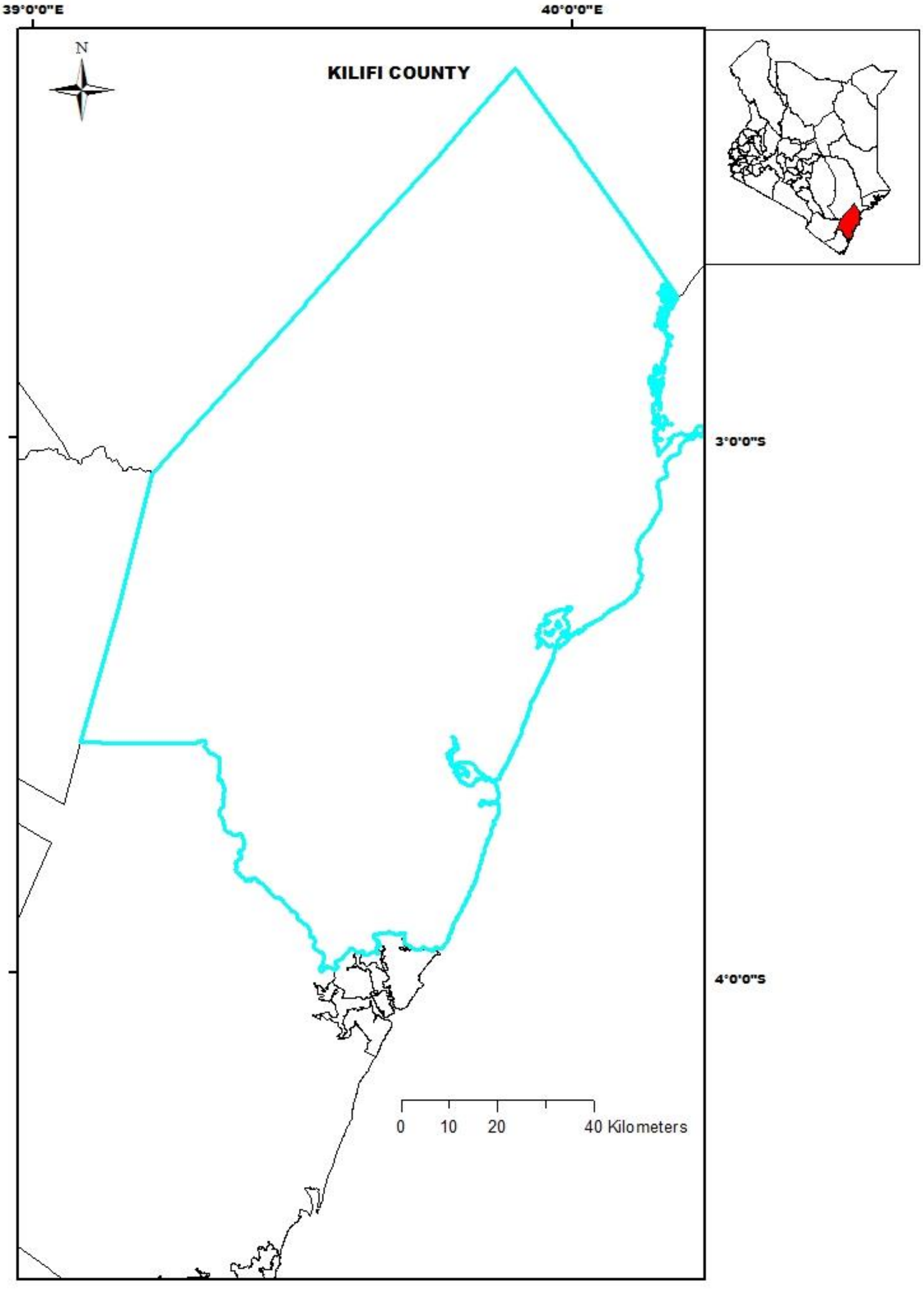

Figure 3.1: Location of Kilifi County in Kenya

3.3 County Administrative Units

Kilifi County has 7 sub counties , 17 divisions, 54 locations and 165 sub-locations(IEBC, Kilifi Office,2016).Magarini Sub-county is the largest while Rabai is the smallest in terms of area in Km^2. The County administrative units are shown in Table 3.1.

Table 3.1: Kilifi county administrative units

Sub -County	**Area (Km^2)**	**No. of divisions**	**No of Locations**	**No. of Sub-Locations**
Kilifi North	530.30	1	6	22
Kilifi South	400.60	2	6	16
Ganze	2941.60	4	16	48
Malindi	627.20	2	8	18
Magarini	6979.40	2	8	28
Kaloleni	686.40	5	11	21
Rabai	205.90	3	7	12
TOTALS	**12371.4**	**19**	**62**	**165**

Source: IEBC –Kilifi Office

The administrative unit used for the study is the sub county. The sub county boundary map is indicated in Figure 3.2.

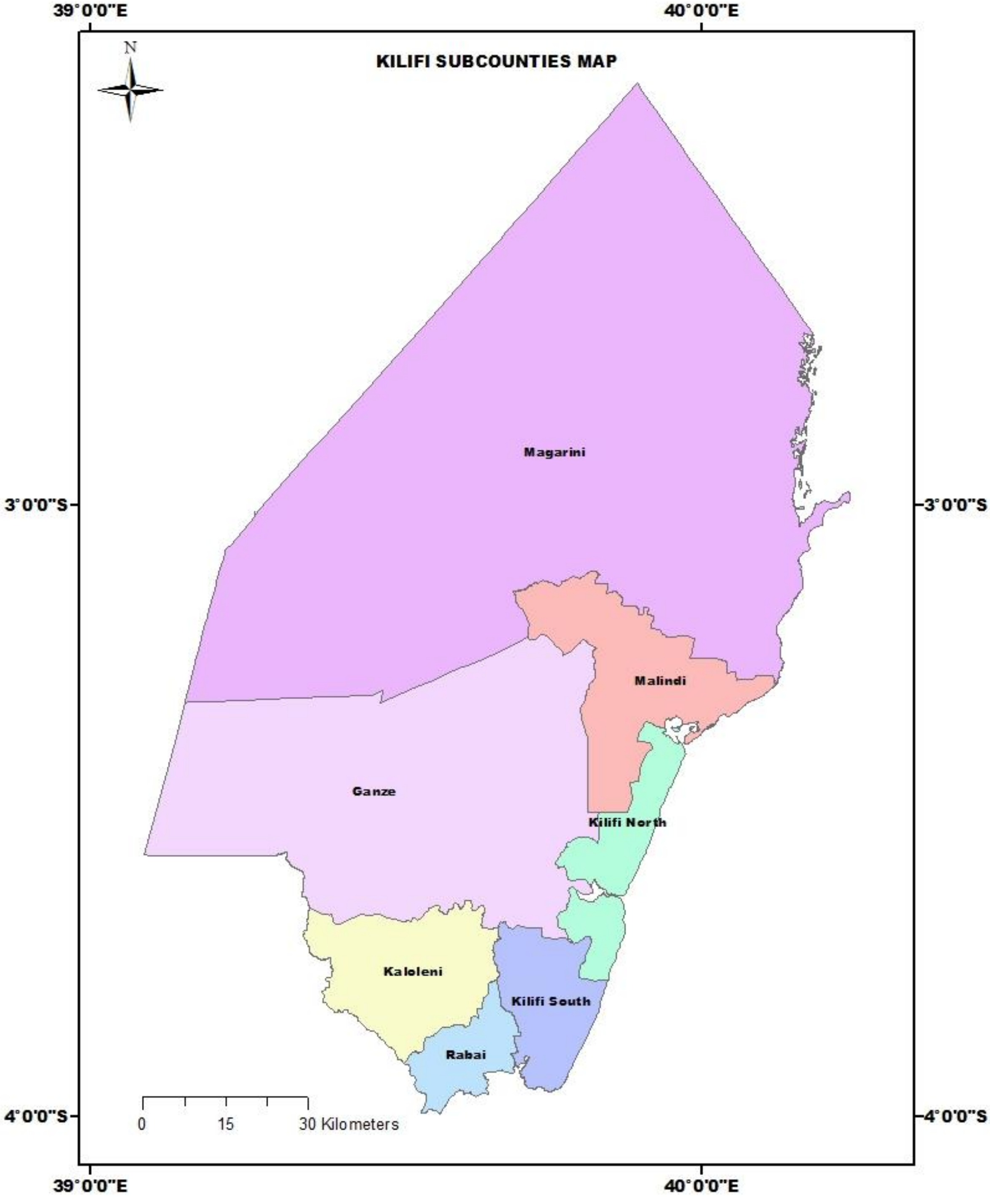

Figure 3.2: Sub county boundary map

3.4 Methodology Overview

The research approach adopted for this study involved the use of relevant and available data sets to determine and map the quantities of per capita water supply. A flow of the study activities is demonstrated in Figure 3.3.

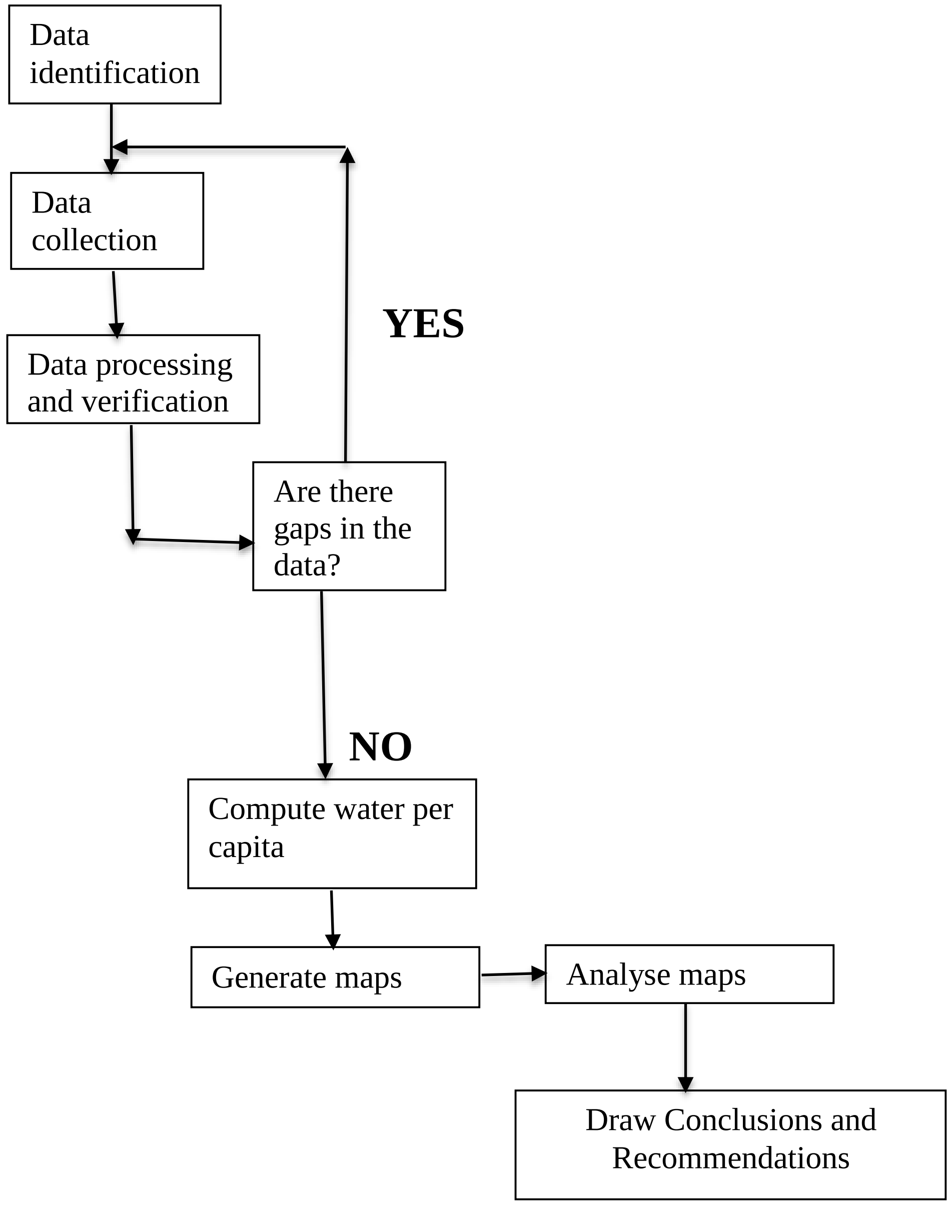

Figure 3.3: Methodology

3.4.1 Data collection

The main types and sources of data identified and collected for this study are indicated in table 3.2.

Table 3.2: Data sets collected

Data set	Description	Source	Format
1	Kenya counties map	SOK-Nairobi	Shape files
2	Kilifi sub counties map	IEBC-Kilifi	Shape files
3	Population data by sub county	KNBS-Kilifi	Microsoft excel worksheet
4	Annual billed water supply for 2012,2013&2014 covering Ganze, Kilifi North, Kilifi South, Rabai and Kaloleni sub counties	KIMAWASCO-Kilifi	Microsoft excel worksheet
5	Annual billed water supply for 2012,2013&2014 covering Malindi and Magarini sub counties	MAWASCO-Malindi	Microsoft excel worksheet

Details of the five data sets collected are as indicated in appendices A, B, C, D and E.

The water supply data provided consists of a summary of the quantities of billed water supplied to the customers of the WSP in each sub county as extracted from their databases.

3.4.2 Data Processing

Some of the polygons on the Kenya counties map and the Kilifi sub counties map had some gaps. These were rectified by using the geoprocessing tool in ArcGIS. Using the population data and the billed water volumes, the annual water per capita for each sub county was computed.

3.4.3 Generating maps

The Kilifi sub counties layer and the water per capita excel sheet were joined using the joins and relates function in ArcGIS. Graduated colour symbology and appropriate colour ramp was then used to generate the maps using five classes of per capita annual supply. The colour ramp was selected such that a deep red colour would symbolise the least per capita supply while deep blue colour would symbolise the largest per capita supply. For purposes of comparison between the actual supply and the basic water requirements, bar chart symbology was used .The bar charts were also used to assess the improvement of water supply over the three year period

3.4.4 Map analysis

Choropleth maps were used to present the actual water per capita supply and also demonstrate the inequality of water supply among the sub counties. The inadequacy of the supply against basic water requirements was illustrated using maps generated through the bar chart symbology. Conclusions were drawn and recommendations made based on the interpretation of these maps.

3.5 Hardware and Software

The hardware and software used in carrying out the study is as indicated in Table 3.3.

Table 3.3: Hardware and software used

Hardware	**Specifications**		**Software**	**Use**
A personal Computer	HP 2000 Notebook PC		ArcGIS 10.3	Map Making
A Printer	HP Deskjet 2050 J510 series		Microsoft office 2013	Report typing and editing

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Water Service Providers

The County of Kilifi is served by two Water Service Providers who supply piped water to the seven sub counties. The water Service providers and the sub counties they serve are indicated in Table 4.1.

Table 4.1: Water service providers and sub counties served

Water Service Provider	**Sub Counties Served**				
KIMAWASCO	Kilifi North	Kilifi South	Ganze	Kaloleni	Rabai
MAWASCO	Malindi	Magarini			

KIMAWASCO has 2 main water sources namely: Mzima springs and Baricho water works while MAWASCO has only one water source, namely Baricho water works. The Mzima springs are located south west of the Chyulu hills in Tsavo West National Park while the Baricho water works are located on River Sabaki. (http://www.malindiwater.co.ke, accessed on 15/03/2016).

About 50% of residents have direct access to piped water in their dwelling places. The rest obtain piped water from water kiosks and vendors. Of the existing customers, about 40 per cent receive water on the 24-hour basis. Out of the total volume of bulk water supplied to the two service providers annually by the Coast Water Services Board, about 40% cannot be accounted for from the billed water volumes of each water service provider. (http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd, accessed on 17/03/2016)

This unaccounted for water, normally referred to as non-revenue water (NRW) is assumed to be lost through pipe breakages, leaks and illegal connections.

4.2 Annual Water Per Capita

Using the annual population data and the annual water supply for each sub county, the water per capita supply was computed. The resultant figures for the annual water per capita for each sub county are shown in Table 4.2.

Table 4.2: Computed annual water per capita for 2012-2014

Sub County	**Water Per Capita 2012(m^3)**	**Water Per Capita 2013(m^3)**	**Water Per Capita 2014(m^3)**
Kilifi North	6.50	6.93	7.36
Kilifi South	2.45	2.61	2.77
Rabai	4.32	4.60	4.89
Kaloleni	2.31	2.46	2.61
Ganze	3.27	3.48	3.70
Magarini	3.30	3.50	3.80
Malindi	7.20	7.40	7.60

4.3 Resultant Maps

The Kilifi sub counties map layer and the computed annual water per capita supply excel sheet were joined in ArcGIS. The resultant layer was used to generate choropleth maps to enable geo-visualisation of the water supply. A comparison was also made between the actual water per capita supply and the annual basic water requirements of 18.3m^3.The comparison was made using proportional symbol maps with the bar chart chosen as the symbol for the comparison.

4.3.1 Water supply for 2012

The annual water per capita supply for 2012 is indicated in Figure 4.1.

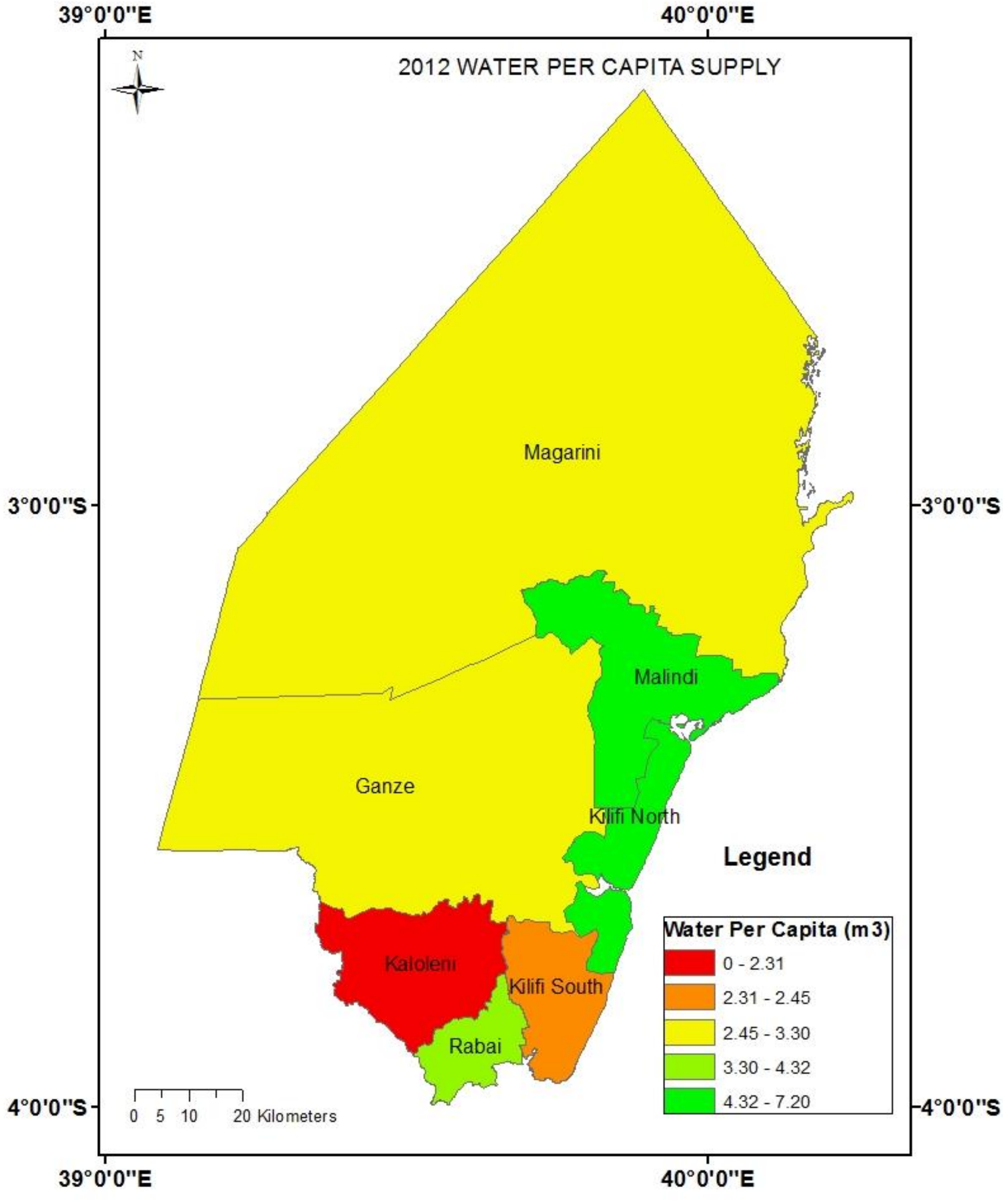

Figure 4.1: 2012 annual water per capita supply

The map indicates that the sub counties of Malindi and Kilifi North received the 'highest' water per capita of 4.3m^3-7.2m^3.This translates to a daily water per capita supply of 11-20 litres. This is against the basic water requirements of 18.3 m^3 annual per capita or daily water per capita of 50 litres. This implies that the 'best' supplied counties only get an average of 40% of their basic water requirements. The worst supplied counties of Kaloleni and Kilifi South received an average of 2.3m^3-2.4m^3 annual water per capita translating into a daily water per capita of about 6 litres only. This is only 12% of the basic water requirements.

The remaining three counties of Ganze, Magarini and Rabai get an average annual water per capita of 2.4m^3- 3.3m^3, which translates into a daily water per capita of 6-9 litres. This is equivalent an average of 38% of basic water requirements.

In interviews with officials of the two WSP, the higher water per capita supply for the sub counties of Kilifi North and Malindi was attributed to a better water pipe network infrastructure in these two sub counties as compared to the other five sub counties. As a result, most of the residents in the two sub counties have water supply connected to their dwelling premises due to the proximity of the water pipe supply network. In contrast, the other sub counties rely mostly on water selling points (water 'kiosks') for their water supply. The cost of installing water supply in one's home in these sub counties is prohibitive due to the sparsely distributed network.

A comparison of the 2012 water per capita and the basic water supply is demonstrated in Figure 4.2.

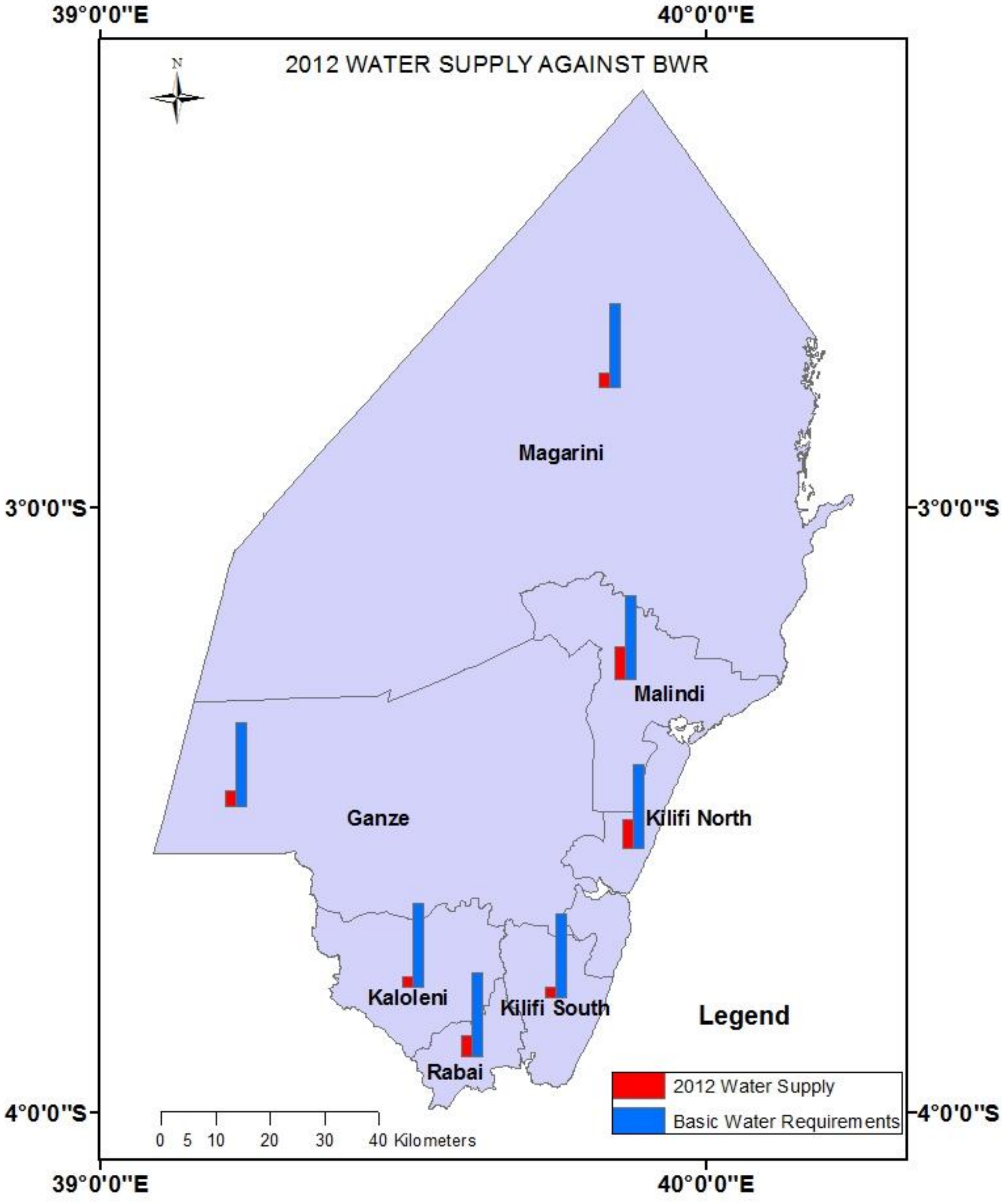

Figure 4.2: Comparison between 2012 supply and BWR

4.3.2 Water Supply for 2013

Water supply for 2013 is indicated in Figure 4.3 while a comparison with the BWR is indicated in Figure 4.4.

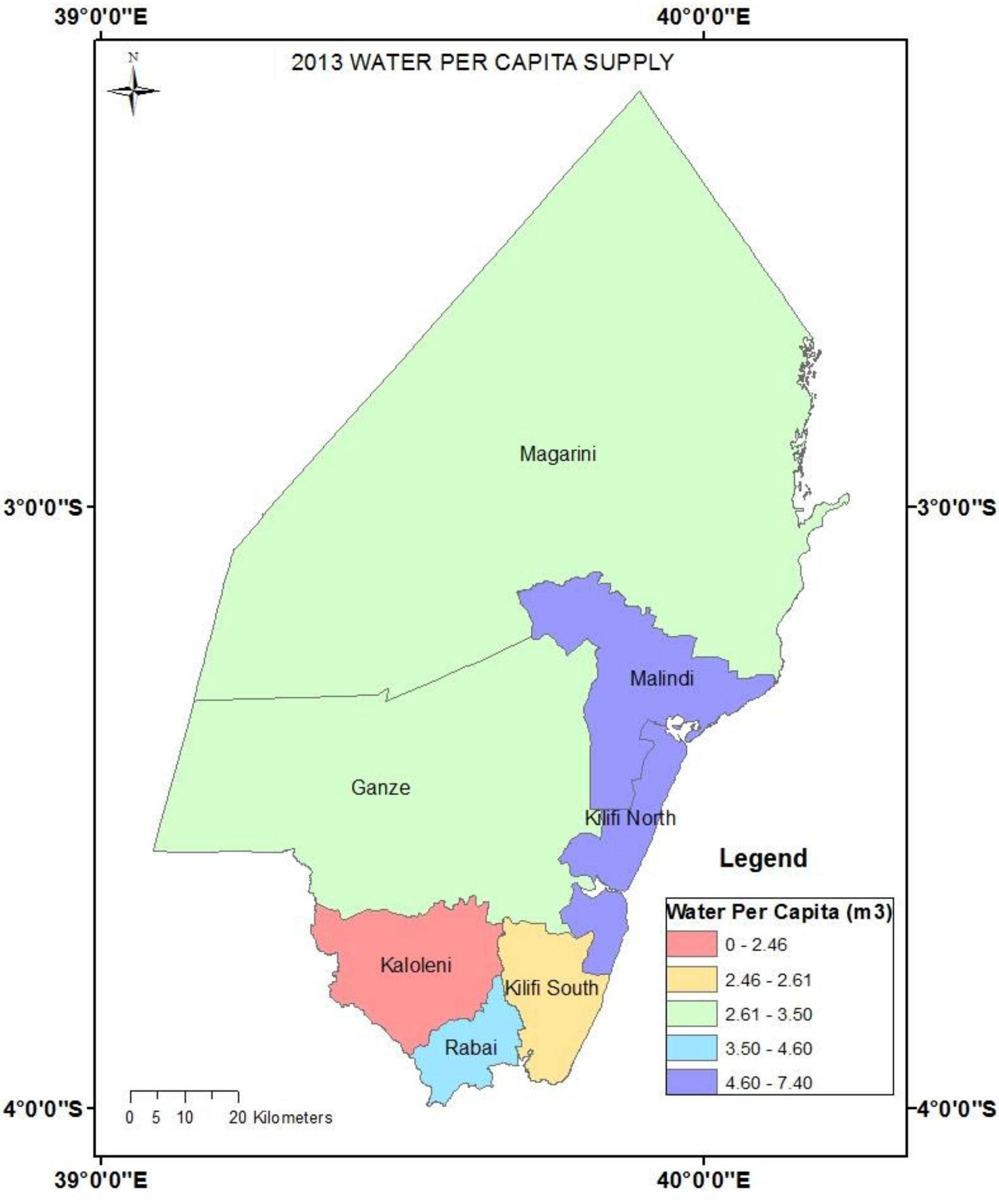

Figure 4.3: 2013 annual water per capita supply

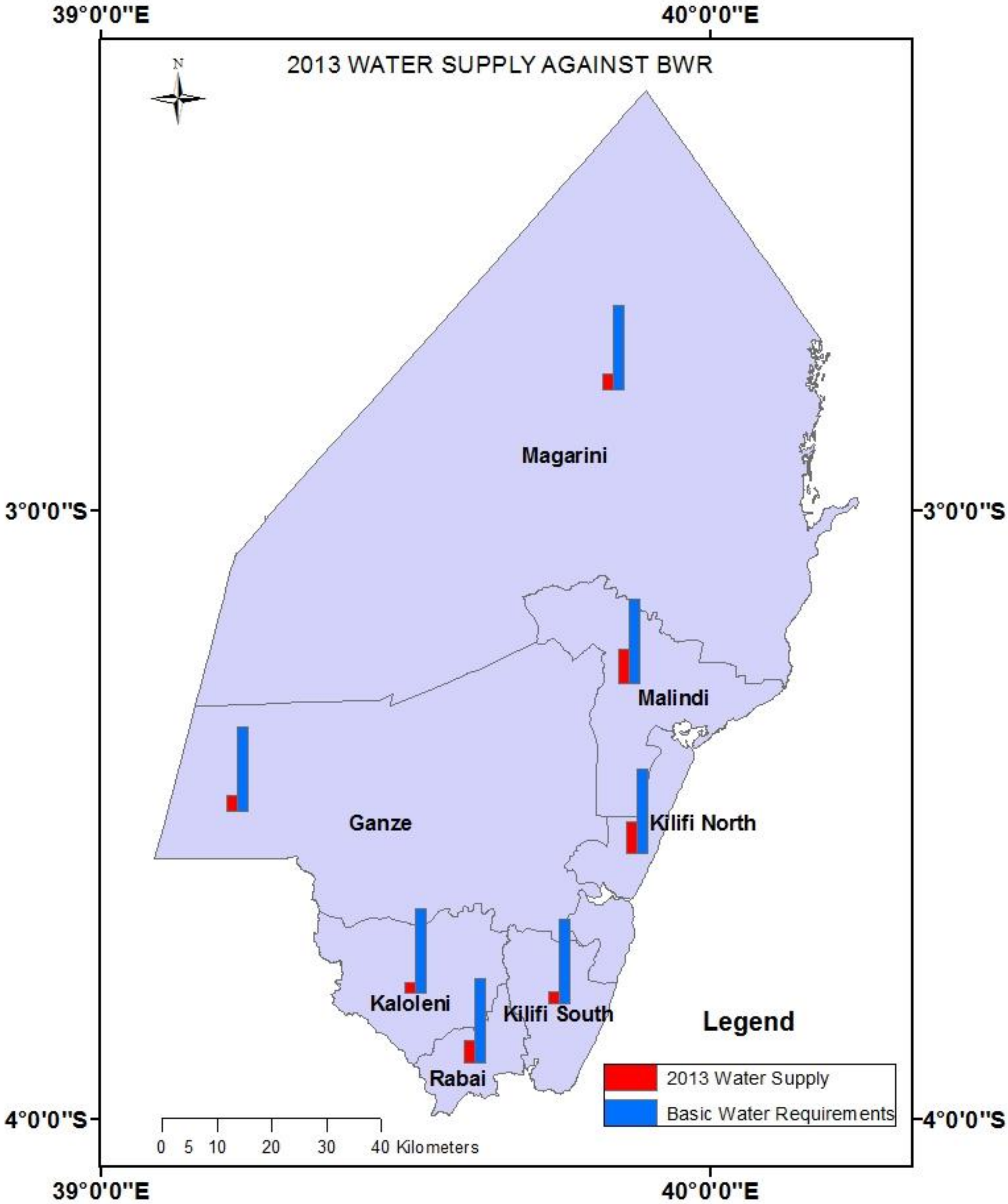

Figure 4.4: Comparison between 2013 supply and BWR

4.3.3 Water supply for 2014

The 2014 per capita water supply is illustrated on Figure 4.5 and a comparison with the BWR shown on Figure 4.6.

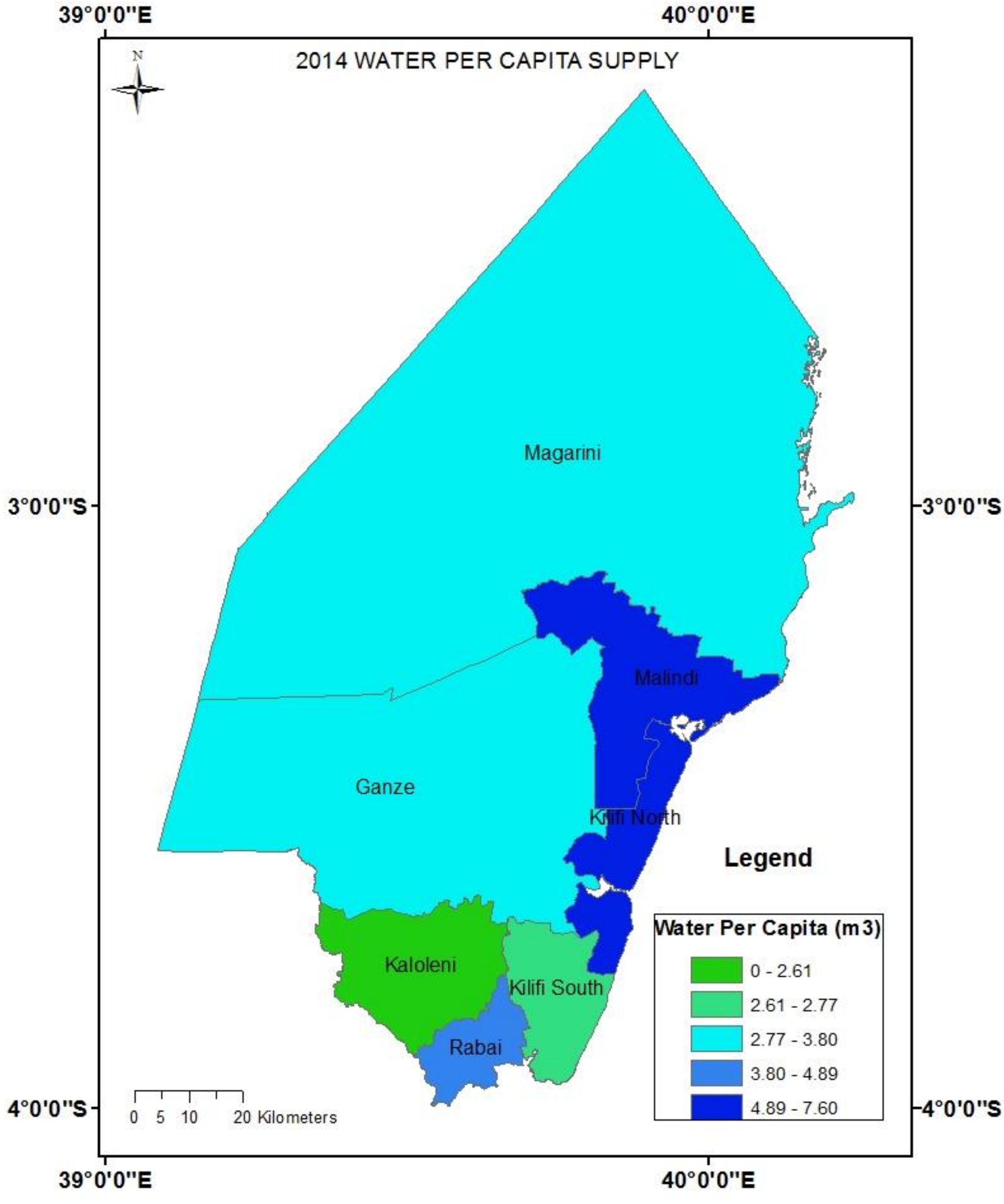

Figure 4.5: 2014 annual water per capita supply

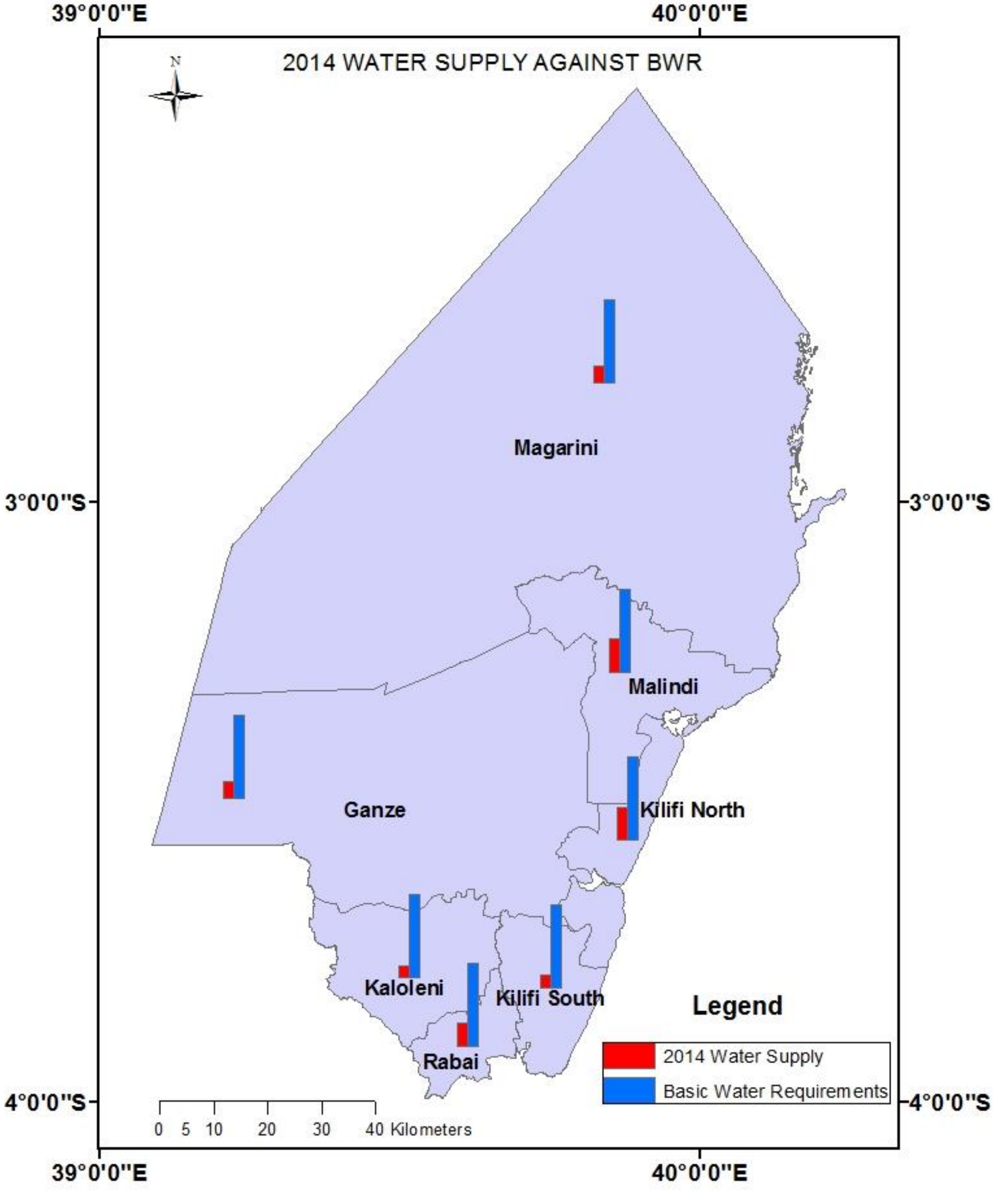

Figure 4.6: Comparison between 2014 supply and BWR

A summary of the 2012-2014 supply is illustrated in Figure 4.7 and a comparison against the BWR indicated in Figure 4.8

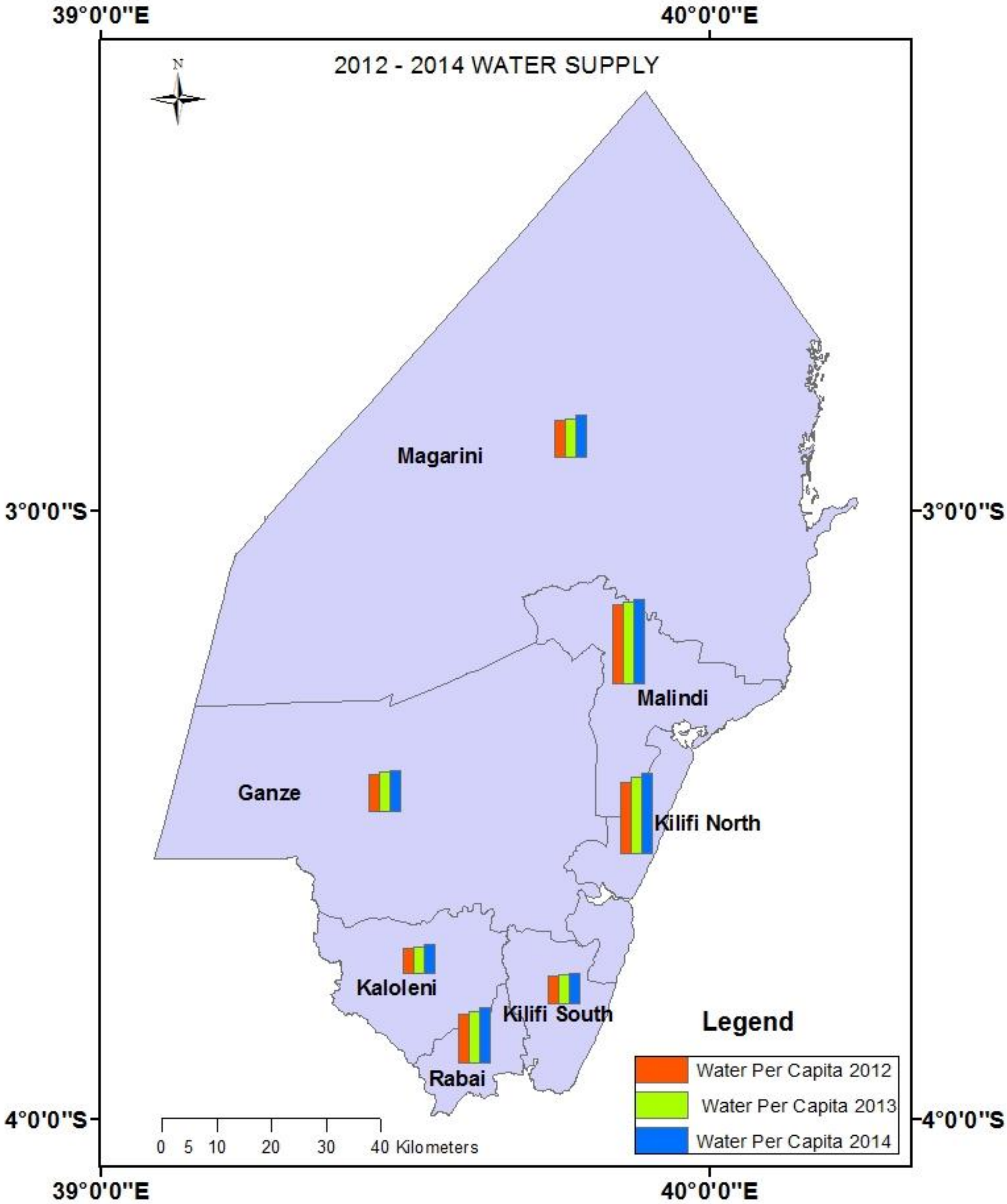

Figure 4.7: 2012 - 2014 annual supply

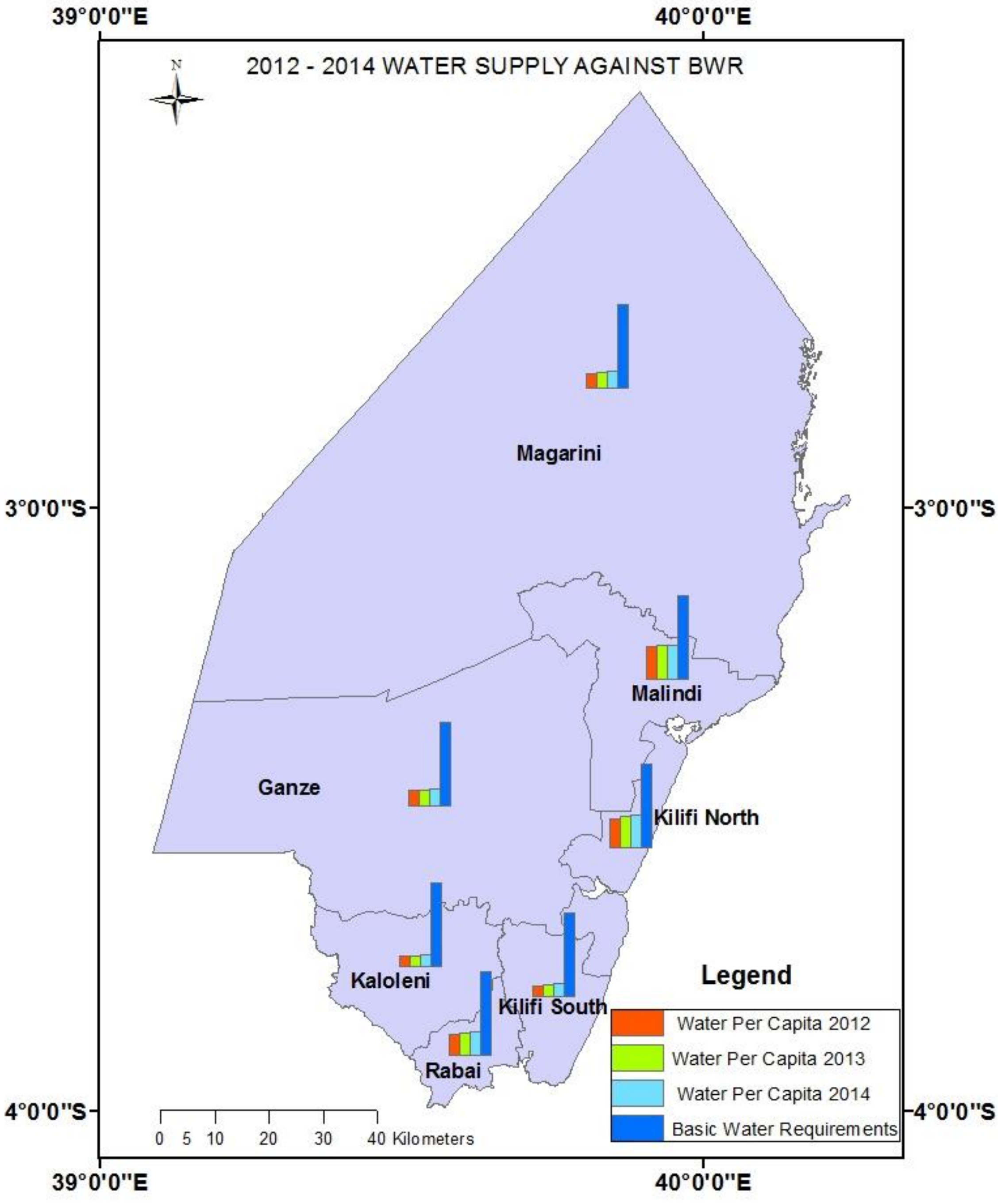

Figure 4.8: 2012 -2014 annual supply against BWR

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The first objective of the study which was to map the actual supply of piped water in Kilifi County during the 2012 to 2014 period was achieved through the generation of choropleth maps. These maps indicate that there is some inequality in the supply of the scarce water resource among the sub counties. Just at a glance, it is obvious that the sub counties of Kilifi North and Malindi get a 'better' supply than the other sub counties with Kaloleni and Kilifi South sub counties being the worst supplied. This inequality is consistent throughout the three year period covered by the collected data with only marginal annual increases in water per capita supply.

The second objective of mapping the adequacy or inadequacy of the supply was achieved through the generation of proportional symbol maps. The maps indicate that the quantities of water supplied by the two service providers are inadequate since they do not meet the basic human water requirements as adopted by WHO in all the seven sub counties. The inadequacy of supply was consistent throughout the three year period covered by the collected data.

It can therefore be concluded that the inhabitants of Kilifi County do not get adequate quantities of piped water as per the requirements of section 43(1) (d) of the constitution. The residents only get at best 40% of their basic water requirements and at worst only 20% of their requirements.

From the accessed annual reports of the water service providers, it is indicated that out of the total annual bulk water supplied by the Coast water services board to the service providers to supply to the consumers, 40% is lost as non-revenue water (NRW) through pipe leakages or pipe bursts and illegal connections.

This study demonstrates how piped water supply mapping using census data and water volumes can be used to identify effectively the most water-poor areas of a given region. Such maps enable water management and distribution authorities to plan for the targeting of water supply since they provide a transparent way of depicting existing water supply scenarios. This assists in the allocation of scarce resources such as finances for the development of necessary infrastructure. By updating these maps at regular intervals, say every five years and also when the census is repeated, they can be used to monitor and evaluate the success or failure of the water management authorities' efforts to address water scarcity in a way that will appeal to the majority of stakeholders.

The maps help to visualise and understanding the geographic inequalities of piped water supply. This in turn goes a long way in tracking progress made towards universal coverage of water supply as well as identifying marginalized populations, thus helping to control a large number of infectious diseases.

5.2 Recommendations

The inequality of water supply among the sub counties as demonstrated by the study should be addressed to ensure fairness and bring all the seven counties at par in terms of water per capita supply. This can be achieved by formulating strategies that target the areas with the lowest supply of piped water. Given that the current water volumes supplied are inadequate to the residents of Kilifi County, it is prudent to shift from the traditional 'supply based management' to a 'demand management' paradigm. Demand management focuses on measures that make better and more efficient use of limited supplies by the application of what the water service providers term as 'water rationing' so as to bring the spatial water per capita supply to almost equal levels.

It is generally recommended that the inadequacy of the water quantities in Kilifi County can be addressed by focussing on increasing overall water productivity by the Coast Water services board. Such increase should at least meet the basic human water requirements as per the constitutional provision irrespective of economic development or poverty levels of geographic areas. As Whittington et. al, (2007) found out in a social survey conducted in rural Ukunda area of Kwale county, the poor are not only able to pay for piped water supply but are also willing to do so. This is despite the easy availability of traditional open channels water sources like dams, boreholes and rivers among such poor communities.

Both water service providers need to develop mechanisms of addressing the 40% of bulk water supply that is lost as non-revenue water through pipe leakages and breakages/bursts as well as addressing the issue of illegal connections. This can be achieved through increased surveillance of their water distribution network.

The maps and the analytical approach presented in this study can be used as a means for monitoring future disparities in piped water supply. Future mapping of water supply can greatly be improved by basing the analysis on smaller geographic units like sub locations rather than sub counties. This is because access to water supply is likely to vary markedly within a large geographic area. To further improve the results of mapping water supply, large water quantity users like manufacturing plants need to be isolated and treated separately. This is because such large consumers may distort the average per capita water usage since the other residents in the same geographic unit may not use such unusual high quantities of water. A future similar study should also incorporate the water pipe supply network to be able to analyse its impact on overall water per capita supply.

At the global and national arena, countries should embrace and facilitate technological changes to achieve greater efficiency in the use of the scarce piped water by the end users. Such technologies like water recycling will in future greatly reduce the current threshold of the basic human water requirements.

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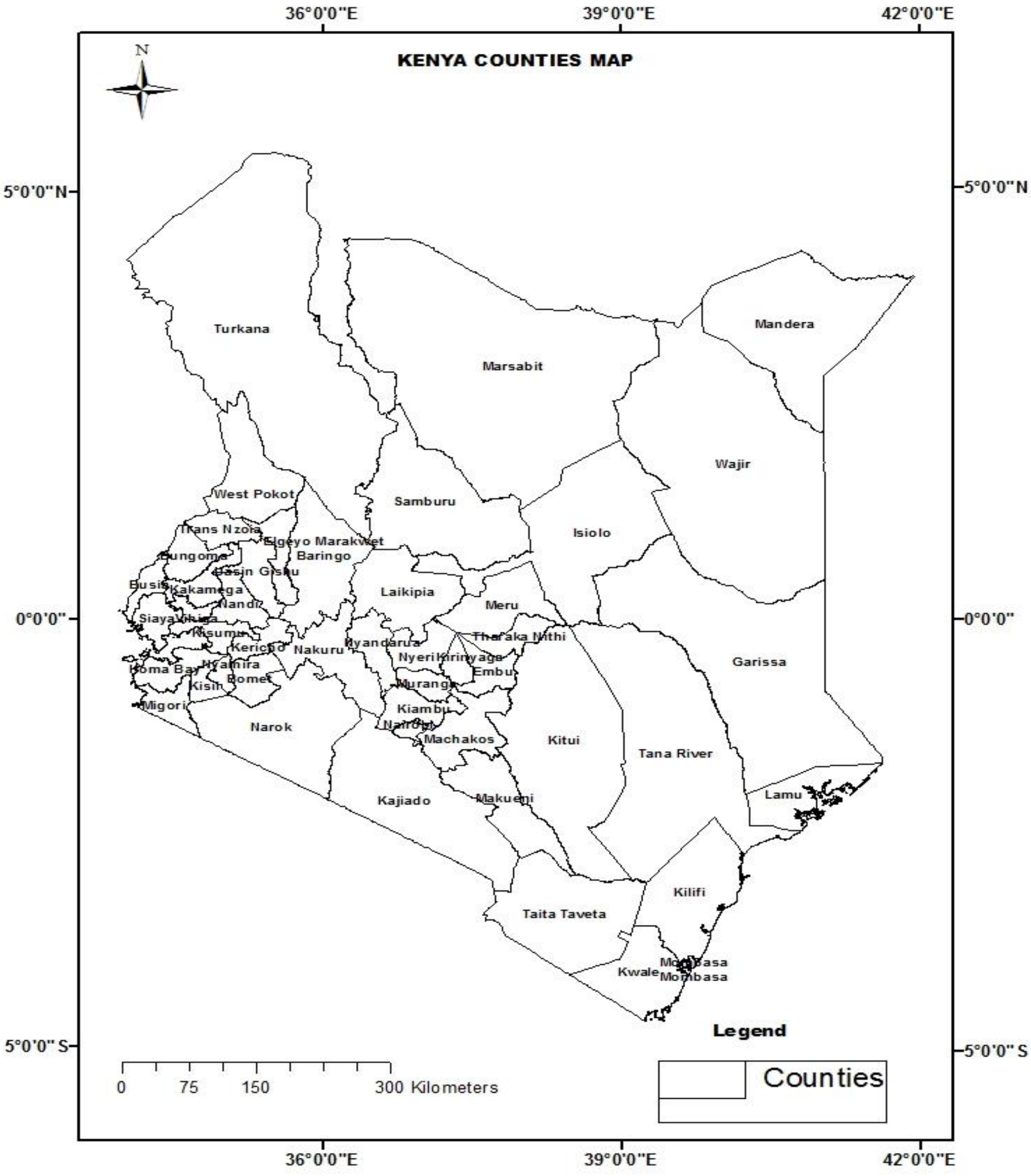
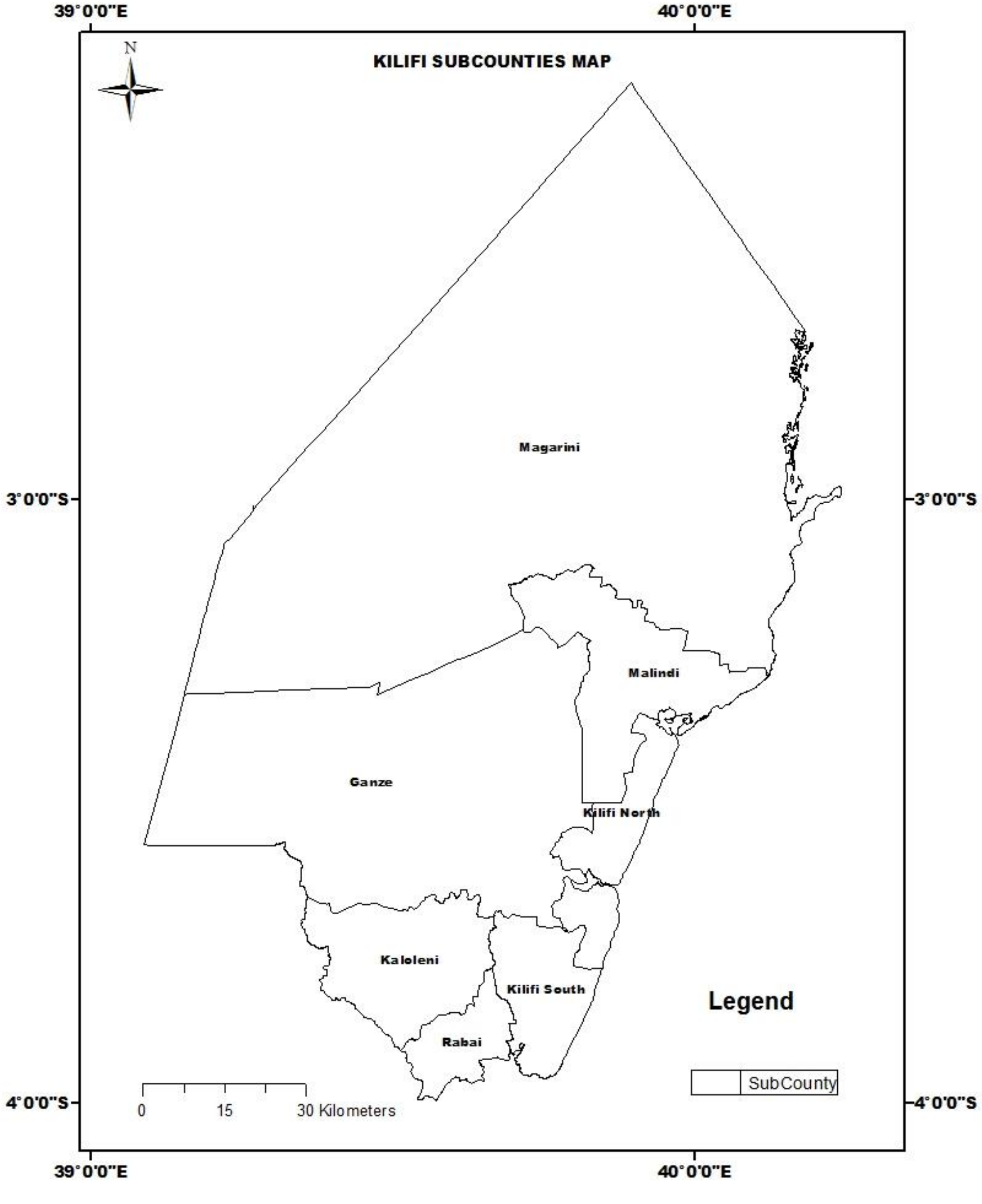
APPENDICES

Appendix A: Kenya Counties Map



Source: Survey of Kenya

Appendix B: Kilifi Sub Counties Boundary Map



Source: IEBC (Kilifi office)

Appendix C: Kilifi County Population Data by Sub County

Sub County	2009 Census	2012 Projection	2013 Projection	2014 Projection
Kilifi North	207587	227818	234095	241234
Kilifi South	171607	188332	193520	199422
Rabai	97185	106656	109595	112937
Kaloleni	155739	170917	175626	180982
Ganze	137664	151081	155243	159978
Magarini	177241	194515	199873	205970
Malindi	162712	178570	183489	189086
Totals	**1109735**	**1217889**	**1251441**	**1289609**

Source: KNBS (Kilifi Office)

Appendix D: Summary of Water Supply Data by KIMAWASCO

Sub County	2012 Water Supply(m^3)	2013 Water Supply(m^3)	2014 SUPPLY(m^3)
Kilifi North	1481370	1621360	1774578
Kilifi South	460870	504423	552091
Rabai	460870	504423	552091
Kaloleni	395032	432362	473221
Ganze	493790	540453	591526

Source: KIMAWASCO (Kilifi Office)

Appendix E: Summary of Water Supply Data by MAWASCO

Sub County	2012 Water Supply(m^3)	2013Water Supply(m^3)	2014 Water Supply(m^3)
Magarini	641899	699558	782686
Malindi	1285704	1357823	1437054

Source: MAWASCO (Malindi Office)