IMPACT OF CLIMATE VARIABILITY ON URBAN WATER SUPPLY AND DISTRIBUTION PLANNING IN CHANCHAGA AND BOSSO LOCAL GOVERNMENT AREAS, NIGER STATE, NIGERIA

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MTech/SPS/2019/11024

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MINNA

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE MASTER DEGREE IN ENVIRONMENTAL MANAGEMENT

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ABSTRACT

This study examined the impact of climate variability on urban water supply and distribution planning in Chanchaga and Bosso Local Government Areas, Niger State, Nigeria. The study used both primary and secondary data sources. The primary data were sourced from the administration of questionnaire to two groups, namely, selected agencies of government directly involved in water supply management and the general public located in the study area. Other primary data include oral interview and field survey. Secondary data sources include water supply, rainfall, temperature and relative humidity which were sourced from Niger State Water Board Minna and Nigerian Meteorological Agency (Abuja). The methods of data analysis include linear trend, multiple regression and descriptive statistics. The result revealed that the distribution of annual rainfall tends to be increasing despite the fluctuation in some years (2004 to 2006, 2013 to 2015). The highest annual rainfall was recorded in the year 2012 with 1520.9mm while the low annual rainfall was recorded in the 2013 with 793.5mm. The result also shows that there is gradual rise in temperature and reaching its peak in the later days of February through March to April. Since this period coincide with dry season, recharge to groundwater reduces which affect water availability and distribution across the study area. The finding shows that the highest water supply was recorded in the month of September with $410M^3$ while the lowest was recorded in the month of May with $240M^3$. The distribution shows that 2006 ranked the highest with $4410M^3$ while the 2007 ranked the least with $3754M^3$. Correlation coefficient of 0.65 for water supply indicates moderate degree of association between maximum temperature and annual water supply. Correlation coefficient of 0.57 for water supply indicates moderate degree of association between relative humidity and annual water supply. This shows that, the higher annual rainfall, the higher the water supply. Conclusively, climate variability greatly influences water supply and distribution in the study area but with variation on yearly bases it is therefore recommended that continues monitoring of the climatic variables and water supply factors be intensified to achieve optimal water availability.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Water is one of the world's most valuable resources. It is a necessity of life for both plants and animals (UN-Water, 2016). The earth is made of 97% saline water, contain in the ocean and 3% freshwater. The freshwater has 68.7% lock up in icebergs and glaciers, 30.1 % is stored in groundwater, 0.3% available as surface water and 0.9% others. Surface water is found as 87% lakes and 11% swamps and 2% rivers (Shiklomanov, 2013). According to UN-Water (2016), globally 70% freshwater sources are used for agriculture, 20% or industrial processes, and only 10% on domestic uses. Water crisis is considered as a foremost global risk based on impact to society as a measure of devastation (World Economic Forum, 2015). However freshwater withdrawals have increased globally by about 1% per year since the 1980s, mainly due to growing demand in developing countries (Gleik, 2010).

Water supply is the provisioning of water by public services, profit-making institutes, and community or by individuals, usually via a system of pumps and pipes; it is the availability of water for the community or region (UN-Water, 2016). Moreover, water provisioning is the source or delivery system of water to society.According to UN DESA (2011), it is projected that populations living in urban areas will almost double, from 3.6 billion in 2011 to 6.3 billion in 2050. Also, it is expected that between 2011 and 2050, the world population is would increase by 33%, that is growing from 7 billion to 9.3 billion people on the earth. This development will result in increasing demand on global freshwater resources. Therefore, beyond the need to meet the world’s growing population drinking water supply, there is the need to ensure that these needs are met sustainably.

Climate variability can be defined as variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events (Luers and Moser, 2016). Climate variability manifests itself mostly through droughts from higher rates of evaporation caused by warmer temperature, floods from extreme rainfall amounts, soil erosion due to intense rainfall, and periodic El Nino and La Nina conditions resultant events (Madu, 2016). Nigeria has experienced climatic variationsand is vulnerable to changes in climate. Contributing factors include both total runoff and rainfall decrease, increasing temperature and a reduction in soil moisture storage. Some observed serious climate variability impacts include dry spells, erratic and late onset of rainfall, drought, and increased frequency of floods, water pollution, water scarcity and soil erosion (Madu, 2016).

The availability of water, demand and its distribution, especially with the advent of climate variability have been of international concern. Globally, studies have demonstrated that people are experiencing water stress, especially in sub-Saharan Africa. The World Bank in 2010 stated that water availability and impacts on society would differ for different areas due to future changes in climate (World Bank, 2010). This correlates with climate change and variability studies on water resourceswith widespread consequences for human societies and ecosystems (Adelalu, 2015).

The challenges associated with climate change are not the same across the country. Nigeria has a tropical climate with two precipitation regimes: low precipitation in the North and high precipitation in parts of the Southwest and Southeast. This can lead to aridity, drought and desertification in the north; and flooding and erosion in the South (Akande*et al.,* 2017; Nkechi*et al.,* 2016). Vulnerability analysis demonstrates that states in the north experience higher degrees of vulnerability to climate change than those in the south(Madu, 2016; Federal Ministry of Environment, 2014).

The Northeast, North central and the Northwest are the most vulnerable. The combination of rising heat and less rain has hastened desert encroachment, with loss of the wetlands, and fast reduction in the amount of surface water, flora and fauna resources on land (Abdulkadir *et al.,* 2017; Akande*et al.,* 2017; Ebele and Emodi, 2016; Federal Ministry of Environment, 2014). Between 1941 and 1970, late onsets of rains occurred in only a few areas of Nigeria. However, from 1971 to 2000, late onset and early cessation of rains had spread to most parts of the country, shortening the length of the rainy season. Only a narrow band in the middle of the country remained with normal conditions (Building Nigeria's Response to Climate Change, 2011). Between 1941 and 2000, annual rainfall decreased by 2-8mm across most of the country, but increased by 2-4mm in a few places (Building Nigeria's Response to Climate Change, 2011).

Human life and socio-economic activities have been subjected to many challenges in the recent time among which climate change/variability is the most important and of great concern. Unfortunately, the rapidly growing population of most cities is the most vulnerable to this climate change. Until recent decades, most water resources projects in Nigeria were planned and designed with the assumption of a stationary climate, whereas climate and hydrology have become both non-stationary stochastic processes. At present, water resources planners in river basins are facing increased uncertainty in evaluating the hydrological condition of the basins under the changing climate. According to the Third IPCC Assessment Report (2015), precipitation will intensify during the 21st century. In some low latitude areas, there will be decreases in total quantities (and drought) and increases (and flooding) in others. In addition, many research projects in Nigeria have confirmed that there is a changing climate in Nigeria. For instance, Udoeka (2018) and Udoeka*et al*. (2018a) in their recent work over the six climatic zones of Nigeria showed that there is a steady rise in evaporation and steady decrease in rainfall throughout the country. Okpara*et al*. (2014) also observed that increased "land-use intensity" due to the rapid rate of urbanization and industrialization was a key factor responsible for the unsustainability of groundwater resources in the country, since it leads to imbalance and social malaise in the society. Also, urbanization does not only ensue in climatic variations, but leads to inadvertent weather modification of a place as well as creating a micro-climate over the region. Gbuyiro&Aisiokuebo (2013) observed an average temperature increase of 0.4°C across the country in the last 20 years.

According to Obasi (2013), projected temperature increases are likely to lead to increased open water and soil/plant evaporation. As a rough estimate, potential evapotranspiration over Africa is projected to increase by 5 to 10% by 2050. Also, with Africa being the continent with the lowest conversion factor for precipitation to runoff (averaging 15%), the dominant impact of global warming has been postulated to cause reduction of soil moisture in the sub-humid zones, as well as reduction in the runoff.

1.2 Statement of the Research Problem

Climate change have both local and global effects on earth surface. One of these effects include decreasing qualities of fresh water and consequently increasing water need (Kusangaya&Aisiokuebo, 2014; Lespinas*et al.,* 2014). Climate change is attributed to human activities, in quest for increasing energy budgets at the global level by modifying land use/land cover (LU/LC) (Lespinas*et al.,* 2014).

The LU/LC Change causes the emission of some aerosols and the concentration of gasses in the atmosphere (Environmental protection agency, 2014), causing imbalance between latent heat flux and sensible heat flux (Lespinas*et al.*, 2014). This prompted several studies on multiple impacts of climate change on the earth environment. For example, its effects are observed in the atmosphere, on land surface in the oceans, on land glaciers and water supply among others.

Several studies have been conducted on the impact of climate variability on water supply and distribution both locally and internationally (Madu, 2016; Okafor *et al.*, 2017; Kelkar *et al.*, 2018; Okeola*et al.*, 2016; Ojo *et al.*, 2013; Ishaku & Majid, 2010). Despite these numerous studies, there is still paucity of knowledge on the impact of climate variability on water supply and distribution in the study area. In attempt to fill this gap, this study examines the impact of climate variability on supply and distribution in Chanchaga and Bosso Local Government Areas, Niger State, Nigeria.

1.3 Aim and Objectives of the Study

The aim of this study is to evaluate the impact of climate variability on water supply and distribution in Chanchaga and Bosso Local Government Areas, Niger State, Nigeria.

The objectives of this study are to:

i. Examine the trend in climate variability between 2000 and 2020 in the study area;
ii. Assess the trend in water supply and distribution in the study area;
iii. Examine the relationshipbetween climatevariability,water supply and distribution in the study area;
iv. Examine population response to water demand and supply of drinking water in the study area; and
v. Evaluate mitigation and adaptation strategies to climate variability impact on water supply and distribution in the study area.

1.4 Research Questions

The research questions for this study will include

i. What is the trend in climate variability between 2000 and 2020 in the study area.

ii. What is the trend in water supply and distribution in the study area.

iii. What is the relationship between climate variability, water supply and distribution in the study area.

iv. What are the population response to water stress vis-à-vis demand and supply of drinking water in the study area.

v. What is the mitigation and adaptation strategies to climate variability impact on water supply and distribution in the study area,

1.5 Justification for the Study

The study could be of significance to policy makers and water resources stakeholders in that the study generated information which could enable themformulate appropriate water resources policies and frameworks that will effectively deal with the impacts of climate variability on future water supply and distribution thus promoting sustainable water supply and distribution in the study area and the entire Niger State.

This study is expected to increase the knowledge and provide up to date information on the relationship between climate variability and water supply/distribution system and its adverse impacts on the urban poor. It will also serve as a working document to policy makers in the water sector and the Non-GovernmentalOrganisations. The study will further serve as benchmark data for any further investigation, as a useful material for academic purposes, and as an added literature to the existing knowledge.

The findings and recommendations of the study shall provide useful information to policy makers and watershed managers so that appropriate developmental programmes and policies can be formulated and implemented for proper utilization and management of the available freshwater resources in a sustainable manner. In addition, the outcome of this study can be used by watershed management experts as a planning and management tool. The results can also be used as supplementary information that may contribute to designing mitigation measures to reduce water supply and distribution challenges in the study area.

1.6 Scope and Limitation of the Study

The scope of this study was to evaluate impact of climate variability on water supply and distribution in Chanchaga and Bosso Local Government Areas, Niger State, Nigeria. The spatial scope coveredBosso and Chanchaga Local Government Areas that are facing more water supply and distribution challenges. The temporal scope of this study was between 2000 and 2020. This study was limited to some selected areas in Chanchaga and Bosso Local Government Areas. Nevertheless, information generated through the study were considered sufficient, important and worthy for this study. Limitation of this study includeslack of published climate and household data.

1.7 The Study Area

1.7.1 Location

The Study area is located between longitude $6^0$31'08'E and 6^0 37.31'E and latitude$9^0$11.11'N and $9^0$60.50'N of the Greenwich Meridian as indicated in Figure 1.2.

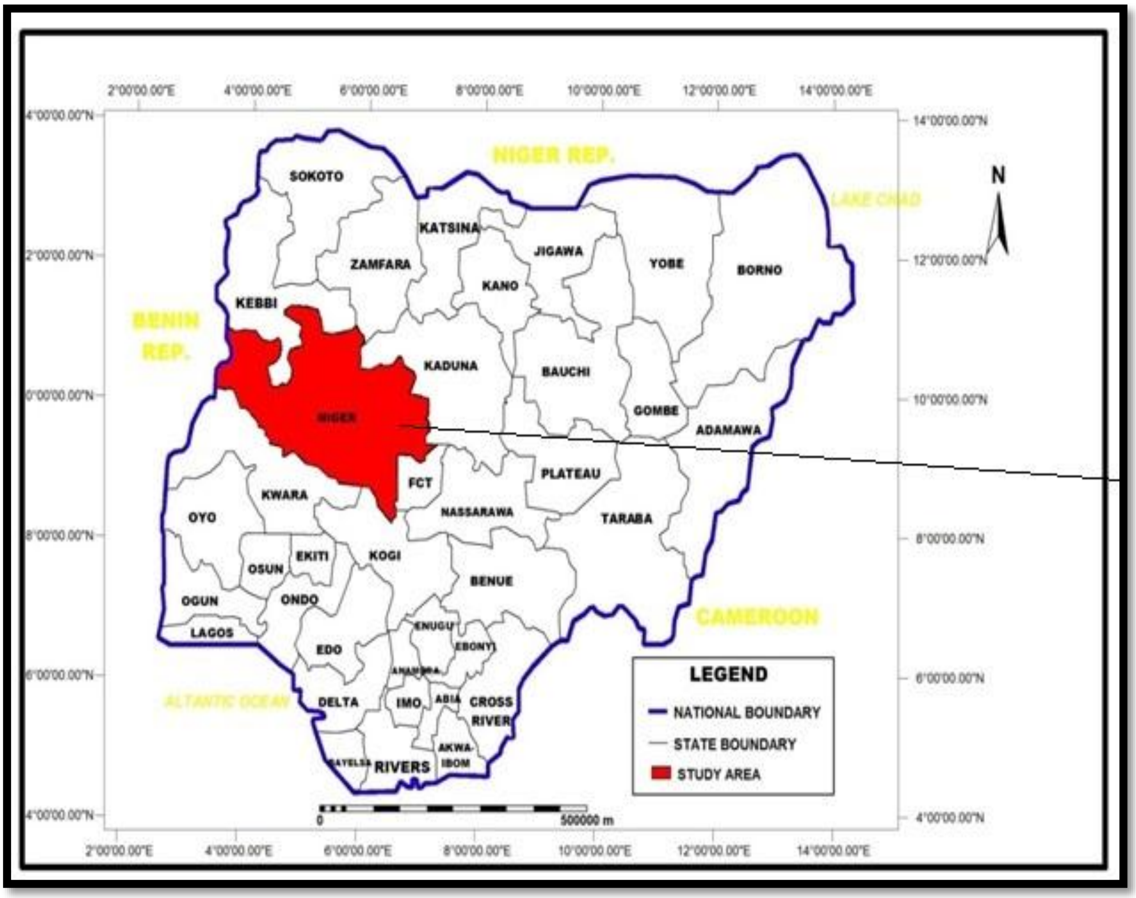

Figure 1.1: The Study Area (map of Nigeria showing Niger state)

Source: Niger State Geographic Information System (2021)

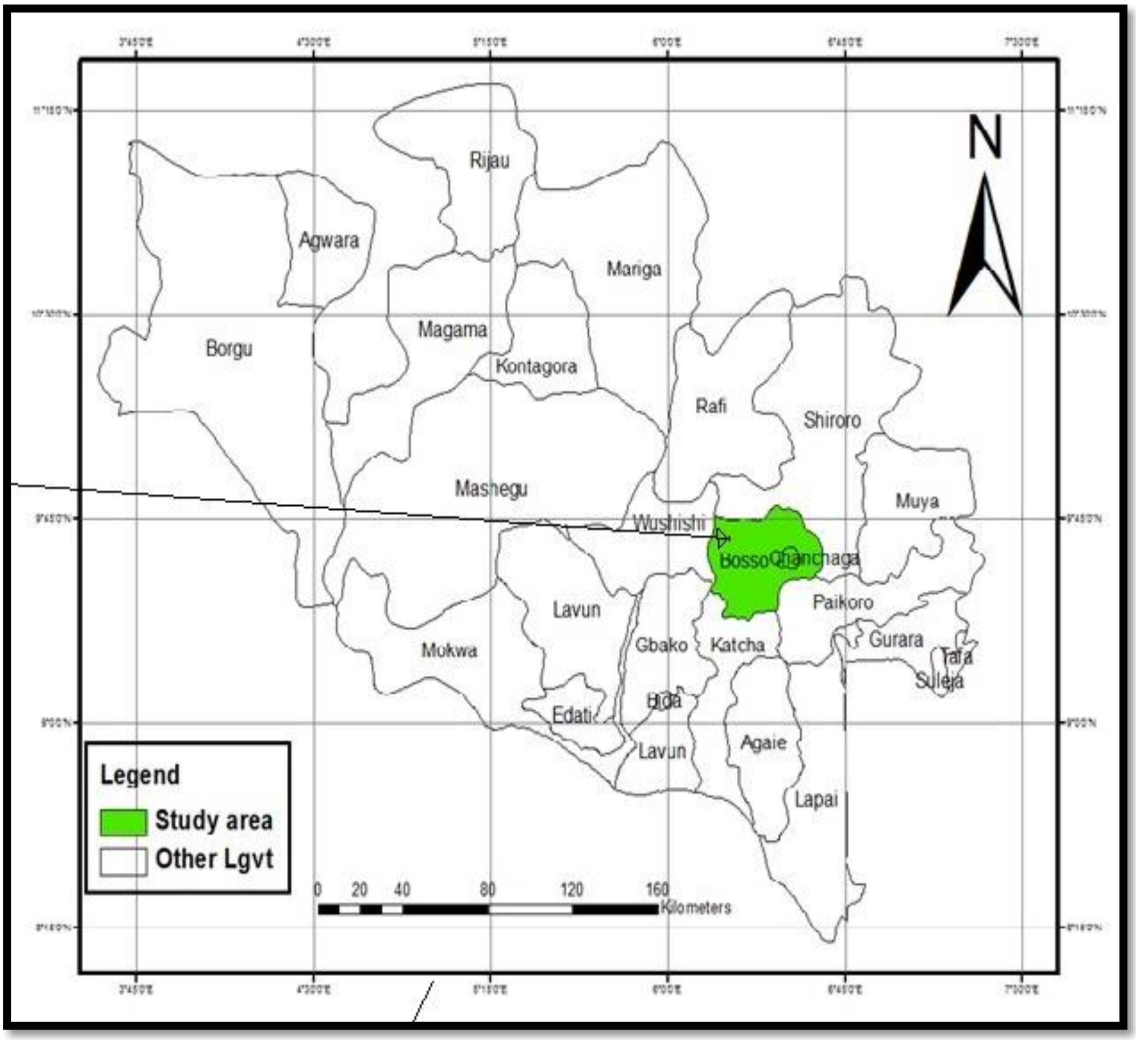

Figure 1.2: The Study Area (map of Niger state showing Bosso and Chanchaga Local Government Areas)

Source: Niger State Geographic Information System (2021)

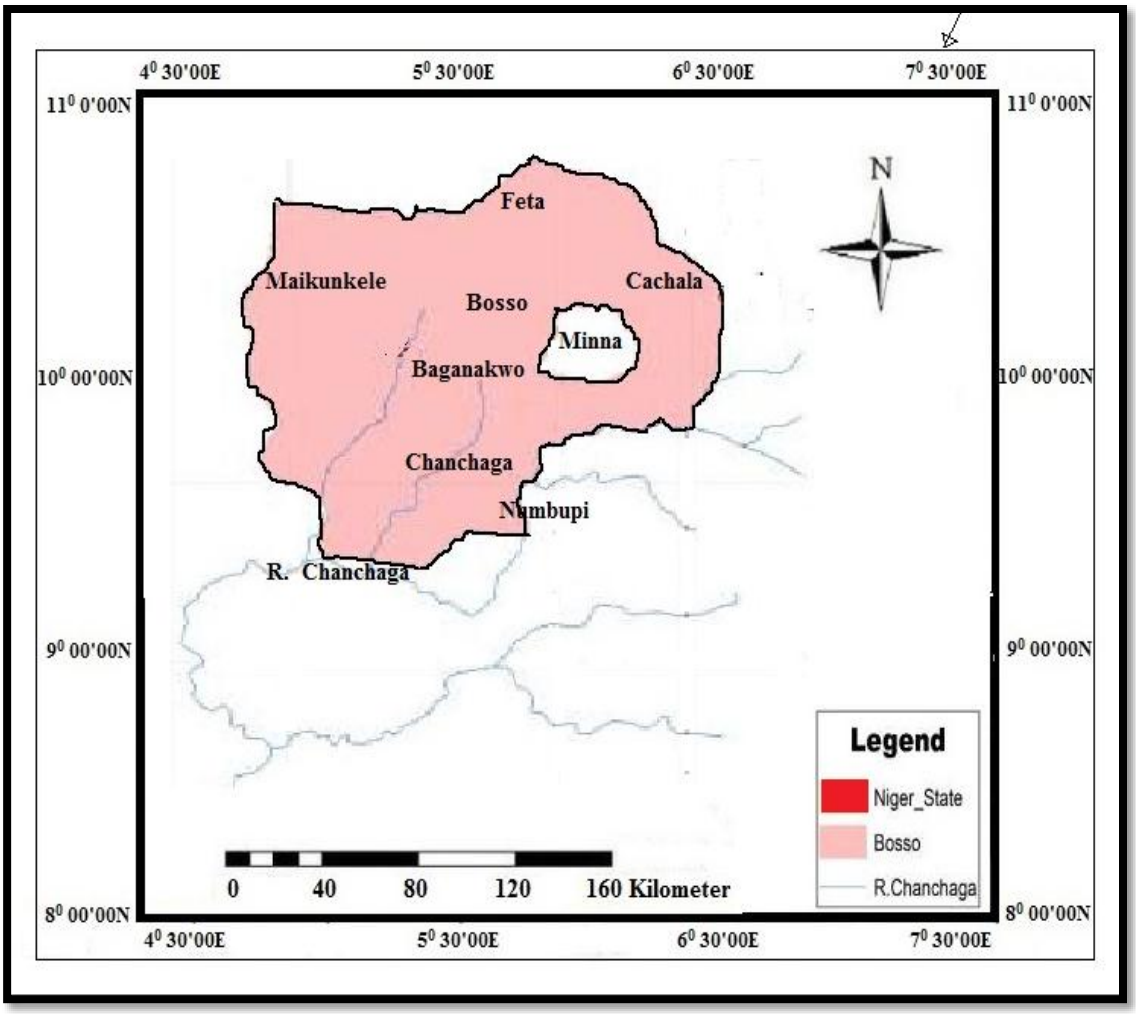

Figure 1.3: The Study Area (Bosso and Chanchaga Local Government Areas)
Source: Niger State Geographic Information System (2021)

1.7.2 Climate

The study area experiences tropical continental type of climate with distinct wet and dry seasons controlled by the shifting position of the inter-tropical convergence zone. The climate of the study area is affected by two main air masses and these are Tropical Maritime air masses and Tropical Continental air masses. The tropical maritime air masses are responsible for rainy season while tropical continental air mass is responsible for dry season. Rainfall occurs in Nigeria along disturbance lines in places overlaid by the warm and humid maritime air mass originating over the Atlantic Ocean in the south. Because of this, the Southern parts of the country receive more rain than the northern parts. Southern coastal areas are permanently overlaid by the humid air mass. Early in the year, between the months of April and May, the air mass begins to move into interior locations and more parts of the country fall into an expanding rainfall belt. By the middle of September, the air mass begins a rapid recession back to its coastal, most southerly positions, thus while coastal locations are perennially humid and receive substantial rainfall throughout the year interior locations experience various lengths of rainless season. The length of the rainy season therefore decreases with distance from the coast line.

Over most of the north-central portion of the country, rainfall starts in April and ends in October with the length of rainy season varying between 160 days to 200 days annually. Agro climatically, the growing period varies from 200 days to 260 days. The mean annual rainfall ranges from between 1100mm to 1500mm in July and August each year. The dry season, which lasts from November to March each year, is very dusty and cold as a result of the northeasterly winds, which bring in the harmattan.

The rainy season begins from April and ends in October, when daytime temperatures reach 28°C (82.4 °F) to 30°C (86.0 °F) and nighttime lows hover around 22°C (71.6 °F) to 23°C (73.4 °F). In the dry season, daytime temperatures can soar as high as 40°C (104.0 °F) and nighttime temperatures can dip to 12°C (53.6 °F). Even the chilliest nights can be followed by daytime temperatures well above 30°C (86.0 °F). The high altitudes and undulating terrain of the study area act as a moderating influence on the weather of the study area (Ogunjumo, 2010).

1.7.3 Vegetation

The vegetation of the study area can generally be described as typical Guinea Savanna with a mixture of trees, shrubs, herbs and tall grasses. The study area falls within the Guinea Savanna zone vegetation of the West Africa sub-region but patches of rain forest, however, occur in the plains that form one of surviving North-most occurrences of the natural forest vegetation in Nigeria. The vegetation of the study area is divided into three savanna type; park or grassy type occupies about 53 percent of the total area. This vegetation type is found in savanna wood land that occur mostly the rugged and less accessible parts on the Robo and Rubochi plains. Sudan savanna type covers 12.8 percent of the north-central region and it's characterized by abundant short grasses of 1.5m to 2m and few stunted trees with height hardly above 15m. While the shrub savanna type occurs extensively in rough terrain close to hills/ridges in all parts of the study area and covers about 12.9 percent of the land area. The trees are green in the rainy season with fresh leaves and tall grasses, but the study area is open during the dry season, showing charred trees and the remains of burnt grasses. The trees which grow in clusters are up to six metres tall, interspersed with grasses which grow up to about three metres and these trees include locust beans, Shea butter, African mahogany, African teak, Iron wood and isoberlinia trees. The different types of vegetation are, however, not in their natural luxuriant state owing to the careless human use of the forest and the resultant derived deciduous and savanna vegetation (Areola, 2014).

1.7.4 Soil

The characteristics of the soil in the study area show that they all have pale colour and the textural character of the soil takes common pattern of loamy sand top soil and sand clay B horizon. The alluvial soils along the valleys of the rivers are sandy, while the adjoining laterite soils are deeply weathered and grey or reddish in colour, sticky and permeable. The soils are generally characterized by a sandy surface horizon overlying a weakly structured clay accumulation. Due to the nature of the soils, they are either loose or they have weak structures. These soils are very vulnerable to erosion due to their nature and farming is usually affected by this phenomenon (Balogun, 2011). Schist, including biotite/muscoriote schist, muscorite and tale schist's with quartzite intrusive account for most of the rugged landscape in the southern parts of the study area. The plains have the most fertile soils and the best agricultural lands of all plains of study area while the high sand content of most soils within study area accounts for the relatively high erosion status. There is however, one major advantage about the type of rocks and soils found in study area because of the ability of construction materials in the form of building stones quartz and pistol tic gravel, building sands and earth for use as foundation materials. The surface soil in some parts of the study area is generally loamy. The soil is well drained and has high water infiltration rate and they are strong brown to red sandy clay with often loamy sand surface layers (Balogun, 2011). The flood plains of the Niger and Benue river valleys have the hydromorphic soils which contain a mixture of coarse alluvial and colluvial deposits. The alluvial soils along the valleys of the rivers are sandy, while the adjoining laterite soils are deeply weathered and grey or reddish in colour, sticky and permeable.

The soil type is suitable for the cultivation of mainly cereal crops like: sorghum, millet, groundnuts, etc. A few black soil types found at the southern part of the town and along the river valleys favour the growth of crops like: maize, yam, potatoes, rice, beans, and vegetables like okra, pepper, onions, etc. (Niger State Agricultural Development Project, 2019).

1.7.5 Geomorphology and geology

The geology of the study area has two main rock types, namely, basement complex rocks of the Precambrian age in the western half of the study area and extending slightly eastwards beyond the lower Niger valley. This is the single most extensive geological formation in Africa and it's on this formation that the whole continent is build upon. Basement complex rocks are very old crystalline rocks which form the Africa landmass which the study area is inclusive. The second formation is the sedimentary rocks in the eastern half. The various sedimentary rock groups extend along the banks of River Niger and Benue and southwards through Enugu and Anambra States, to join the Udi plateau. The rock lies in the valley of Niger, Benue, Cross River, Gongola Rivers and new formation in the Northeast of the Chad basin and extreme Northwest of the country. The basement complex rocks have an elevation which range between 273m to 333m in the west and 200m to 364m in the East. The landscape of the region (study area) is relatively flat; this means it is located on a plain. The igneous rocks are made up of biotite granite, rhyolite, and syenite. The granite accounts for most of the rock domes and massive hills in the north-eastern and north-western parts of the study area. The magnetite's and gneiss complex, which are metamorphic rocks consisting mostly of magnetite's, granite, gneiss and biota granite underline the site of the area. These are rocks of medium to high strength which were not expected to present serious engineering problems and the rocks of the study area are generally quartz rich, acidic types which account for the generally sandy nature of the soil especially on the Robo and Rubochi Plains. The study area has proven deposits of a wide range of mineral resources including marble, gold, columbite, tin, mica, clay, wolfromite, tantalite and talc (Areola, 2014).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Clean and safe drinking water

Water is the source of life, the most precious and important of all natural resources, without which the human species cannot survive (Rowan, 2015). Access to safe water is a human right. Access to water should be framed as a human right for at least three reasons. First, ensuring access to clean water could substantially reduce the global burden of disease. Millions of people are affected each year by a range of water-borne disease. Second, the privatization of water, which exploits the view that water is a commodity rather than a public good, does not result in equitable access. Third, the world is changing in ways that will both exacerbate water scarcity and threaten the quality of the current water supply. The human right to water entitles everyone to sufficient, safe, physically accessible and affordable water for personal and domestic uses (Rowan, 2015).

Clean and safe drinking water is vital for human health and can reduce the burden of common illnesses, such as diarrheal disease, especially in young children. Unfortunately, in 2010, it was estimated that 1.8 billion people globally drank water that was not safe. This scenario is most common in developing countries, and the problem is exacerbated in rural areas (Henry, 2017). Significant amounts of time are spent by adults and school children upon water abstraction from various sources. It is estimated that, in developing countries, women (64%) and girls (8%) spend billions of hours a year collecting water. The erratic supply of safe drinking and domestic water often affects good hygiene practices. In most developing countries of the world, inadequate supplies of drinking water can contribute to the underage death of children in the region (Henry, 2017).

Storage of collected water from rivers, springs, community stand-pipes, and boreholes is a common practice in communities that lack potable water supplies piped into their homes. Even when water is piped into the home, it is often not available on a continuous basis, and water storage is still necessary. Water is stored in various containers which include jerry cans, buckets, drums, basins and local pots. It has been reported that when collection of water from sources of high quality is possible, contamination during transport, handling and storage and poor hygienic practices often results and can cause poor health outcomes (Dayo, 2020).

Access to water" was broadly defined as the availability of at least 20 litres per person per day from a source within one kilometre of the user's dwelling. Types of source that did not give reasonable and ready access to water for domestic hygiene purposes, such as tanker trucks and bottled water, were not included (bottled water was not considered "improved" because of concerns about the quantity of supplied water, not the water's quality). While "Improved sanitation facilities" was defined as including connection to a sewer or septic tank system, pour-flush latrine, simple (or double) pit or ventilated, improved pit latrine, again allowing for acceptable local technologies. The excreta disposal system was considered adequate if it was private or shared (but not public) and if it hygienically separated human excreta from human contact (World Health Organization, 2010). According to the USAID, planning access to improved water and sanitation is a daily challenge for most Nigerians. The problem is particularly acute in the rural Northern Nigeria, where only about 30% of the population has access to safe drinking water and adequate sanitation. This situation leads to a high prevalence of waterborne diseases, threatens the livelihoods of smallholder farmers, and contributes to low levels of school enrolment, especially among girls.

2.1.2 Water shortage/scarcity

There are various degrees of water shortage/scarcity and these could be absolute, life threatening, seasonal, temporary, and cyclical. Water shortage is a situation of absolute shortfall between available water and defined minimum requirements (Bhatia, 2009; Okoye, 2015). On the other hand water security is a condition where peoplehave reliable and adequate access to good quality water to meet the full range of their needs and are able to take advantage of the opportunities that water resources present. They are protected from water related hazards and have fair recourse where conflicts over water arise. From a regional planning perspective, water shortage is often explained in terms of urban morphology.

United Nation Habitat (2013) stressed that water is one of the ecological footprint of a city. Its production, distribution and management often affect and are affected by the settlement forms and structures, which are manifested in the illegality and informality of urban neighborhoods. Urban locations which are densely populated and inaccessible are definitely without water service networks and are mostly inhabited by the poor. This makes the urban slum dwellers to be mostly affected by water shortage. The importance of water and its effective management cannot be overemphasized. Inadequate water supply and poor water quality give rise to health and other societal issues, limit agricultural productivity and economic prosperity, and pose national security risk. In order to effectively harness and manage water, there is need to adopt sustainable measures and one of these measures is cost recovery (Adah and Abok, 2013). Treating water as an economic good enhances financial viability, by ensuring that tariffs cover the costs of investments and operation and maintenance.

FRN (2010) observed that Universal and sustainable provision of water supply services is possible only if water is recognized as an economic good, subject to the relation of supply and demand. Thus, people's demand for water is a function of the price of water. Their willingness to pay for water is influenced by the level of service they desire and the quality of the service they receive. The management of water and other natural resources is too often subject to poor governance, which contributes to insufficient and polluted water and threatens the health and livelihood of millions of people. These problems are particularly acute in poorer countries, in which people are mostly dependent on their national resource base. Water management is highly complex and extremely political. Therefore, balancing competing interests over water allocation and managing water scarcity requires strong institutional approach (Adah and Abok, 2013).

2.2 Challenges of the Provision of Water Supply in Nigeria

Furthermore, the United Nations and World Health Organization posit that the minimum required amount of water per person per day is fifty to hundred (50-100L) litres. Adah and Abok, (2013)contended that this requirement must be defined in clear terms since the basic need for potable water includes water used for personal hygiene that is often determined by availability and accessibility. The WHO adopts specific metrics to estimate water needs based on specific needs that are supposed to be met, such matrices include; the basic access that allows for hand washing, consumption and basic hygiene, but does not promise water for bathing and laundry. These limitations have significant impacts on the health of humans. Also, the transitional access allows individuals to access up to 50 litres of water daily at less than 100metres or 5minutes from the source to destination. This access could cater for laundry and bathing as well as basic access requirements for water. In this scenario, the impact on health is minimal as optimal access indicates the consumption of 100litres per person per day on average which is supplied continuously through multiple taps that meet all hygiene and consumption for persons who provide water for themselves and own boreholes (Adah and Abok, 2013).

Researchers have identified some of the challenges and concerns relating to water supply and provision as socio-institutional.Respondents of this survey were drawn from utility workers, drinking water facilities consultants, water/wastewater facilities, manufactures and government regulatory agencies. Other studies also revealed that there is an institutional inertia clogging the pace of change in the water sector with very limited understanding on how to resolve such challenges.Most of the water companies are losing money on their services to the public and this has made the public to take water service for granted (UN Habitat, 2013). The high cost of infrastructure maintenance of water utilities thus making companies operate in a deficit. Climate change-related consequences have also contributed to water scarcity and drought in many places and require utility companies and managers alike to be proactive, not reactive as existing in most developing countries.

Other challenges include the proper replacement of retiring and an ageing workforce in the utility companies, the status of wastewater and drinking water infrastructure, water supply and scarcity, lack of appreciation of water value. Inadequate funding for water infrastructure improvement projects and facilities; customer and community relations to communicate the challenges of water stewardship and develop for public support; poor emergency planning and response regarding water infrastructure, operational cost and energy usage of utility facilities and intentional contamination of water and inconsistent government policies and regulations (Oni and Ogunkule, 2013).

In the early 20th century public water supply schemes started gradually in some strategic urban towns in Nigeria such as Kano, Lagos, Abeokuta, Calabar and Enugu with minimal administrative challenges. These schemes were sustained with the income from water sales as the government did not provide any subventions until the regionalization of Nigeria which witnessed a slow response to the management of water supply in these urban towns. As population surged in the cities, the water demand spiked as well but with a limited corresponding increase in capacity to satisfy the demand. This led to a myriad of impediments to water supply in Nigeria ranging from poor management of water supply facilities, inadequate financing and use of funds, inadequate data regarding the operation and maintenance, flawed system design, inadequate policies, overlapping responsibilities and legal frameworks, undue political interference. Other factors include the absence of distinct institutional objectives and outright corruption leading to the incapacitation of water supply agencies in Nigeria (Oni and Ogunkule, 2013).

In the Nigerian context, UNICEF/WHO Joint Monitoring Programme (JMP) 2010 reported that Nigeria is unlikely to achieve the Millennium Development Goal (MDG) targets of access to water supply unless it takes drastic steps to improve current performance levels. Since the machinery to reform the sector has been agreed upon at the federal level, it is expected to be rolled out in all the states of Nigeria. These include sector policies and strategies, a review of legislation to conform with intentions regarding the roles of government and the private sector, and separation of policy formulation and regulation from service delivery. It was estimated that financial investment to meet MDG water requirement targets as of 2015 was US$1.7 billion which is about NGN6.12 trillion for the entire nation and NGN17 billion for each state annually. Most states in Nigeria may not want to invest this huge amount on water, hence, residents and government alike resort to private sources of water supply.

Ele (2013)highlighted some of the challenges of potable water supply in Nigeria since 1999 and its consequences on economic development. They include surges in industrial and urban pollution, infrastructure decay, inadequate power supply, under-funding and demographic changes as some of the factors militating against the provision of potable water in Nigeria. Similarly, the Federal Ministry of Water Resources in a Draft National Water Policy identified poor community and other stakeholders' participation, poor management of the infrastructure as part of the challenges.

2.3 Review of Related Literature

Kevin and Nicholas (2012) assessed the impact of climate change on water resources in Africa. Climate change is having a multitude of immediate and long-term impacts on water resources in African countries. These include flooding, drought, sea-level rise in estuaries, drying up of rivers, poor water quality in surface and groundwater systems, precipitation and water vapour pattern distortions, and snow and land ice mal-distribution. These effects when compounded together have devastating impacts on ecosystems and communities, ranging from economic and social impacts to health and food insecurity, all of which threaten the continued existence of many regions in

Africa. Vulnerability varies according to individual countries, geographical positioning and the capacity to mitigate or adapt to the changes. Coping, adapting and building the resilience capacities of African countries towards the impacts of climate change on water resources requires a holistic approach involving systems thinking and risk management strategies. Solutions pivot on taking urgent action to utilize science technology and innovation, policies relevant to water audit and management, and engagement of private, civil and international sectors if a major crisis is to be averted.

Joshua *et al.* (2017) challenges to sustainable safe drinking water: A case study of water quality and use across seasons in rural communities in Limpopo province, South Africa. Surveys were conducted in 405 households in rural communities of Limpopo province to determine their water-use practices, perceptions of water quality, and household water-treatment methods. Drinking water samples were tested from households for microbiological contamination. Water from potential natural sources were tested for physicochemical and microbiological quality in the dry and wet seasons. Most households had their primary water source piped into their yard or used an intermittent public tap. Approximately one third of caregivers perceived that they could get sick from drinking water. All natural water sources tested positive for fecal contamination at some point during each season. The treated municipal supply never tested positive for fecal contamination; however, the treated system does not reach all residents in the valley; furthermore, frequent shutdowns of the treatment systems and intermittent distribution make the treated water unreliable. The increased water quantity in the wet season correlates with increased treated water from municipal taps and a decrease in the average contaminant levels in household water.

Henry (2017) worked on assessing the challenges of water supply in urban Ghana: The case of North Teshie. A survey of 100 households from the study area, coupled with information from officials from the Ghana Water Company Limited, Ghana Statistical Service, Public Utility Regulation Commission, have revealed that illegal connections and continuous unplanned developments have resulted in scarcity of water in the study area. The study further indicated that the Government of Ghana, acting on the recommendations of the WB/IMF's SAP policies, has ignored the opposition of the civil society and officially privatized the urban water supply in 2005, with a key objective of getting the low-income consumers to have access to constant flow of the water at affordable prices. Protracted water crisis in the study area was found to have led to very high prices of water from the local vendors; putting more socioeconomic burden on women. Between 1995 and 2005, water supply through the joint efforts of the GWCL and Government has increased from 8 litres per person in 1995 to 27 litres in 2005. The increase is expected to continue beyond the 2005 figure, if GWCL is given the needed technical, financial and logistic support. On account of the vital role of water to socio-economic life of humans, the author recommended an overall involvement of the private sector; the public sector; women; the local inhabitants and the donor institutions to play their supportive roles in the improvement of the provision of water to the urban dwellers in Ghana.

Rowan (2015) studied an assessment of the water and sanitation problems in New Forest, Bushbuckridge Local Municipality, South Africa. The purpose of the study was to assess the problems facing the world, South Africa and in particular New Forest in the provision of water and sanitation. New Forest is a small village found in Mpumalanga province. The issue of improving water and sanitation began over centuries ago, but still there are countless factors hindering water and sanitation services. The study has progressed through various phases. The first phase of the case study included sampling of the household in New Forest. The second phase included the use questionnaires, literature review, site observation and telephone interview as a data collection tools. In parallel with the literature survey, collection of basic background data was obtained from journals, water reports and approved thesis from internet, for site observation collection of data was done by taking photos and for telephone interviews data was collected through notes writing. The study used the combination of qualitative and quantitative approach. The third phase included combining the findings of several studies and this data was critically analysed using, notes writing, tables and graphs.

Through the distribution of questionnaires to members of the village it was confirmed that there was water and sanitation problem. For most people the desire was to have access to water and sanitation. The community's access to water and sanitation is severely limited due to their socio-economic status, mostly poverty. The villager's access to water and sanitation is caused by lack of employment. Lack of unemployment forces people migrate to urban to look for better opportunities. Most rural people are poor and are highly affected by privatisation. Lack of participation is another socio-economic factor that deprives people from receiving water and sanitation services, people in this village are poorly informed on almost aspect of water and sanitation problems. Water and sanitation coverage is poor in this village due to infrastructure failure. People use indigenous knowledge to survive water and sanitation problem. People in New Forest dig traditional hand dug wells to survive water problems and some access water from the community river. The community borehole also supply water to the villagers, but when water is not available people hire cars to collect water for them in areas where water is available. People in New

Forest use pit latrine for sanitation. Pit latrines are considered as part of improved sanitation options. These facilities are cheap, easy to operate and no maintenance is required. Majority of the villagers do not own flushing toilets because of water shortage and some villagers do not have toilets at all; they share toilets with their neighbours. In conclusion the assessment of water and sanitation problem led to recommendations of mitigating these problems in the village of New Forest (Rowan, 2015).

Nelisiwe (2018) studied challenges in water provision in Mbulwane area of uMvoti Municipality. Clean water provision is a challenge around the world. The aim of this study was to explore the challenges to water provision in Mbulwane area of uMvoti Municipality. The study sought to explore water provision, challenges and possible solutions in Mbulwane area. The study used the Social Justice and Human Right Theory as an anchor. The study employed the qualitative research approach by interviewing key informants and community members as well as examining documents related to water provision. The findings of the study revealed that that in Mbulwane there water is scarce and is of poor quality. This is due to poor governance and corruption. The study recommended community empowerment; improved distribution of infrastructure, concrete government approaches public participation as well as environmental change mitigating factors.

Batsirai (2015) studied unreliable water supplies and household coping strategies in peri-urban South Africa. Many developing countries face severe challenges with the reliability of water supplies. These supplies are often characterized by intermittence, low pressure and poor water quality. Despite its contribution towards water-related illness and the significant coping burden it imposes on households, water supply reliability remains a difficult attribute to measure. A key challenge is the lack of a universal definition of water supply reliability. The issue of unreliability in water supply and the financial cost it imposes on households is of profound relevance in South Africa – a country whose social policies include a Free Basic Water policy which entitles all households to a free lifeline supply of 6,000 litres per month. This thesis examines household experiences of unreliable water supplies and in particular, explores the question as to what constitutes a reliable water supply, and household responses to unreliable water supplies.

The analysis draws on literature reviews and a household survey conducted in peri-urban communities in the Limpopo Province of South Africa in 2012. A systematic review of definitions and assessment criteria used in studies of water supply reliability demonstrates that there is no consensus on what constitutes a reliable water supply. Assessment criteria also vary greatly, with the most common criterion in urban settings being the duration and/or continuity of supply in hours per day. In rural settings, the proportion of functional water systems is commonly assessed. A discrete choice experiment was conducted to elicit households' preferences for a reliable water supply. Results indicate that overall, households value notification of interruptions and having water available for longer durations during the day, and would be willing to pay for these improvements. However, there is some heterogeneity in these preferences as wealthier households, who have drilled their own wells and are no longer dependant on the public supply are less willing to pay for improvements in the water supply. The findings from the study highlight the need for consensus on the definition, and assessment approach for water supply reliability. Further, the analysis of households' responses to unreliable water supplies in South Africa draws attention to how poor reliability negates the Free Basic Water policy. Without reliable water supply services, the objectives of improving public health and promoting equity cannot be met (Batsirai, 2015).

Kevin (2015) assessed water supply management policy in Nigeria: Challenges in the wetland area of Niger Delta. The Niger Delta wetland is currently facing serious challenges of sustainable water supply management. Despite the availability of water, the region has been struggling with acute potable water shortage due to ineffective water supply management culture. To combat water shortage various governments within the region have set up water corporations to manage this important resource. The study examined the widening gap between water need and supply in the wetland despite continuous efforts made to develop the regions' vast surface and groundwater resources. The study employed the review of literature on water supply management policy documents and other works so as to understand the challenges of water supply management in the wetland. The study revealed that the challenges facing sustainable water supply management in the Niger delta wetland include lack of effective compliance to policies, fragmented responsibility, poor state of infrastructure, corruption, and low rate of costs recovery. In order to ameliorate these challenges, the researcher recommends the need to comply with water management policies that aim at economic efficiency, encourage stakeholder participation, and enforce existing laws and regulatory responsibilities.

Kankara and Farouk (2018) studied portable water distribution problems in Kano municipal, Nigeria: Implications for urban agriculture. The aim of this research work was to evaluate and assess the main sources of water and the various factors that affect potable water distribution problems in Kano municipal. The methodology adopted here is primary method and secondary method where the data collected from the 384 questionnaires distributed to six (6) selected sampled areas, namely: Zango, Sheshe, Yakasai, Shahuchi, Zaitawa and Gandu. Institutions that relate to water supply in Kano state were also summoned and investigated. The collected data were analyzed by statistical techniques and presented in the study. The study showed that 90.36% of the population in the sample area have the availability of water during the wet season, 6.77% of the population have the availability of water during the dry season and only 2.86% of the sample population have the availability of water All year round. That is means the highest number of the sample population have the availability of water only during the wet season. Also, the research concluded that the water supply in Kano municipal do not meet the demand due to some problems such as insufficient number of water treatment plant, power failure and shortage of fund and so on. Finally, the research suggests solution to the identified shortcoming in water supply in the study Area.

Sridhar, Okareh and Mustapha (2020) worked on the assessment of knowledge, attitudes, and practices on water, sanitation, and hygiene in some selected LGAs in Kaduna State, Northwestern Nigeria. Access to safe water, sanitation, and hygiene (WASH) facilities is a basic necessity for human livelihood, survival, and well-being.
Adequate WASH facilities provision is a critical issue to most developing countries around the world including Nigeria. Knowledge, attitudes, and practices regarding WASH are integral to effective and sustainable WASH facilities provision. The study assessed the level of knowledge, behavior, and practices towards water, sanitation, and hygiene in Kaduna State, Nigeria, with a view to ensuring sustainable WASH facilities intervention in the region. Data collection tools included spot check observation and questionnaire involving 854 participants, selected from five local government areas (LGAs): Chikun, Kajuru, Soba, Kachia, and Zango-Kataf. From the

results, major drinking water sources were surface waters (52.5%) and unprotected hand dug wells (44.8%); only 46.2% treated their water supply and few (16.6%) used chlorination method. Pit latrine toilets were the major (76.5%) excreta disposal means, and open defecation practices were widespread (41.4%). Level of personal and environmental hygiene understanding was fairly good in all the local government areas, and 65.4% claimed to use water and soap for washing hands after defecation. Incidence of water related diseases is generally low in the area. Despite the commendable findings in the study areas, communities are still at risk due to lack of safe water supply and poor practices of home treatment and excreta disposal. Therefore, provision of WASH facilities and WASH education is fundamental for ensuring public health in the study area.

Ben *et al.* (2021) worked on the assessment of water resources development and exploitation in Nigeria: A review of integrated water resources management approach. The research aimed to review the current state and limitations of water resources management in Nigeria and explore how adopting an integrated approach to water management can strengthen socio-economic development. As the support for integrated water resources management (IWRM) grows, it is necessary to explore how feasible it is in the Nigerian context especially with many Nigerian states facing water stress even with the country's substantial resources. The study reviewed literature related to the implementation of IWRM around the world with particular reference to developing countries in Africa and draws parallels between their experience and the possibilities that exist for IWRM in Nigeria. Progress on adopting IWRM in Nigeria is discussed and the pitfalls to implementing IWRM in practice are identified. Among the hindrances to effective water resources management in the country is the lack of good water governance, which has affected the quality of water legislation and institutions. The study concludes that the slow progress of IWRM implementation in Nigeria is the result of an unclear framework for implementing IWRM in the country. This paper recommends an iterative approach to implementing IWRM that allows for adaptation and is tailored to solve specific water problems in Nigeria.

Shadrach and Osazee (2020) assessed the quality and effect of borehole water proliferation in Benin City, Nigeria and its public health significance. Water is life, essential for human existence, and its importance for individual health as well as the well-being of a nation and access to good quality water cannot be overemphasized. Water makes up about 70% of the earth's surface and about 97% of this volume of earth's surface water is contained in the oceans, only about 0.3-0.8% makes up underground water. Ground water is the water beneath the surface where all the voids in the rocks and soil are filled. It is a source of water for wells, boreholes and springs. A borehole is a hydraulic structure which when properly designed and constructed, permits the economic withdrawal of water from an aquifer. It is a narrow well drilled with machine. Due to the poor investments of the Nigerian government in water supply, many have resulted in construction of boreholes as an alternative source of portable water. Benin City is located in Edo State, southern Nigeria with a growing population. There is a high degree of borehole proliferation as housing development projects are on the increase. There is hardly any residential house, office or business building that does not have a constructed borehole in Benin City. As the population of Benin City continues to rise, human activities including soil fertility remediation, indiscriminate refuse and waste disposal, and the use of septic tanks, soak-away pits and pit latrines are on the increase. These activities are capable of producing leachates into the groundwater formation that serve as source of water to the inhabitants in the city. Proliferation and Contamination of groundwater can pose a serious public health risk and as well as a long-term environmental hazard. It is therefore recommended the Edo State government look urgently at this issue and provide solutions to safeguard the health of the citizens and the environment. It is drawn conclusively stated that the proliferation of boreholes in Benin City, may lead to a long-term environmental hazard and as well as pose a potential serious public health concern.

Eja*et al.* (2020) examined the variation in existing domestic service level of pipe-borne water supply and associated challenges in a tourism destination of Uyo Capital City, Nigeria. Domestic water supply plays a very significant role in the day-to-day life of humans in the global society and without water, life cannot be continued and that while water provisions are one of the basic requirements for human's survival. This study therefore examined the evaluation of pipe borne water supply in Uyo Capital City, AkwaIbom State, Nigeria. In an effort to approximate pipe borne water supply in the study area, the research was hinged on the following objectives, to examine variation in the existing domestic service level of pipe-borne water among communities in the study area and to examine the challenges associated with pipe-borne water supply in the area. Furthermore, a multistage sample technique was used to circumvent a practical difficulty in sampling the study area as the region was delineated into six zones. Geographic Information System was employed to collect coordinates while questionnaire was also used for data collections. 400 copies of questionnaires were purposively administered to the respondents in different zones as follows; Uyo (197), Ibesikpo-Asutan (98), Uruan (45), Ibiono-Ibom (9), Itu (30) and NsitIbom (21). Nevertheless, additional 25 questionnaires representing about 10% of the staff (248) of AkwaIbom Water Company Limited were interpreted with statistical techniques. For hypothesis one, which states that there is no significant variation in the existing domestic service level of pipe-borne water among communities. One way analysis of variance was used and it was discovered that existing service level of pipe-borne water does not differ significantly among communities in the study area ($p = 0.81$. This result was further supported by Water Production and Supply Intensification Model. Grounded on the findings, it is recommended that water distribution network and supply should be expanded to all the communities within the study area by the government. It is also recommended that the government should partner with organisations for a viable pipe-borne water supply to its residents in the area.

Bamiji*et al.* (2015) worked on problems of water supply and sanitation in Kpakungu area of Minna, Nigeria. Access to clean water and adequate sanitation has been a challenging issue in Kpakungu. Due to the unavailability of clean water sources and poor sanitation most of the inhabitants of Kpakungu are threaten with the spread of diseases such as diarrhea and cholera and this has led to the degenerating situation of Kpakungu. Assessing the problems of water supply and sanitation in Kpakungu area of Minna, Niger State using GIS (Geographic Information System) is aimed at providing access to adequate portable water supply and a better sanitation through the use of research and advocacy. This is achieved by identifying the pattern of access to public water supply and sanitation in Kpakungu and the creation of a database of the existing water source and their yield was determined to enhance planning. The research involved the use of both primary and secondary data to achieve a thorough assessment of the problems of poor water supply and sanitation in the study area. It was discovered that the problems of poor water supply and sanitation often leave most women and children on queues for several hours and those that cannot endure are forced to travel long miles in search for alternative source of water, which may not be fit for drinking. In the light of this, mothers are prevented from domestic work and most children are kept away from school. At the end of the research water and sanitation blue print for the study area was designed and a proposal was sent to relevant government agencies and ministries for the provision of more sources of potable water in the community. In this regard, Public Private Dialogue (PPD) was initiated and adequate follow up process was made until the aim of the research was achieved.

Kara (2015) investigated the impacts of climate change on water resources through precipitation and discharge analyses in Omerli catchment Istanbul, Turkey. Precipitation and temperature data are obtained from GCM (Global Circulation Model)/RCM (Regional Climate Model) combinations based on A1B carbon scenario via Europen Union (EU)-ENSEMBLES project. The data is obtained at 25 km resolution on daily time scale for reference period between 1960 and 1990 and future period between 2071 and 2100. The HBV (HydrologiskaByrånsVattenbalansavdel-ning) model is used to investigate discharge properties of study area. First the HBV is calibrated by some of catchment properties along with PEST (parameter estimation) method. Because RCM scale is comparatively coarse (25 km) for catchment scale its results are downscaled to 1 km using the Geographically Weighted Regression (GWR) method. RCM precipitation with and without GWR method are evaluated for characteristics of extreme precipitation events and they are used in the HBV model for estimating the extreme discharges along with reference and future periods. All RCMs strongly underestimate precipitation. GWR improves underestimation tendency of RCMs precipitation especially for extreme events. Depending on precipitation input from RCMs with and without GWR the HBV also shows significant underestimation in daily and extreme runoff but it provides better estimates with GWR input. The magnitude of extreme events increases in winter, spring, and summer but decreases in fall from reference to future period. Return periods of the extreme events increase in the future period and therefore, Omerli Basin is under water stress with changing climate.

Wocha*et al.* (2020) examined challenges of private provision of potable water in Obio/Akpor Local Government Area and its socio-economic implications. Water is a basic and necessary requirement for the existence of animals and plants, yet it is limited in supply in several parts of the world. Surges in human population and demand for water for different purposes such as agricultural, domestic and industrial usages are the major factors leading to water scarcity. Nigeria and the study area are blessed with abundant water resources including surface and groundwater, yet there is a palpable lack of adequate and safe potable water. Consequently, the populace resorts to private sources of water supply which has its negative externalities even though the effort seems laudable. Based on the above, the study examined the proliferation of private water supply, its challenges and socio-economic implications in Obio /Akpor local government area. The study adopted a cross-sectional survey, and data were collected with the use of both closed and open-ended questionnaire. It also involved the collection of the private borehole points with the use of a handheld global positioning system (GPS). Data were analyzed using the descriptive method of analysis and data presented in charts and tables. The result of the study showed that there were no specific distances maintained between borehole points, a good number of borehole locations were clustered in some parts of the study area. Also, distances between soak away pits and borehole points were inadequate in some communities. Based on the prevalent minimum wage in the study area, both households that operate boreholes and those that buy water spent more. Some of the socio-economic implications of private provision of water supply include too much spending on water, creation of livelihoods for water vendors and vulnerability to waterborne disease such as typhoid since there is no minimum standard for borehole drilling and distance in the study area. The study recommended that the government should develop a private borehole drilling standard that would include the minimum distance that must be maintained between two boreholes on vertical and horizontal lines. Also, the activities of the private water vendors should be regulated, and operating license obtained before operating commercial boreholes. The study concluded thus, there should be a synergy between the private and public sector to ensure safe and affordable water supply since their activities cannot be undermined.

Mohammed *et al.* (2020) evaluated challenges in water resources of Lagos mega city of Nigeria in the context of climate change. The study assessed the water resources and environmental challenges of Lagos mega city, Nigeria, in the context of climate change. Being a commercial hub, the Lagos population has grown rapidly causing an insurmountable water and environmental crisis. In this study, a combined field observation, sample analysis, and interviews were used to assess water challenges. Observed climate, general circulation model (GCM) projections and groundwater data were used to assess water challenges due to climate change. The study revealed that unavailability of sufficient water supply provision in Lagos has overwhelmingly compelled the population to depend on groundwater, which has eventually caused groundwater overdraft. Salt water intrusion and subsidence has occurred due to groundwater overexploitation. High concentrations of heavy metals were observed in wells around a landfill. Climate projections showed a decrease in rainfall of up to 140 mm and an increase in temperature of up to 8^0C. Groundwater storage is projected to decrease after the midcentury due to climate change. Sea level rise will continue until the end of the century. As the water and environmental challenges of Lagos are broad and the changing characteristics of the climate are expected to intensify these as projected, tackling these challenges requires a holistic approach from an integrated water resources management perspective.

Ayeni*et al.* (2017) evaluated urbanization and water supply in Lagos State, Nigeria: The challenges in a climate change scenario. Population and water production data on Lagos State between 1963 and 2006 were collected, and used for trend and projection analyses. Land use/Land cover maps of 1975, 1995 and NigeriaSat-1 imagery of 2007 were used for land use change analysis. The population of Lagos State increased by about 557.1% between 1963 and 2006, correspondingly, safe water supply increased by 554%. Currently, 60% of domestic water use in urban areas of Lagos State is from groundwater while 75% of rural water is from unsafe surface water. Between 1975 and 2007, urban land use increased by about 235.9%. The 46years climatic records revealed that temperature and evaporation decreased slightly while rainfall and Relatively Humidity (RH) decreased consistently. Based on the current trends, the Lagos State population and required water are expected to increase to about 19.8millions and 2418.9ML/D respectively by the year 2026. Rainfall is likely to decrease by - 6.68cm while temperature will increase by 0.950C by 2026. Urban land use is expected to increase by about 20% with expectation of serious congestion in the suburb areas. With these results, over 50% of the urban inhabitants will be highly water poor in years to come if the present trends continue unabated.

Dayo (2020) assessed sustainable water resource and environmental management in developing countries. Water supply service delivery has been recognised as a complex challenge facing communities in developing countries. Its particularly serious in sub-

Saharan Africa where a significant proportion of the population still lack basic access to safe drinking water supply. Over the years, many externally supported community-managed water facilities have failed to deliver sustainably. This results not only in a loss of financial investment but also constitutes a real threat to people's health and well-being. Therefore, this study aimed to explore options for innovative water service delivery approach that can support vibrant water supply provision as well as provide a guidance framework for sustainable water service delivery in Nigeria.

Due to the socio-technical complexity of the research, the mixed method approach was found to be the most suitable research method after extensive considerations and reviews of other several available research methodologies. The study found that the hand-dug wells (HDW) have enormous potential in sustainable water service delivery to households within the proposed framework arrangement. The research successfully presented a unique model, based on the concept of HDW self-supply, using rope pump technology in conjunction with a community-based water resource management concept. The proposed approach led to the production of a set of Guidance Frameworks that will aid planning and implementation of a proposed solution. This was validated with key stakeholders and its applicability was rated highly relevant in the water sector. The approach did not only address the question of technical and financial sustainability but also make a case for environmental sustainability. Hence, ensuring that meeting present domestic water needs will not jeopardise the ability of future generations to meet their own needs. Further research was recommended to ensure wider applicability of the model (Dayo, 2020).

Gloria *et al.* (2018) studied assessment of the impact of climate change on the freshwater availability of Kaduna River basin, Nigeria. Changes in runoff trends have caused severe water shortages and ecological problems in agriculture and human well-being in Nigeria. Understanding the long-term (inter-annual to decadal) variations of water availability in river basins is paramount for water resources management and climate change adaptation. Climate change in Northern Nigeria could lead to change of the hydrological cycle and water availability. Moreover, the linkage between climatic changes and streamflow fluctuations is poorly documented in this area. Therefore, this study examined temporal trends in rainfall, temperature and runoff records of Kaduna River basin. Using appropriate statistical tools and participatory survey, trends in streamflow and their linkages with the climate indices were explored to determine their amplifying impacts on water availability and impacts on livelihoods downstream the basin. Analysis indicates variable rainfall trend with significant wet and dry periods. Unlike rainfall, temperature showed annual and seasonal scale statistically increasing trend. Runoff exhibit increasing tendency but only statistically significant on annual scale as investigated with Mann–Kendall trend test. Sen's estimator values stood in agreement with Mann–endall test for all variables. Kendall tau and partial correlation results revealed the influence of climatic variables on runoff. Based on the survey, some of the hydrological implications and current water stress conditions of these fluctuations for the downstream inhabitants were itemized. With increasing risk of climate change and demand for water, we therefore recommend developing adaptive measures in seasonal regime of water availability and future work on modelling of the diverse hydrological characteristics of the entire basin.

2.4 Water Availability and Demand in the Future

Eighty percent (80%) of the world's population is already affected by water security due to increased water demands, decreased availability, and pollution factors (Vörösmarty*et al.,* 2010). Climate variability may affect water security by affecting the availability of water. Studies have demonstrated that fresh water resources will decrease, especially in Mediterranean environments (Ludwig *et al.,* 2017) and southern Africa, and that variations in water availability will increase in southern and eastern Asia (IPCC, 2014). However, increased surface runoff will prevent increases in agricultural water demand in some parts of the world. Schewe*et al.* (2013) suggested that if temperatures increase 1°C, 8% of the global population would experience severe water scarcity. If the amount increases 2°C, 14% of the global population will be affected. Due to climate change, rainfall variations will increase and these variations will alter some climaterelated events such increased stream flows and decreased surface runoff through decreased snow and ice deposits. Similarly, climate simulations predict a decreasing trend in ground water resources as well. Some simulations suggest a linear decreasing trend in ground water owing to global temperature increases (Portman *et al.,* 2013).

Climate variability will alter temperature, precipitation, and radiation time, and these alterations will affect the water needs of vegetation, which are fed by precipitation or irrigation. It is likely to increase the amount of irrigation in 40% of Europe, USA, and some parts of Asia. Wada *et al.* (2013) used seven different global hydrological models in their study and suggested that water demands will increase in agricultural areas, making up 7–21% of the World by the 2080s. However, some researchers suggest water demands in agricultural areas will change by only very small amounts in the future (Zhang and Cai, 2013). Rivers that are fed by rainfall are more sensitive to the impacts of climate change. Types of agricultural products will be altered with changing quantities of precipitation in the future. The negative impacts of climate change on agricultural areas may be decreased by widening irrigated agricultural areas and increasing irrigation (McDonald and Girvets, 2013).

Some important aspects of climate change are temperature increase, decreased snow and ice cover, and temperature and evaporation increases in lakes and rivers, and these changes will decrease the amount of fresh water available where they occur (EPA, 2014). Consequently, water demands will increase and central and local governments will need to secure fresh water resources (Beck and Bernauer, 2014). The need for human-developed water depots will increase owing to decreased stream flows, and severe and intense droughts. Increased water temperatures will increase organic material compounds in water and different purification and cleaning processes will be required. Drier climate conditions will increase pollutant intensity in water. This issue is a more important problem where ground water resources are already polluted. Flood-affected surface runoff will increase and, owing to this, the amount of pathogens, nutrients, and suspending sediments in waters will increase. Increases in sea level will affect both surface and ground water negatively and, in particular, areas where the ground water level is low will be negatively affected more significantly (IPCC, 2014).

Climate change is expected to increase the frequency and intensity of extreme precipitation events all around the world (IPCC, 2014). Several climate change studies have been conducted to assess the impact of these changing conditions (Fowler and Ekström, 2019). These studies are usually conducted using GCM (Global Circulation Model)/RCM (Regional Climate Model) combinations and downscaling methods. Following this, high-resolution data are used in hydrological models to estimate changes in hydrological variables. GCM data are widely used in climate change studies but the spatial resolution of these data is approximately 2-200km. Climate projections for the future are accomplished using physical-based climate models. According to these global and regional climate models, evaporation will increase because of warmer climate conditions in the future (IPCC, 2014). Long-term projections of evaporation do not show certain results because evaporation is affected not only by air temperatures, but also by soil moisture, CO_2 concentrations, and plant cover changes (Katul and Novick, 2019). It is expected that evaporation will increase in southern Europe, Central America, southern Africa, and Siberia. The number of hot days (Hirschi*et al.,* 2015) and heat waves will increase along with evaporation.

It is anticipated that fresh water shortages will increase all around the world due to higher demands by growing populations and increased evaporation (Chattopadhyay and Hulme, 2017). Therefore, direct and indirect water needs of populations will increase. Agricultural areas are one of the biggest consumers of both surface water and ground water. If precipitation decreases, soil moisture will decrease and the water needs of soils will increase. Fresh water resources and permafrost are decreasing in arctic regions and these events will remain the same until the mid-21st century (IPCC, 2014). All glacier simulations indicate a melting trend in glaciers and ice caps during the 21st century. In the future, it is expected that rivers will reach their peak in spring instead of summer owing to vanishing glaciers and ice caps (Huss, 2014). It is estimated that if glacier melt continues, glacier-covered areas will narrow and this will increase surface runoff and stream flows. Rivers will peak in China between 2010 and 2050 (Xie*et al.,* 2016) and Scandinavia after 2050s (Johannesson*et al.,* 2015) because of this glacier melting events.

Climate simulations indicate that average annual precipitation will increase in high latitudes and the humid tropics, but it will decrease in the dry tropics. There are constant uncertainties the amount of precipitation in China, south Asia, and large parts of South America (IPCC, 2014). There are several examples of the effects of snowfalls and snow melts on stream flows. On a global scale, it is anticipated that rivers will peak earlier than before owing to earlier snow melt (Adam *et al.,* 2019). Despite increased snow melt, it is expected that the amount and level of ground water will decrease in the future (Taylor *et al.,* 2013). Generally, ground water levels and the number of fountains, which are fed by ground water, will increase where surface runoff is increased (IPCC, 2014). Ground water level is expected to decrease despite the amount of rainfall remaining the same where the amount of snowfall decreases in North America (Earman*et al.,* 2016). Increases in sea level rise result in ground water being invaded by salty water, and this will make ground waters salty and decrease fresh water resources (Werner *et al.,* 2012). Deltas will be affected from rising sea levels and fresh water resources in deltas will become salty (Masterson and Garabedian, 2017).

The frequency and intensity of heavy precipitations and soil erosion will increase (Seneviratne*et al.,* 2012) while total precipitation decreases. Soil erosion is expected to increase in dry and semi-dry areas where only one rainfall accounts for more than 80% of total annual rainfall (Bussi*et al.,* 2013). Climate change will affect the amount of sediment carried in rivers by affecting discharge and land cover. Thodsen*et al.* (2018) suggested that and 11–14% increased discharge will increase sediment load 9-16%. Soil erosion and suspended sediments in rivers will increase in cold regions owing to increased precipitation, glacier melting, permafrost melting, and transformation of snowfalls to rainfalls (Lu *et al.,* 2016). Soil erosions and landslides are expected to increase in the tropics too, owing to increased heavy rainfalls (Knutson *et al.*, 2015).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Types and Sources of Data

The types of data used for this study include primary and secondary. This study employed both primary and secondary sources of data collection.

3.1.1 Primary data

The primary data were sourced from the administration of questionnaire to two groups, namely, selected agencies of government directly involved in water supply management and the general public located in the study area. Other primary data include oral interview, field survey and used of GPS to know the location of the selected sample points.

3.1.2 Secondary data

Secondary data sources include water supply per year, annual rainfall, annual temperatureand annual relative humidity which were sourced from Niger State Water Board Minna and Nigerian Meteorological Agency (Abuja) respectively.

3.2 Research Design

This study applied the explanatory research design. The explanatory research design seeks to establish relationships between variables through the collection of quantitative data, in-depth study of the phenomena and statistical analysis of data to draw conclusions and make recommendations (Osaze&Izedonmi, 2008; Otokiti, 2010).

3.3 Instruments of Data Collection

The instruments for the collection of primary data include structured questionnaire, field survey and oral interview.

3.3.1 Structured Questionnaire

The questionnaire to be used in obtaining primary data was structured and divided into two sections. Section 'A' contained six items relating to the target populationsocialeconomic data, which include respondent's gender, highest qualification, length of service, discipline as well as professional affiliation. Sections "B" covered areas relevant for the achievement of the research objectives and addressing the research questions for this study. The respondents made up of people of eighteen (18) years and above and from all works of life.

3.3.2 Oral interview

The direct interview (one on one discussion) was embarked to achieve objectives II, III and IV which included: Assess climate variability impact on water supply and distribution in the study area; examine major household response to water stress due to high demand for drinking water in the study area; and evaluate mitigation strategies put in place to reduce the impact of climate variability on water supply and distribution in the study area.

3.3.3 Reconnaissance survey

A comprehensive reconnaissance survey of the entire study was carried out in order to accustom the researcher with the realistic and actual scenario on ground. The survey avails the researcher with firsthand information and data on the extent of challenges of water supply in the study area. The field investigation took the researcher to all the different parts of the study area in order to familiarise the researcher with the particular challenges characteristic to each part of the study area.

3.4 Sampling Procedure and Sample Size

3.4.1 Sample size

Sample size was drawn using Taro Yamane (1967) statistical formula. This formula is concerned with applying a normal approximation with a confidence level of 95% and a limit of tolerance level (error level) of 5%. Sample points for this study include household heads and Niger State Water Board in charge of Chanchaga and Bosso Local Government Areas.

To this extent the sample size is determined by $n = \frac{N}{1+Ne^2}$ (3.1)

Where: n = the sample size

N = population (population of the study area)

e = the limit of tolerance (0.05)

Therefore, $n = \frac{304,113}{1 + 304,113(0.05)^2} = \frac{304,113}{1 + 304,113(0.0025)} = \frac{304,113}{1 + 760} = \frac{304,113}{761}$

n = 400 respondents.

The study respondents were 400 and simple random sampling was used to distribute the questionnaires among the respondents, where 379 questionnaire were returned for data analysis.Out of 138 questionnaires administered in Chanchaga, only 125 (90.58%) were returned, while in Bosso, 262 questionnaires were administered and only 254 (96.95%) were returned.

3.4.2 Sampling procedure/technique

Simple random sampling was used for this study. To conduct a simple random sample of this study, the sample was drawn so that each person or item has an equal chance of being drawn during each selection round and the samples may be drawn with or without replacement.

3.5 Method of Data Analysis

Each objective identified in section 1.4 of the study were achieved through the following:

3.5.1 Examine the trend in climate variability from 2000 to 2020 in the study area

Objective One (1) was achieved through statistical mean. Rainfall, maximum temperatureand relative humidity data obtained were on monthly and annually basis for a period of 21 years (2000 to 2020) and this was converted into mean annual value using the statistical technique. (3.1)

$$\bar{x} = \frac{\sum x}{n}$$

Where x is the mean monthly rainfall value and n = number of months. The same was applied for maximum temperature and relative humidity data.

3.5.2 Assess the trend in water supply and distribution in the study area

Objective Two (2): To be achieved through three-point likert rating scale analysis. This objective was achieved using a 3-point Likert scale with response options as Severe Challenges (SC) = 3, High Challenges (HC) = 2 and Low Challenges (LC) =1. The mean value of the responses will be calculated thus:

Mean value (x) = $\frac{3+2+1}{3} = \frac{6}{3} = 2$ (3.2)

3-point Likert scale is basically a scale used to represent people's opinions and attitudes to a topic or subject matter. 3-point Likert scale ranges from one extreme to another, for example, “extremely likely” to “not at all likely. It uses psychometric testing to measure the beliefs, attitudes, and opinions of subjects. The likert scale is important for research because it can be used to measure someone's attitude by measuring the extent to which they agree or disagree with a particular question or statement.

3.5.3 Examine the relationship between water supply, distribution and climate variability in the study area

Multiple regression was used to test the relationship betweenwater supply, distribution and climate variability in the study area.

$$Y = \pm a_1 \pm b_{\underline{1}} x_1 \pm b_2 x_{\underline{2}} + b_3 \underline{x}_3 \pm b_n x_{\underline{n}} \qquad (3.3)$$

Where: Y = Water supply; x_1, x_2, x_3= rainfall and temperature

a_1, b_1, b_2, b_3..........b_n = are constant

$$b_1 = \frac{\sum(x_{2y}X^2{}_1 - \sum x_1\, y. \sum x_1\, x_2}{\sum x^2{}_1 . \sum x^{2\partial} - [\sum x_1 \sum x_2]^2}\ for\ 2\ variables$$

$$b_1 = \frac{\sum(x_2 - \bar{x}_2)(y - \bar{y}). \sum(X_1 - \bar{X}_1)^2 - \sum(x_1 - \bar{x}_1) \atop (y - \bar{y}). (\sum x_1 - \bar{x}_1 . x_2 - \bar{x})}{\sum(x_1 - \bar{x})^2 . \sum(X_2 - \bar{X}_2)^2 - [\sum(x_1 - \bar{x}_1)(x_2 - \bar{x}_2)]^2}$$

$$b_2 = \frac{\sum x_1 y. \sum x_2^2 - \sum x_2 y. \sum x_1 x_2}{\sum(X_1 - \bar{X}_1)^2 . \sum x_2^2 - (\sum x_1 x_2)^2}$$

$$b_2 = \frac{\sum(x_1 - \bar{x}_1)(y - \bar{y}). \sum(x_2 - \bar{x}_2) y - \bar{y} \sum(x_1 - \bar{x}_1) \atop (x_2 - \bar{x}_2)}{\sum(x_1 - \bar{x}_1)^2 . \sum(x_2 - \bar{x}_2)^2 - [\sum(x_1 - \bar{x}_1)(x_2 - \bar{x}_2)]^2}$$

$$a = \bar{y} - b_1 \bar{X}_1 - b_2 \bar{X}_2$$

3.5.4 Examine population response to water stress vis-à-vis demand and supply of drinking water in the study area

To achieve objective IV, structured questionnaires data and information gathered from several direct interview was employed. Structured questionnaires were administered to the residents of the study area with a section of questions about the issues of the objective and research question as they were in section 1.3 and 1.4 of the study. The information and results generated from questionnaire and direct interview were subjected to statistical analysis using descriptive statistics (frequency-percentage) and presented in figures with analyzing comments so as to demonstrate the effectiveness of the responses.

3.5.5 Evaluate mitigation and adaptation strategies to climate variability impact on water supply and distribution in the study area

Objective Five (5): was achieved through four-point Likert rating scale analysis with numerical response options in descending order of Very High Mitigation Strategy (VHMS)-4 points, High Mitigation Strategy (HMS)-3 points, Low Mitigation Strategy (LMS)-2 points and Very Low Mitigation Strategy (VLMS)-1 point. Likert scale is a very popular rating scale used to determine a respondents' agreement level. Likert scales are odd numbered scales. Most commonly used is the 5 point scale, some researchers also use the 7 point scale. Now, at times there are situations when a respondent chooses the 'Neutral' option in a 5 point Likert scale. Researchers have started using a 4 point scale in which there is no neutral option. This is done in order to extract a specific response from the respondents which why this study choose 4 point scale.

Table 3.1: Research objectives and method to achieve them

S/N	Objectives	Data to be used	Source of data collection	Method of analysis
1	Examine the trend in climate variability between 2000 and 2020 in the study area	Climatic data	Secondary data	Linear trend method
2	Assess the trend in water supply and distribution in the study area	Hydrological data (water supply data)	Secondary data	Linear trend method
3	Examine the relationship between water supply, distribution and climate variability in the study area	Climatic and hydrological data	Secondary data	Multiple regression method
4	Examine population response to water stress vis-à-vis demand and supply of drinking water in the study area	Qualitative data (question)	Primary data (Questionnaire)	Descriptive statistics
5	Evaluate mitigation and adaptation strategies to climate variability impact on water supply and distribution in the study area	Qualitative data (question)	Primary data (Questionnaire)	Descriptive statistics

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Examination of the Trend in Climate Variability between 2000 and 2020 in the Study Area

The climatic variables analysed in this study include rainfall, maximum temperature and relative humidity.Figure 4.1 shows that monthly rainfall is higher in months of August and September and low the in the months of April, May and October. The months of November to March are dry season months. The highest mean monthly rainfall was in the month August with a value of 280.9mm while the least was in the month of November with a value of 3.6mm.

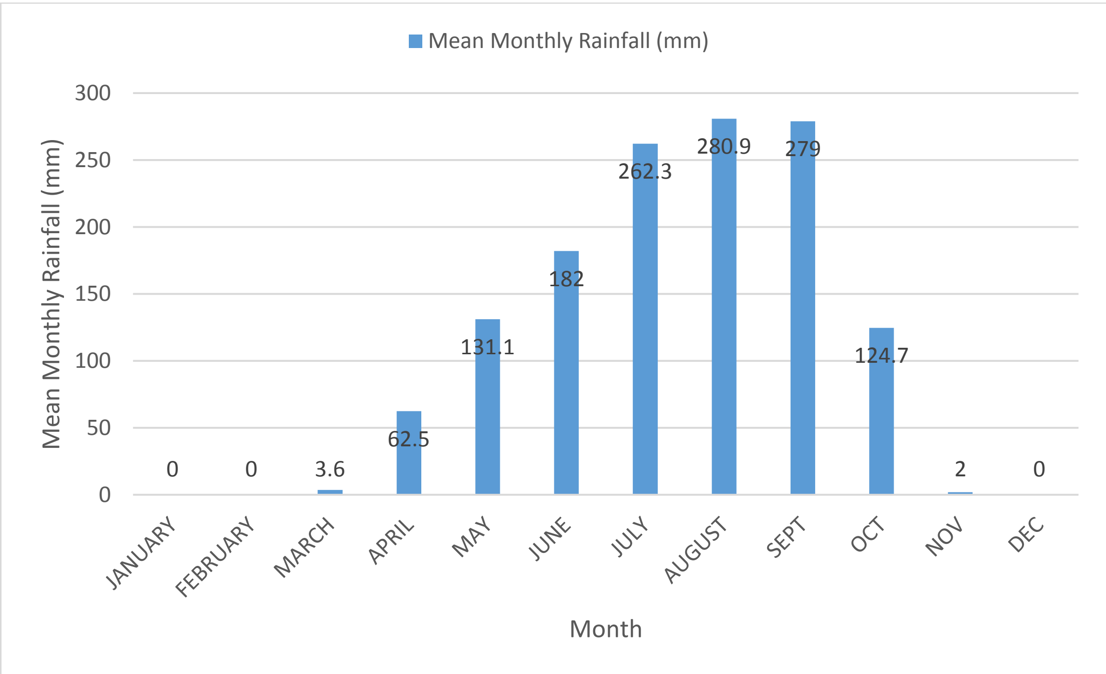

Figure 4.1: Mean Monthly Rainfall Distribution of the Study Area

Figure 4.2 shows the distribution of annual rainfall in the study area spanning about 20 years (2000 to 2020). The distribution of annual rainfall tend to be increasing despite the fluctuation in some years (2004 to 2006, 2013 to 2015). The highest annual rainfall was recorded in the year 2012 with 1520.9mm while the lowest annual rainfall was recorded in the 2013 with 793.5mm. This shows that annual water supply and distribution is increasing since recharge to ground waterdepends on the increase of annual rainfall across the study area.

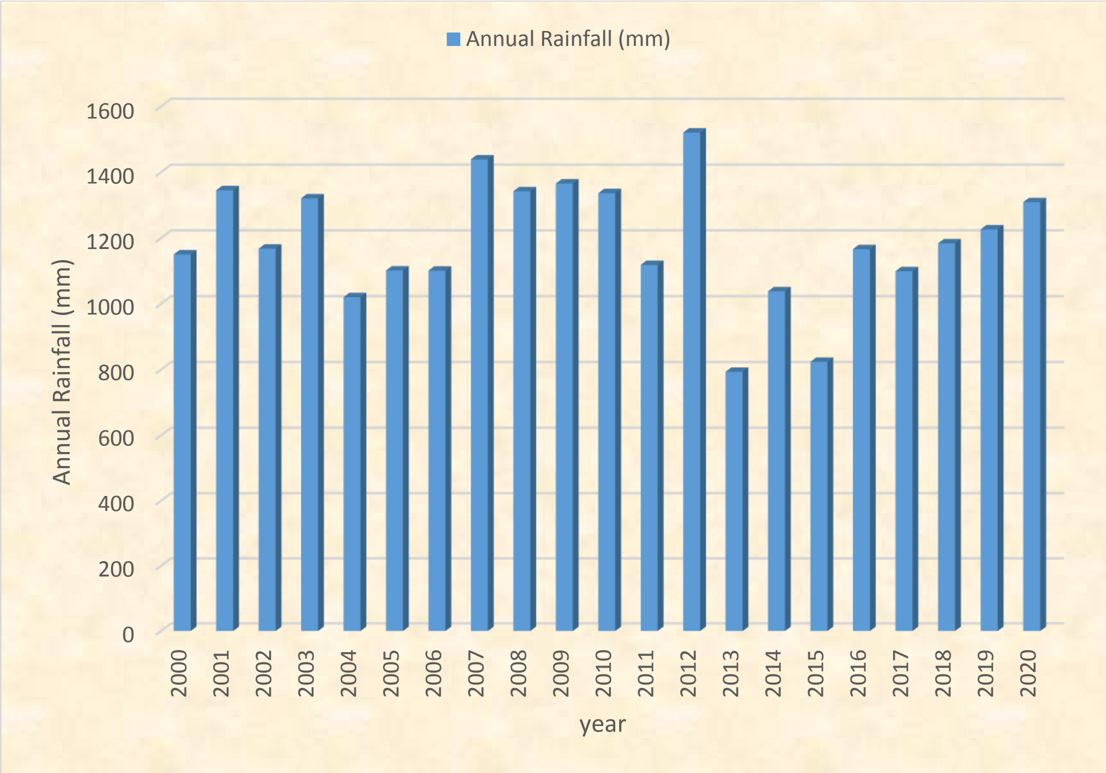

Figure 4.2: Annual Rainfall Distribution of the Study Area (2000 to 2020)

Figure 4.3 shows that mean monthly maximum temperature decreases from November to February which coincide with dry season and harmattan period. There is gradual rise in temperature and reaching its peak in the later days of February through March to April. Since this period coincide with dry season, recharge to groundwater and absence of rainfall will affect water availability and distribution across the study area.

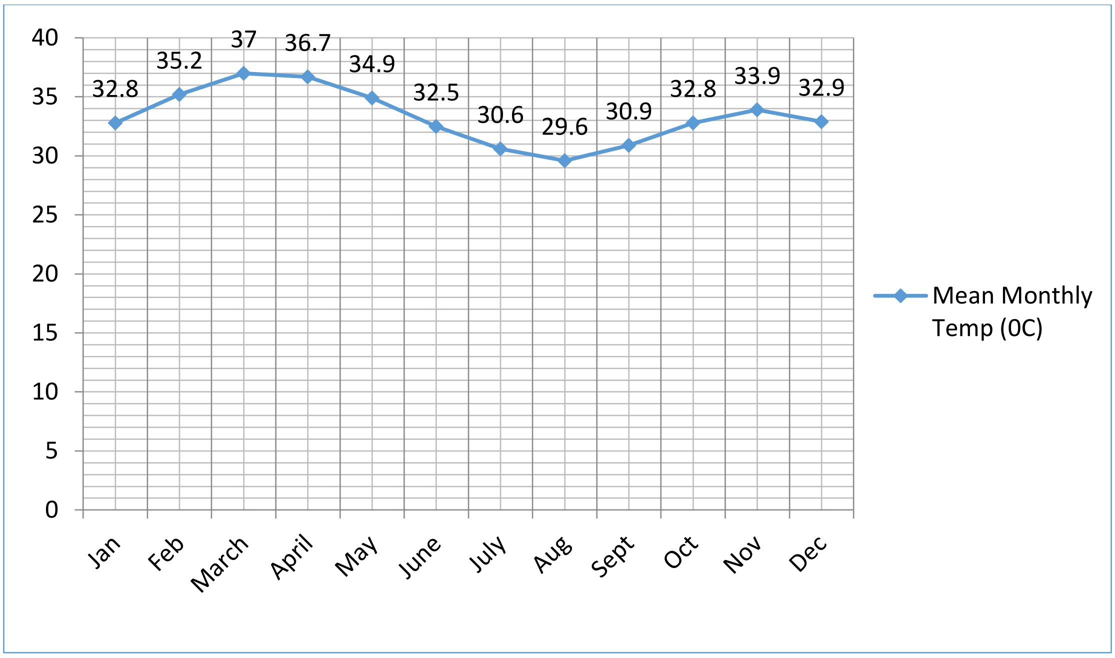

Figure 4.3: Mean Monthly Maximum Temperature (2000 to 2020)

Figure 4.4 shows the mean annual maximum temperature of the study area. Year 2010 ranked the highest with 33.8^{0}C while 2019 ranked the least with maximum temperature of 32.9^{0}C. The distribution of maximum temperature across the study area shows that the temperature is on the increase despite some years (2007 to 2008, 2012, 2015, 2018 and 2019) with decrease values. This shows that the water supply and distribution will be affected negatively through increase evaporation.

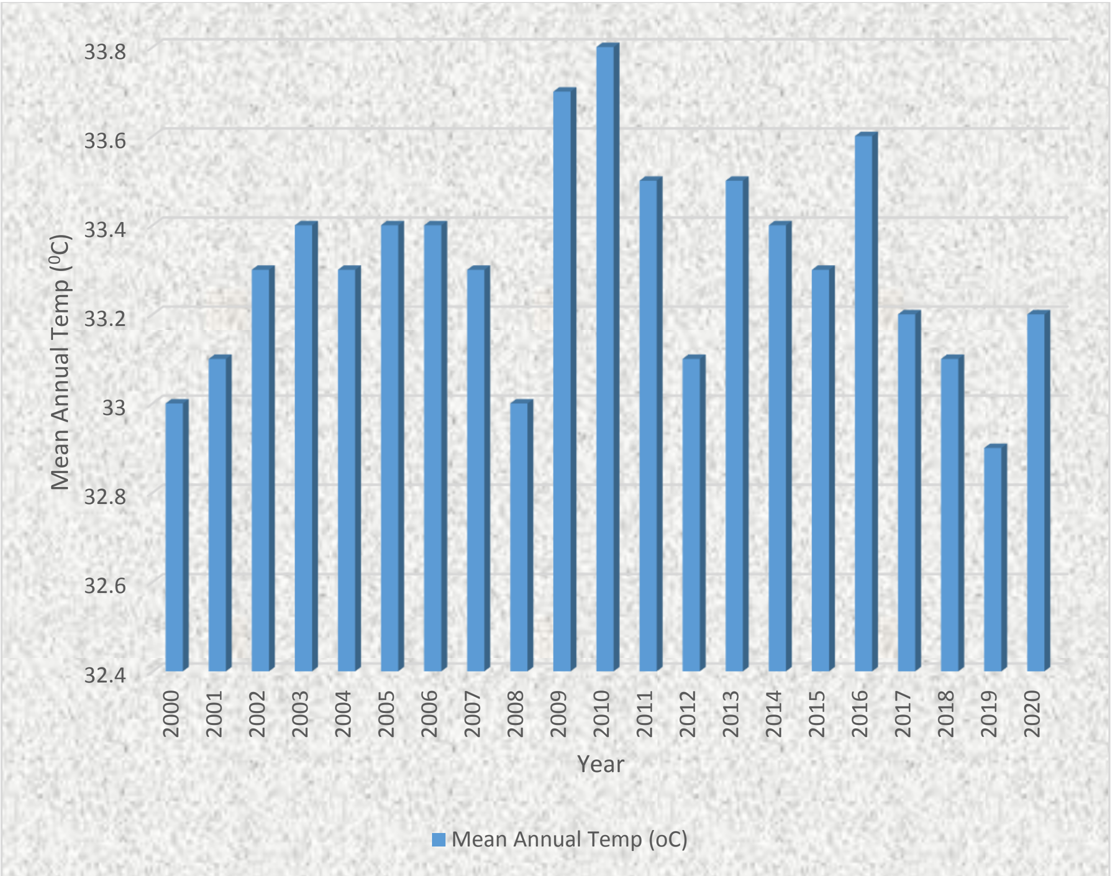

Figure 4.4: Mean Annual Temperature of the Study Area (2000 to 2020)

Figure 4.5 shows the distribution of mean annual relative humidity across the study area. The mean annual relative humidity is increasing with some fluctuation (2005 to 2006, 2014 to 2017). The highest mean annual relative humidity was recorded in the year 2009 with 74.25% while the least was recorded in the year 2015 with 59.06%. This shows that annual relative humidity will continue to increase which in turn will leads to increase in water supply and distribution across the study area.

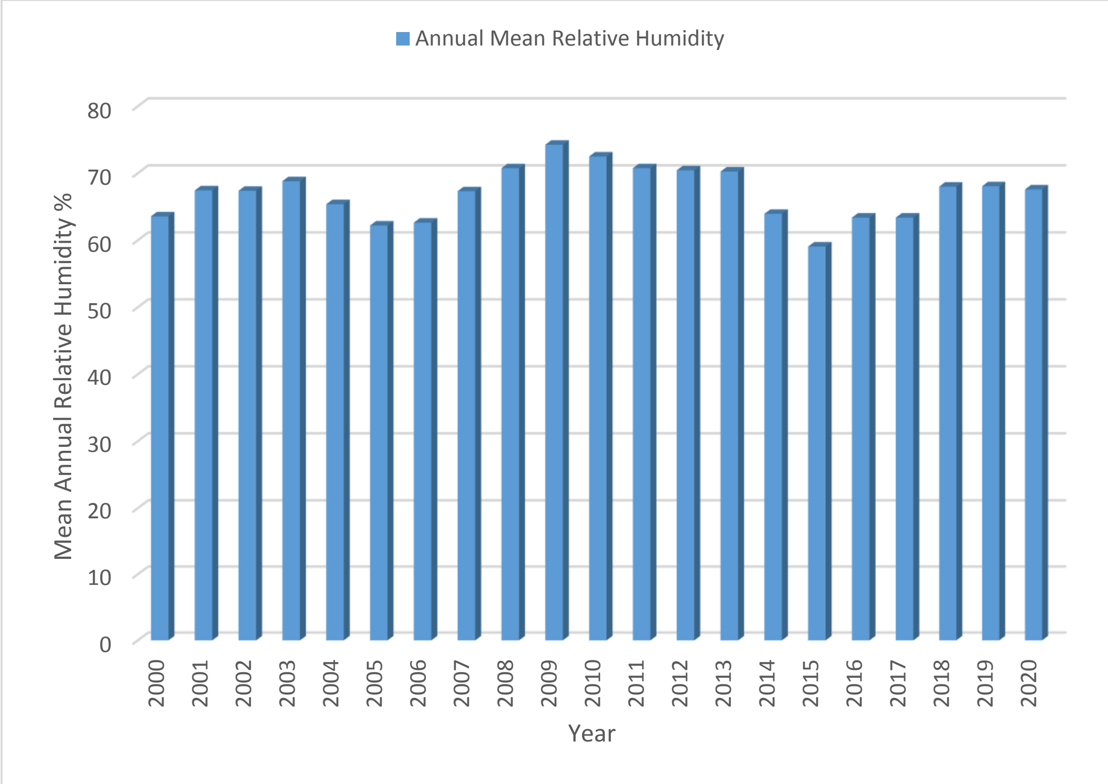

Figure 4.5: Mean Annual Relative Humidity Distribution (%) (2000 and 2020)

Figure 4.6 shows the distribution of mean monthly relative humidity across the study area. Rainy season has the higher relative humidity while dry season has lower relative humidity. Month of August has the highest monthly relative humidity with 86.56% while the month of March has the lowest value of 40.94%. This shows that rainy season relative humidity has contributed positively to water supply and distribution across the study area.

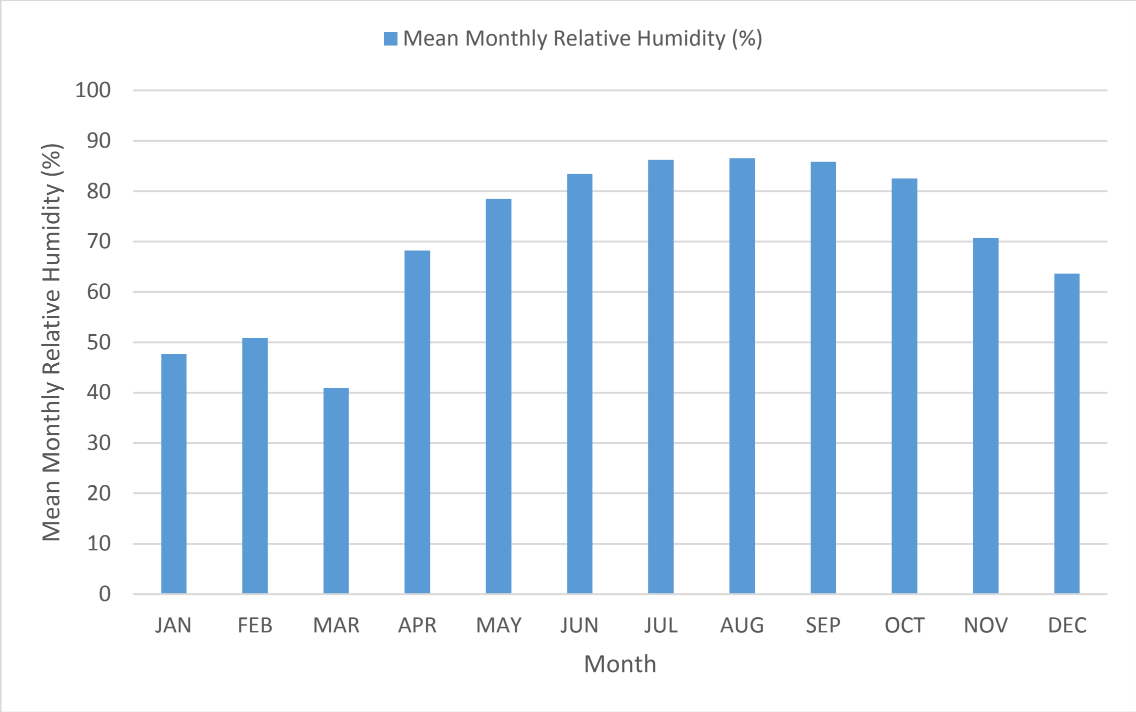

Figure 4.6: Mean Monthly Relative Humidity (%) (2000 to 2020)

Climate variability has the potential to impose pressures on water supply and demand across the study area.

4.2 Assess Extent of the Trend in Water Supply and Distribution in the Study Area

Figure 4.7 shows the distribution of water supply across the study area and this distribution agrees with the monthly rainfall distribution in Figure 4.1 of the study. The highest water supply was recorded in the month of September with 410M^{3}while the lowest was recorded in the month of May with 240M^3. This shows that rainy season provide the study area with water supply and dry season provide the area with little or no water supply which limit distribution and apparently leading to water supply shortage across the study area. This shortage is partially taken care-off from supplies coming fromboreholes and hand dug wells.

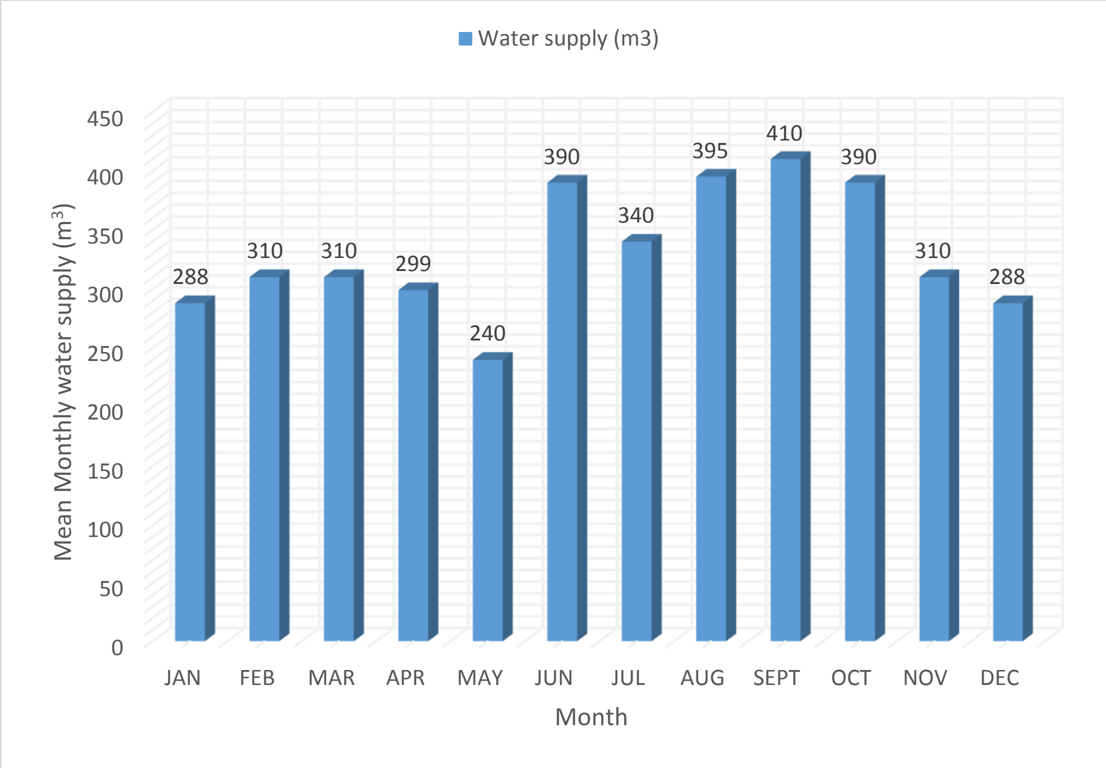

Figure 4.7: Mean Monthly Water Supply Distribution across the Study Area (2000 to 2020)

Figure 4.8 shows the annual water supply across the study area. The distribution shows that 2006 ranked the highest with 4410M^3 while the 2007 ranked the least with 3754M^3. This revealed that annual water supply is increasing with some deficit years below 4034M^3.

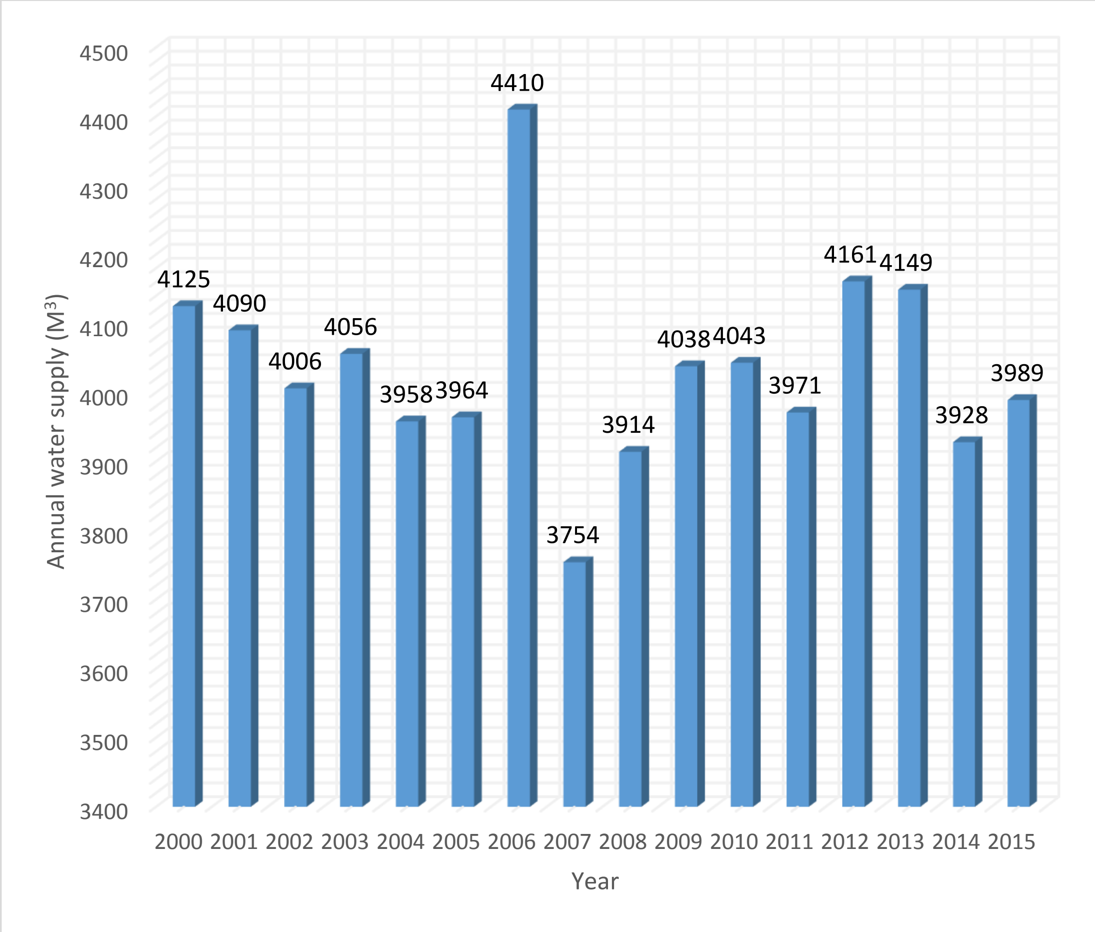

Figure 4.8: Annual Water Supply Distribution across the Study Area (2000 to 2015)

Three main issues impacting water supply and distribution in the study area were identified and discussed. Firstly, the natural conditions, high rainfall with low evaporation rates, together create conducive environment for water availability. Secondly, population growth and economic developmentlead to greater water demand and increased pollution of available resources. Thirdly, the policiespertaining to management of water resources determines the approach taken by relevant authorities tomanaging the resource and directly impacts other driving forces and pressures on water supply and distribution. Hydrological responses are known to be sensitive to changes in rainfall of the study area.

4.3 Examination of the relationship between water supply, distribution and climate variability in the study area

This correlation analysis was carried out based on climatic parameters like annual rainfall, maximum temperature and relative humidity and these were the independent variables, while annual water supply was the dependent variables of this study.

Table 4.1: Descriptive Statistics of variables under study

Variables	Mean	Std. Deviation	N
Annual water supply	4037.8	146.866	20
Annual Rainfall (mm)	1085.35	151.646	20
Max Temp (^{0}C)	31.85	.745	20
Relative humidity (%)	51.50	2.646	20

Table 4.1 depicts mean annual rainfall and indicate a mean of 1085.35mm and the standard deviation of 151.646mm; mean of annual maximum temperature was 31.8^{0}C and the standard deviation of 0.7^{0}C and mean of annual relative humidity was 51.50% and the standard deviation of 2.6%. Meanannual water supply was 4037.8M^3 and standard deviations of 146.866. The significance of this analysis of the standard deviation is that in any given body of raw data, the likelihood of any observation falling outside the range from the mean is so small.

Table 4.2: Correlation between maximum temperature, annual rainfall, relative humidity and water supply

		Annual water supply (M^3)	Annual Rainfall (mm)	Max Temp (^0C)	Relative humidity (%)
Spearman's Correlation	Annual water supply (M^3)	1.000	.095	.065	.576
	Annual Rainfall (mm)	.095	1.000	.047	.247
	Max Temp (^0C)	.065	.047	1.000	.387
	Relative humidity (%)	.576	.247	.387	1.000
Sig. (1-tailed)	Annual water supply (M^3)	.	.491	.299	.017
	Annual Rainfall (mm)	.491	.	.423	.147
	Max Temp (^0C)	.299	.423	.	.046
	Relative humidity (%)	.017	.147	.046	.
N	Annual water supply (M^3)	20	20	20	20
	Annual Rainfall (mm)	20	20	20	20
	Max Temp (^0C)	20	20	20	20
	Relative humidity (%)	20	20	20	20

A correlation coefficient of 1.00 indicates a high degree of association between water supply and annual rainfall and this shows that, the higher the annual rainfall, the higher the water supply. Correlation coefficient of 0.65 for water supply indicates moderate degree of association between maximum temperature and annual water supply. Correlation coefficient of 0.57 for water supply indicates moderate degree of association between relative humidity and annual water supply.This shows that, the higher annual rainfall, the higher the water supply. The study also revealed that there is high strength of association between water supply examined as indicators for water security with climatic parameters.

As indicated in Table 4.3, the ratio between the variance estimates (F) was 1.75. Since the calculated F of 1.75 was lower than 3.24, so the predictors (relative humidity, maximum temperature and annual rainfall) do not significantly differ as independent variables, and any of them can be chosen as the independent variable for the water supply in the study area.

Table 4.3: ANOVA

Model		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
1	Regression	39028.248	3	13009.416	1.759	.195[b]
	Residual	118322.952	16	7395.184		
	Total	157351.200	19			

a. Dependent Variable: Water Supply

b. Predictors: (Constant), Relative humidity(%), Annual Rainfall (mm), Max Temp (^{0}C)

4.4 Examine population response to water stress vis-à-vis demand and supply of drinking water in the study area

Water supply in the study area has faced various challenges and these challenges include poor maintenance, inadequate power supply, lack of autonomy and insufficient fund as indicated in Figure 4.9.

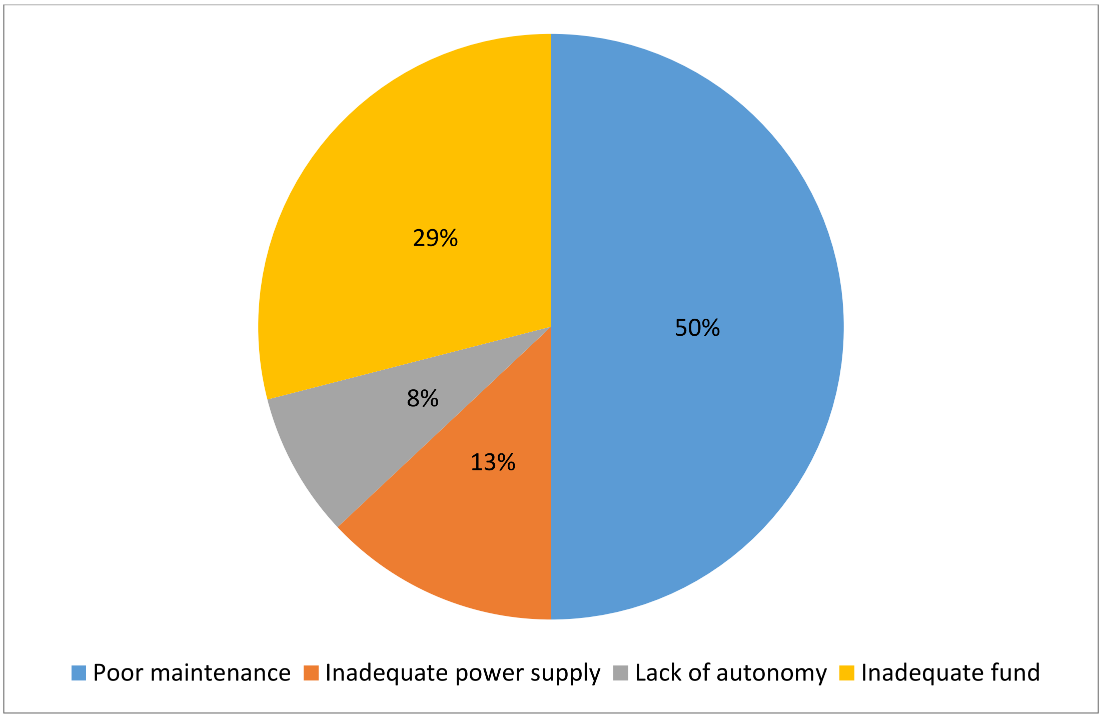

Figure 4.9: Challenges of Water Supply in the Study Area

Figure 4.9 shows that 50% of the respondents were of the opinion that poor maintenance is the challenges of water supply, 13% said inadequate power supply and this has to do with pipe borne water in the study area, 8% pick lack of autonomy with respect tape water and 29% were of the opinion that inadequate fund is the challenge of water supply. This implies that poor maintenance of water supply and distribution facilities was the major challenge of water supply in the study area.

Table 4.4, reveals that the major water supply problem in the study area is distance from source 64.8%, 16% said that inadequately in supply is their problem, 10.4% were of the opinion that poor quality or water has being their problem. The table also shows that effects of inadequate supply, 8.8% of the respondents said that low dependability from source makes them do things they don't like i.e. sleepless nights, fighting and quarreling, sleeping without food and cooking late, dirty clothes and surroundings.

While poor quality of water is associated with high level of health concern, hygiene not assures and consumption needs may be at risk and quality difficult to assure emphasis on effective use and water handling hygiene. Distance from source is associated with late to schools and working place, backache, leaving other works half done and snakes bites.

Table 4.4: Nature of Water Scarcity and Associated Effects in the Study Area

Problem	**Number of response**	**(%)**	**Effects**
Long distance covered from source	110	55	Late to schools and working place, backache, leaving other works half done and snake bites.
Poor quality of water supply	26	13	Very high levels of health concern, hygiene not assure and consumption needs may be at risk. Quality difficult to assure emphasis on effective use and water handling hygiene.
Inadequate supply of water	44	22	Sleepless nights, fighting and quarreling, sleeping without food or cooking late, dirty clothes and surroundings.
Low dependability of water from source	20	10	Sleepless nights, fighting and quarreling, sleeping without food or cooking late, dirty clothes and surroundings.
Total	**200**	**100**	

Source: Field Survey, 2022

From Figure 4.10, water supply is severe between the months of March and April which has 85.2% while between September to October ranked the least with 2.4%. This coincides with the pick period of dry season, when the water table is very low.

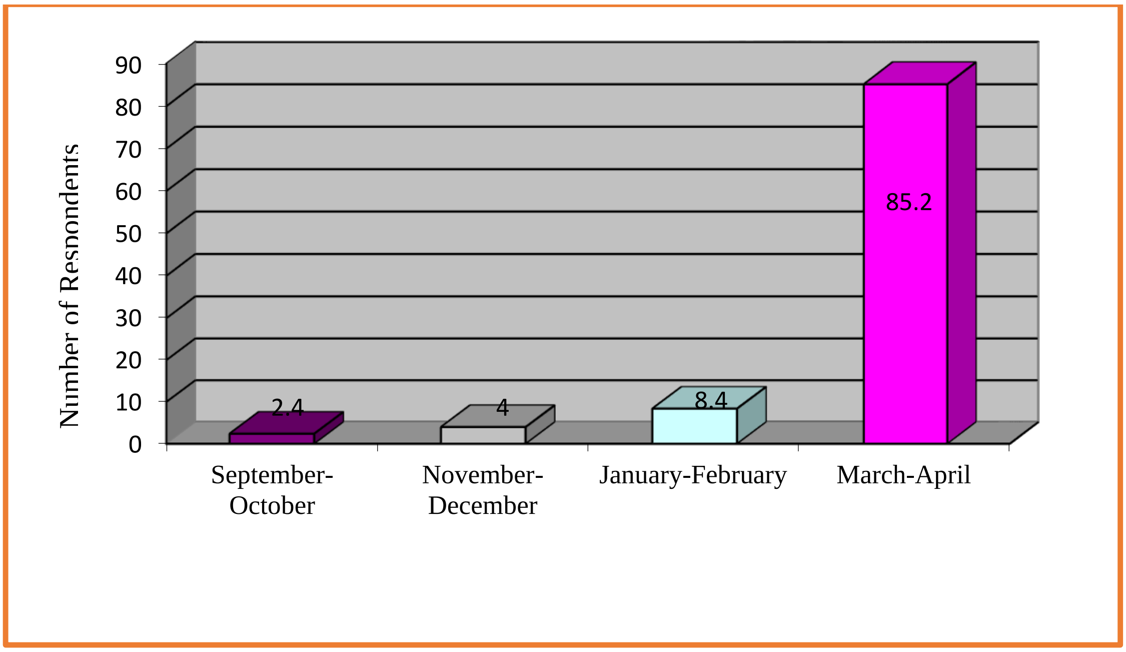

Figure 4.10: Period of water scarcity

Source: Field Survey, 2022

4.5 Evaluatemitigation and adaptation strategies to climate variability impact on water supply and distribution in the study area

Adaptation strategies adopted to reduce water shortage in the study area include distribution of water via water tankers, more hand-held borehole, rainwater harvesting, effective zoning of the distribution system of water supply and repair of visible and reported leaks of water pipe andthis is indicated in Figure 4.11.

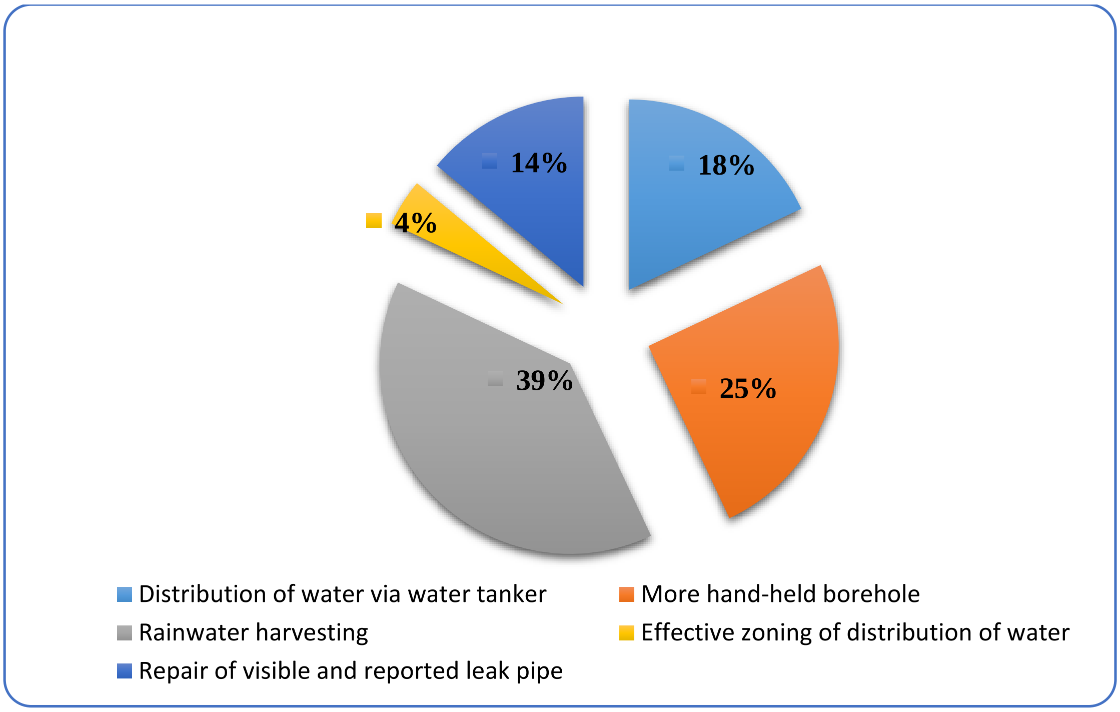

Figure 4.11: Adaptation Strategies Adopted during Water Supply Shortage

Source: Field Survey, 2022

From Figure 4.11, rainwater harvesting rank the highest with 39% of respondents', hand-held borehole rank second with 25%, distribution of water through water tankers ranks third with 18%, repair of visible and reported leaks rank fourth with 14% of respondents' and effective zoning rank the least with 4% of the respondents. This shows that, the respondents highly depend on rainwater for domestic usages in the study area.

According to Table 4.5, increased supply of water has been a major strategy of mitigating water supply scarcity in the study area because 50 out the 200 respondents ranked it as most appropriate mitigation strategy for the study area. The mitigation strategy that has made very negligible contribution out of 9 mitigation strategies identified is private sectors involvements in water management with only 13 out of the 200 respondents ranking it as an appropriate strategy.

Table 4.5: Mitigation strategies adopted to cope with water supply scarcity

Sampled settlements	DD	ISW	GWE	PSI	PP	PR	PC	ECW	OT
Mekunkele	1	7	1	1	3	2	8	2	-
Bosso	-	9	1	-	9	3	2	1	-
Maitumbi	3	-	5	4	-	1	9	1	2
F-layout	1	5	3	2	5	2	2	3	2
Kpakungu	-	5	3	-	12	1	1	-	3
Chanchaga	-	10	-	2	7	1	1	4	-
Limawa	3	-	10	-	2	4	1	4	1
Tunga	1	11	2	1	4	2	1	-	3
Total	**18**	**50**	**32**	**13**	**49**	**20**	**31**	**22**	**15**
Percentages of respondents	**7.2**	**20**	**12.8**	**5.2**	**19.6**	**8**	**12.4**	**8.8**	**6**

Source: Field Survey, 2022

KEY

DD – Decreased demand for water	ISW – Increased supply for water	GWE – Groundwater exploitation
PSI – Private sectors involvements in water management	PP – Public participation in water management	PR – Planned rationing
PC – Pollution control	ECW – Enlightenment campaign on water resource	OT – Other unspecified measures/strategies

4.6 Summary of Findings

The summary of findings for this study includes

The examination of the trend in climatic variables in the study area indicates that rainfall varies with time and space. Mean monthly rainfall tend to be higher in months of August to September and the least in the months of January to February. The highest mean monthly rainfall was in the month August with a value of 280.9mm while the least was in the month of November with a value of 3.6mm.and that,the distribution of annual rainfall in the study area, spanning about 20 years (2000 to 2020), The distribution of annual rainfall has been increasing despite the fluctuation in some years (2004 to 2006, 2013 to 2015). The highest annual rainfall was recorded in the year 2012 with 1520.9mm while the least annual rainfall was recorded in the 2013 with 793.5mm. This shows that annual water supply and distribution should be increasing since it depends on the increase of annual rainfall across the study area.

The distribution of temperature also shows that mean monthly maximum temperature increasing from march to April(33.9^{0}c to 37.2^{0}c) while the temperature tend to decrease from month of May to October (35.4^{0}cto 32.7^{0}c) this shows that the water supply and distribution will be affected negatively which will leads to shortage of water supply during the dry season (Higher evaporation).the mean annual maximum temperature of the study area, year 2010 ranked the highest with 33.8^0 c while 2019 rankedthe least with maximum temperature of 32.9^0 c. The distribution of maximum temperature across the study area shows that the temperature is on the increase despite some years (2007 to 2008, 2012,2015, 2018 and 2019) with decrease values. This shows that the water supply and distribution will be affected negatively through increase evaporation. The highest water supply was recorded in the month of September with 410m^3 while the lowest was recorded in the month of May with

240M$^{3.}$ This shows that rain season provide the study area with more water supply and dry season provide the area with less water supply which limit distribution apparently leading to watershortageacross the study area.This shortage is. partially taken careoff with boreholes and well waterThis shortage is partially taken care off with boreholes and well water. The distribution also shows that 2006, ranked the highest with 4410m^3 while the 2007 ranked the lead with 3754m^3.This reveal that annual water suppl supply is increasing with some deficit years. Below 4034m^3.

On the population response to water supply and distribution, shows that 50% of the respondents were of the opinion that poor maintenance is the challenges of water supply, 13 % said inadequate power supply and this has to do with pipe borne water in the study area.8% pick lack of autonomy with respect tape water and 29% were of inadequate fund is the challenge of water supply. This implies that poor maintenance of water supply in the study and distribution facilities was the major challenge of water supplyin thestudy area.

The major water supply problem in the study areais distance from source 64.8%, 16% said that inadequate in supply is their problem 10.4%were of the shows that effects of inadequate supply,8.8%of the respondents said that low dependability from course makes them do things they don't like i.e sleepless nights fighting and quarreling, sleeping without food, cooking late dirty cloths and surrounding^s.water supply is severe between the month of march and April which has 85.2%, while between September and october ranked the least with 2.4% This coincides with the pick period of dry season, when the water table is very low.

With respect to mitigation and adaptation strategies rain water harvesting rank the highest with 39% of respondent, hand held borehole rank the second with25%distribution of water through water tankers third with 18% repair of visible and reported leaks ranks fourth with 14%of respondents and effective zoning ranks the least with 4% of respondents. This shows that, the respondent highly depends onrain water for domestic usages in the study area.

According to table 4.5,Increased supply of water has been a major strategy of coping with water supply scarcity in the study area because 50 out the 200 respondents ranked it as most appropriate mitigation strategy for the study area. The mitigation strategy that has made very negligible contribution out ofMitigation strategies identified is private sectors involvement in water management with only 13out of the 200 respondents ranking it as an appropriate strategy.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The impact of climatic variability on water supply and distribution in study area.was investigated.The various challenges of water supply and adaptation strategies put in place to reduce the impact of climate variability on water supply in the study area were analyzed.Climatic variability precisely rainfall, relative humidity and maximum temperature has affected the availability and quantity of water supply in the study area and the evidence suggests that the causes of climatic variability are complex, involving both natural forces and anthropogenic activities. The study area is endowed with abundant surface water resources which remain largely untapped. Planned development of available surface water resources in the study area through surface and underground storage and planned exploitations of ground resources through boreholes, would minimize the seasonality of water supply in most parts of the study area, promote year-round efficient water supply/distribution and enhance the welfare of the people.

5.2 Recommendations

1) There is need for continues monitoring and assessment of climatic variables as they affect water supply and distribution in the study area.
2) There should be effective water management practices to forestall scarcity experienced during drought period.
3) Community participation should be encouraged as it can lead to a successful water supply and distribution scheme as witnessed in Malawi. This could be

done through personal involvement in the form of contributing money for the purchase and installation of additional storage and distribution facilities.

4) Community deep wells or boreholes should be constructed in areas with adequate ground water resources.
5) Rainwater may also be collected and stored in durable but non-rusty storage tanks during the rainy season for use during the dry season when surface streams may dry up and the yield from wells may be insufficient.

5.3 Contribution to Knowledge

The study established that there is a general increase in rainfall amount across the study location which hovers between 793mm. and 1520 mm with clear volatility in the amount unthin individual years, the inghest annual rainfall of 1520 mm was recorded in 2012 while the increase of 793 mm was recorded in 2013. The implication of this vocation in rainfall amount is reflected interms of decrease in water availability for urban use and groundwater recharge during drought years, it further revealed a gradual rise in temperature, which reaches its peak in the February to April, during which ground water recharge reduces which consequent reduction coefficient of 0.65 the study. Indicated moderate degree of association between maximum temperature and annual water supply. The finding shows that the highest water supply was recorded in the month of September with 410m3 while the lowest was recorded in the month of may with 240m3. The implication of this study is that future temperature rise in the study area may have adverse effects on water availability and supply in the study area.

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