IMPLICATION OF RAINFALL AND TEMPERATURE VARIABILITY ON PORTABLE WATER SUPPLY ANALYSIS IN CHANCHAGA LOCAL GOVERNMENT AREA, NIGER STATE, NIGERIA

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MTech/SPS/2017/7320

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ABSTRACT

In recent time, Minna, the Niger State capital has witnessed prolong period of dry season, heat stress and fluctuating pattern of rainfall. Also, Chanchaga Local Government Area of Niger State has been facing serious challenge of portable water supply despite the effort of the government in providing pipe borne water. This study therefore, investigates rainfall and temperature variability and its impact on portable water supply in Chanchaga Local Government area of Niger State. Thirty years meteorological data (1989 -2018) consisting of monthly mean rainfall and air temperature were collected from the archives of the National Aeronautics Space Agency (NASA) for the study. Also, two hundred questionnaires were administered within five selected locations in Chanchaga Local Government Area to generate data related to portable water supply within the study area. This along with information on water production trend collected from the Chanchaga station of Niger state Water Board was analysed in this study. Descriptive statistics such as the mean, standard deviation, coefficient of skewness, coefficient of Kurtosis and coefficient of variation was computed from the climatic data obtained. The result of this study revealed that coefficient of variation of the annual mean rainfall data falls between 88.46% in 1997 and 126.51% in 2015 indicating extremely high rainfall variability over the study area while, air temperature data over the study area shows a slight variation with values between 0.19% in 2015 and 4.39% in 1990. There is a general decreasing trend in rainfall amount recorded in the study area while temperature show a general increasing trend over the last two decades (1999-2018). Moreover, investigation into portable water sources in the study revealed that Borehole, Hand pump, Tap and Hand dug wells are the main water sources in the selected locations. The main sources of drinking water identified are borehole water (35%), tap water (22%), well water (17%) and sachet water (16%) while, the sources of domestic water supply identified are boreholes (32%), hand dug wells (30%), tap (23%), vendors (7%), hand pump (6%) and water tankers (2%). However, this show that tap water supply to the study area is not sufficient as many people depend on alternative water sources for drinking and domestic use. Therefore, there is need for increase in tap water pipe network and water supply to cope with increase in population in Chanchaga local government area of Niger state. Finally, this study clearly shows that there is notable change in portable water supply in the study area over the past decades and the change is partly attributed to climate change and partly to the increase in population of people in the study area. Hence, government need to put in place strategies to mitigate the impact of climate change on water supply system in the study area.

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ABBREVIATIONS, GLOSSARIES AND SYMBOLS

CH_4	Methane
CHIRPS	Climate Hazards Group InfraRed Precipitation with Stations
CO_2	Carbon dioxide
CV	Coefficient of Variation
DFID	Department for International Development
DTR	Diurnal Temperature Range
FEWS NET	Famine Early Warning Systems Network
GDP	Gross domestic product
GHGs	Green house gases
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Area
MK	Mann Kendall
MMK	Modified Mann Kendall
N_2O	Nitrous oxide
NASA	National Aeronautics Space Agency
NCE	National Certificate in Education
ND	National Diploma
NIMET	Nigerian Meteorological agencies
NSWBM	Niger State Water Board Management
PW	Pre-Whitening
SAI	Standardized Anomaly Index
WMO	World Meteorological Organization
Z_1	Coefficient of skewness
Z_2	Coefficient of Kurtosis
σ	Standard deviation

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Water availability is crucial to human existence, as water is required for human consumption, agriculture, production in industry, power generation and many other human activities such as cooking, cleaning, recreation and washing. The availability of fresh water in the form of surface water (like stream, lakes, rivers, reservoirs) and ground water in soil layers or rock and natural springs is beneficial to mankind and is one of the determinant of human settlement. Availability of clean and unpolluted water is a basic necessity for sustainable development (Enefiok and Ekong, 2014). Thus, provision of clean water was listed as one of the main targets of the millennium development goals (Carr and Neary, 2006). Changes in the availability of water through droughts, precipitation and depletion of aquifer volumes, have serious consequences for the development of villages and urban communities (Duran-Encalada *et al.* 2017). Aside, the direct demands people place on fresh water sources, climate change is one of the major challenges militating against availability of portable water supply (McBean and Motiee, 2008). On the global scale, the warming associated with climate change result in the melting of polar ice into the sea. This turns fresh water into sea water, leading to shortage in fresh water supply.

The reality of climate change in the past years has been an issue of great concern to the global community of researchers and various governments across the world. Climate change is said to be one of the crucial environmental issues widely discussed in the last two decades (Singh *et al*., 2013). The change in climate will remain for a long time; therefore, researchers all over the world are investigating the cause in other to proffer solutions (Obot *et al*., 2010). The activities of man on earth result into the production of greenhouse gases that cause global warming. Climatic variation is not universal, it occurs in both time and space. Therefore the nature and extent of global, regional and local variations of climate differs. The existing indications of climate change is the increase in global temperature which cause the melting of glaciers/polar ice leading to rise in sea level, shifting of global climate zones and increased heat stress. Also, other manifestation of climate change is the fluctuation in rainfall duration and pattern. This leads to flooding, drought, desertification, poor agricultural yield, lowering of water table, changes in the ranges of disease vectors and occurrence of other extreme weather events (Abaje *et al*., 2010; Adakayi, 2012).

In numerical terms, record shows that the mean global earth temperature has increased by $0.74 \pm 0.18^{o}C$ during the last one hundred years (IPCC, 2007). However, this value is not fixed for all locations across the world, as the changes differ from one region to the other (IPCC 2007). For instance, the annual temperature average for Ethiopia has reportedly risen by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade. Also, average annual temperature rise of 1.1 to 3.1°C is expected in Ethiopia by the 2060s, and projected increase of 1.5 to 5.1°C by the 2090s (McSweeney *et al*., 2007; Fentahun and Gashaw, 2014). In Bangladesh, the annual temperature average has reportedly risen by $0.31^{o}C$ from 1895 to 1980 (Mehrotra and Mehrotra, 1995), while the average annual maximum temperature has been anticipated to rise by $0.4^{o}C$ and $0.73^{o}C$ in the years 2050 and 2100 respectively (Karmaker and Shrestha, 2000). An increase of one to two degrees in mean annual temperature is expected throughout the United States over the coming decades. Nigeria is not left out in the issue of climate change and climate variability. According to Akinsanola and Ogunjobi (2014), there have been significant increases in air temperature and rainfall in many parts of the country with observed rising and declining trends rainfall and temperature in other parts. A study of the temperature variation across the six ecological zones of Nigeria reveals a rising trend in most of the studied region (Eludoyin, 2011). In 2012, Nigeria recorded unusually high amount of rainfall in many states across the country. This led to severe flooding which caused loss of many lives and destructions of properties value at several millions of naira. Udoimuk *et al*. (2014), noted that the flooding is a perennial occurrence in Calabar, South southern region of Nigeria. They further reported that the inconsistence nature of rainfall patterns in the state has so many adverse effects (such as flooding, outbreak of diseases, destruction of farm lands, displacement of residence) on the inhabitants of the state.

Considering the discussion above, it is worth noting that temperature and rainfall variations are vital indicative factors of climate change (Obot *et al*., 2010; Amadi *et al*., 2014; Owolabi, 2016). The climate of a locality or region is best understood by analysing the temperature and rainfall of the location (Akinsanola and Ogunjobi, 2014). The decreasing rainfall and increasing temperature, with resultant increasing evapotranspiration has serious implication on water availability. The change in rainfall and temperature affects water cycle and cause change in the natural processes of surface runoff, evapotranspiration rates, sediment transport, with attendant effects on water availability. However, with increase understanding of the negative effects of climate change on water resources, an evaluation of portable water supply at local and regional scales is imperative (Kumar *et al*., 2010). Such assessment requires a critical analysis of rainfall and temperature trends, as well as, its implication on water availability at different geographical locations.

In Nigeria, increasing temperature trends, variation in rainfall patterns and shifting season have been reported by researchers across the country (Eludotin *et al*., 2009; Ogungbenro and Morakinyo, 2014; Akinsanola and Ogunjobi, 2014). Decline in rainfall amount in Nigeria has been specifically reported by Odjugo (2005, 2009). In a study on water availability in Ikeduru, Imo state Nigeria, Onyenechere *et al*., (2011) observed that reduction in rainfall amount has adverse effects on water supply to rural community in the study area. Although, many studies on the recent trends in rainfall and temperature have been done across the various locations and climatic zones of Nigeria, there are only few of such studies that focus on water availability. Thus, the focus of this study is to analyse the implication of rainfall and temperature variability on portable water supply in Chanchaga local government area of Minna, Niger State. Water supply is a major social infrastructure that is grossly inadequate in Minna metropolis. Considering the rapid population growth in Minna and the challenge of water supply in the town, as well as, the changing rainfall and temperature patterns in recent times, this study is aimed at analysing the implication of rainfall and temperature variability on portable water supply in Chanchaga local government area of Niger State.

1.2 Statement of the Research Problem

Intergovernmental Panel on Climate Change (IPCC, 2007), reported that climate change will affect agriculture and bring about the risk of hunger. It is also causing rapid melting of glaciers and increase water scarcity. Climate change, with reference to variation in rainfall and temperature, is a global phenomenon. Hydrological resources such as ponds, streams and rivers that are largely dependent on rainfall are negatively affected by climate change and this calls for a serious concern, as it indicates danger on water availability and human society. Climate change shows overall net negative impact on water bodies and freshwater ecosystems across different regions of the world. Investigation on the impacts of the changing climate on the water resources of Indian rivers systems revealed that freshwater availability in many river basins in India will possibly reduce as a result of climate change (Gosain *et al.*, 2006). According to United Nation report, the present climate change situation will make about half of the world's populace to live in places of high water stress by 2030. Also, the report indicated that almost 75 million to 250 million people in Africa will be subject to high water stress.

In Nigeria, a good number of people, especially in the rural communities, depends on streams, ponds, rivers and rainfall collection for their water supply. In Northern Nigeria, report indicates that, decrease in rainfall, increase in temperature and high evapotranspiration observed have resulted in complete dry up of some rivers and reduction of water levels in other rivers. For instance, Lake Chad at the northern boundary of Nigeria is observed to be decreasing in size at a rapid rate over the last forty years (Chindo and Nyelong, 2005; Odjugo, 2007).

In the last one decade, Minna, the Niger State capital has witnessed remarkable population growth and expansion in buildings infrastructure due to high influx of people from the neighbouring states. In this regard, Chanchaga Local Government area in Minna has been facing serious challenge of portable water supply despite the effort of the government in providing pipe borne water. Adegbehin *et al*. (2016), examined the challenge of domestic water supply in Dutsen Kura Gwari area of Chanchaga Local Government through field investigation. The result shows that the supply of pipe borne water in the area is grossly inadequate and most of the hand dug wells dry up in the dry season, leaving the residents with a serious water supply challenge. This problem results in an individual effort to meet their daily water demand through other water sources such as boreholes, hand dug wells and patronising water vendors (Ishiaku *et al.*, 2014). Also, Minna has been experiencing prolong period of dry season, heat stress and fluctuating pattern of rainfall in recent time. The prolong period of dry season couple with the heat stress experience in Minna make life uncomfortable for people and animals in the town. The high temperature and the associated heat stress results to outbreak of diseases and sometime loss of life. Moreover, the onset of rainfall in Minna has been drifting between April and May while the offset of rainfall has been either September or October. Moreover, the quantity of annual rainfall in Minna is changing almost every year. The unpredictable rainfall pattern in the town is affecting the agricultural production and water cycle. Some researchers have investigated the trends of rainfall and temperature in Minna but, no particular attention has been placed on the impact of these climatology factors on portable water in Chanchaga area of Minna. Adequate knowledge of the effects of climate change especially of rainfall and temperature trends on portable water supply in Chanchaga area is imperative for future water availability in the city. This study is set to address the challenge pose by changing rainfall and temperature on the present and future portable water supply in Chanchaga local government area (LGA) of Niger State.

1.3 Research Questions

This study is design to address the following questions:

i. What is the trend of monthly and annual rainfall and temperature in Chanchaga Local Government Area?

ii. What is the source(s) of portable water supply and trend of water production in Chanchaga LGA?

iii. What is the implication of rainfall and temperature variability on portable water supply in Chanchaga?

1.4 Aim and Objectives of the Study

The aim of this study is to investigate rainfall and temperature variability and its impact on portable water supply in Chanchaga Local Government area of Niger State. The objectives of the study are to:

i. identify the trend of monthly and annual rainfall and temperature in Chanchaga LGA;

ii. examine the sources of portable water supply and their capacity in Chanchaga LGA;

iii. determine the implication of rainfall and temperature variability on portable water supply in Chanchaga LGA.

1.5 Scope and Limitation of the Study

This work covers only Chanchaga Local Government Area in Niger State. The study examined the climate variations in the study area using temperature and rainfall data of Minna. Monthly mean data of temperature and rainfall for a period of thirty years was used for the study. The temperature and rainfall data recorded in Minna was collected and analysed using statistical data analysis technique to detect the monthly and annual variation in the data. The study examined the sources of portable water supply in the study area and the possible implication of rainfall and temperature variability on them.

1.6 Justification for the Study

The reality of climate change and its resultant challenges on the global population in recent time informed the need to understand the trends of the changing climate, as well as, its implication on portable water supply. In Nigeria, evidence of climate change has been established with rapid changing patterns of rainfall and temperature leading to flooding and other consequences (Adakayi, 2012; Akinsanola and Ogunjobi, 2014). Rainfall and temperature are two common climatic parameters usually analysed for evidence of change in climate. Therefore, it is important to examine the implication of rainfall and temperature trends on portable water supply. This study is particularly important to study area because access to freshwater supply is one of the major social challenges of the residents of the area.

This study helps us to understand rainfall and temperature trends in Chanchaga LGA of Niger state. This information will be useful to farmers in the area in planning there farming activities. It will equally be beneficial to the residents in planning coping strategies, and for government to developed policy for adaptive strategies against the changing climate. Moreover, this study enables us to understand the effects of rainfall and temperature trends on domestic water supply in the study area. This information will be useful in proffering solution to the current and future water supply problems in the area. The work will also serve as a blueprint to the water management board and individual seeking to have privately own water source on how to plan for sustainable water supply. Therefore, this work is imperative to the understanding of climate change and sustainable water supply for both domestic and industrial use in Chanchaga LGA of Niger State. This work will contribute considerably to the well being of the people by helping the government and the people to prepare for adaptive strategies against the changing climate and taking proactive measures for the present and future water supply in the study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water Distribution on Earth

A large proportion of the earth surface is covered by water. The water body occupy 71% of the earth's surface. However, water distribution on earth is not uniform. Countries along the equator and those that are farthest away from the equator (countries with highest latitudes) have high level of rainfall to provide them enough fresh water. Countries at latitude around 30^o north and south of the equator don't have enough rainfall, thereby, experiencing water scarcity. The earth's water supply is not still, but in a continuous motion from one place to another and from one form to another. This dynamic movement of water is referred to as 'water cycle'. Saline water in the ocean forms the vast majority (about 97.5%) of the total water on the earth's surface. The remaining 2.5% of water on the earth surface is fresh. Only 1.2% of the freshwater forms surface water; 30.1% forms groundwater; and 68.7% is in the form of ice and glaciers (Gleick, 1993). The freshwater resources provide useful water for everyday need of mankind. The distribution of water on the earth's surface is shown in Figure 2.1.

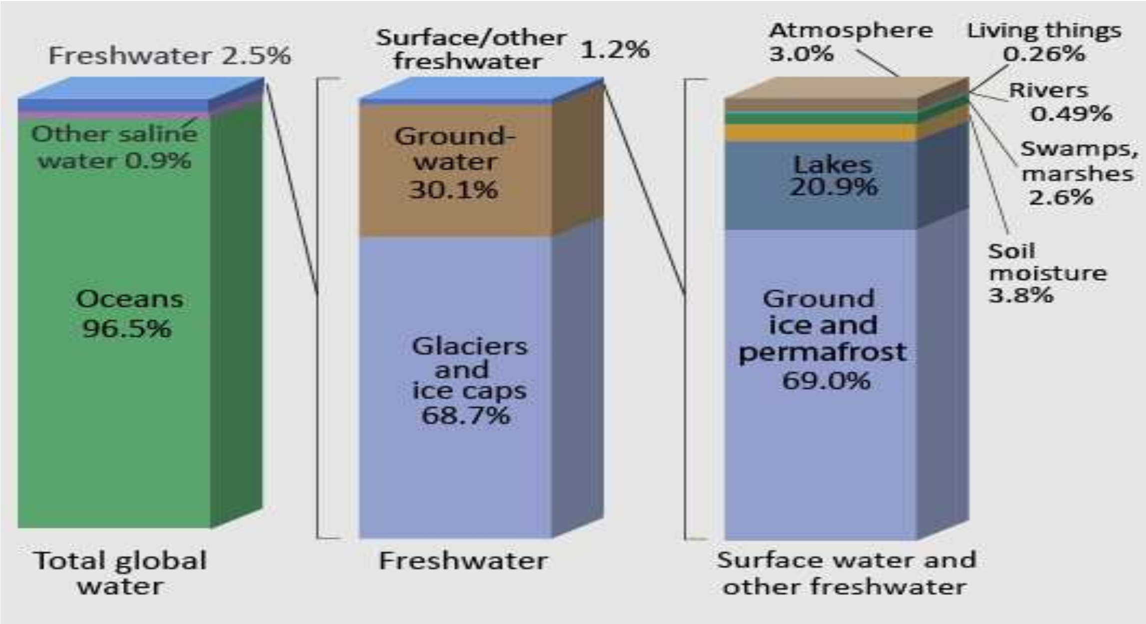

Figure 2.1: Distribution of water between Earth's major reservoirs

Source: Gleick, 1993

2.2 Portable Water Supply in Niger State

Portable water is water that is safe for drinking or food preparation. It is also sometimes refer to as drinking water. Portable water supply is required for healthy living because contaminated water is the cause of many illnesses and other health hazard. Provision of clean and adequate water is one of the social responsibilities of government. However, in Minna, like in most state in Nigeria, this social amenity is in short supply. Minna metropolis is made up of Bosso and Chanchaga Local Goverment with an estimated population of 350,287 people as at 2006 Census (Ishiaku, 2014). Lack of adequate water is a common phenomenon within the two local government area of Minna. Reports show that 67% of the people in Dutsen Kura area (in Chanchaga Local Goverment) are without tap water supply (Adegbehin *et al.*, 2016), while only about 28% of people in Bosso have access to tap water supply (Gimba, 2011). A study across other locations in the city reveals that the alternative water sources in Minna are boreholes, wells and water from vendors (mai ruwas) (Adegbehin *et al.,* 2016). Availability of both drinking water and water required for domestic use is a source of great concern to many people in Minna. This has led to proliferation of water vendors and increase in the number of sachet water (known as ‘pure water’) factories in the town. Water from vendors is not safe for drinking because some of them are gotten from unimproved/unhygienic sources.

Major sources of water in Minna include tap water (from water board), privately owned boreholes and hand dug wells. As earlier stated, Minna is fast growing in term of building infrastructure and human population, but most of the newly developed sites are connected to water board water distribution network. This places the burden of water provision on the house owners in such locations. Another challenge about water availability in Minna is the fact that most of the hand dug wells dry up at the peak of dry season thereby increase water scarcity. It is also reported that, some geological areas in Minna do not support drilling of borehole, this make it impossible to drill boreholes in such locations ((Ishiaku *et al*., 2014). Even where the geology of the area supports drilling, the cost of having a functional borehole is out of the reach of common man.

The current water supply capacity form the Niger State water board is not enough to support the growing population in Minna metropolis. Ishiaku *et al*., (2014) attribute the shortage in water supply from the water board to the inadequate budgetary allocation to ministry of water resources. Tap water supply in to Chanchaga LGA is from the Chanchaga office of the Niger State water board management. The source of the water processed and supply from the water cooperation is Tagwai dam.

2.2.1. Features of Tagwai Dam

Tagwai dam is the major source of tap water supply to Chanchaga Local government and other locations in Minna metropolis. Tagwai dam was constructed in November, 1978 and the major sources of water for the dam are River Jidua and Lumo (NSWB, 1978; Ibrahim *et al*., 2012). The dam is strategically located at the confluence of these two rivers. Other important features of the dam are shown Table 2.1.

Table 2.1: Features of Tagwai Dam

Feature	Size
Average annual rainfall	1270mm
Catchment area	$110km^2$,
Average annual rainfall	$25.0 \times 10^6\ m^3$
Total storage capacity	$28.3 \times 10^6\ m^3$
Dead storage capacity	$1.8 \times 10^6\ m^3$
Active storage capacity	$26.5 \times 10^6\ m^3$
Surface area of lake	550 hectares
Type of dam	Zoned Earth filled
Crest length	1770mm
Crest width	10m
Hydraulic height	21m
Total volume of Earthwork	$870 \times 10^3\ m^3$
Service spill way	110m
Emergency spill way	170m
Intake tower	2 x 24” diameter steel pipe

2.3 Factors Affecting Water Availability

The factors affecting availability of fresh water supply is broadly categorized into two: Physical and human factors.

2.3.1: Physical factors affecting water supply

i. **Climate:** Climate determines the availability of snowfall, rainfall and rates of evaporation. Climate varies with time leading to the occurrence of different seasons as wet and dry periods, hot and cold periods (Cool Geography, 2015). This can affect water availability. The recent change in climate brings about low levels of rainfall and high temperatures which in-turn leads to water deficits. When there is reduction in rainfall amount, there will be less water available for use (BBC, 2019). Also, high temperatures lead to rapid evaporation of water and reduction in fresh water. Water surpluses are common in location with high rainfall and low temperatures. Areas with few lakes or rivers, low groundwater supplies, low rainfall and generally arid conditions experiences scarcity of water. The prevailing climate of a place determines access to water supply in such location.

ii. **Geology:** The geology of a place determines where water is stored and the location of groundwater and aquifers. When rain falls, water flows down to the rocks beneath the ground, where the rocks are impervious, water remains on the Earth's surface in rivers. The water is then transported to other place by the rivers. In place where there are permeable rocks like sandstone, water infiltrates into the ground and either be carried away by underground river systems or be stored. Permeable rocks form aquifers, which mean they are stores of water.

2.3.2 Human factors affecting water supply

(i) Pollution: Water pollution is a major threat to freshwater sources all over the world. The threat to water resources occurs by dumping of wastage into water bodies and careless dirtying of it (Cool Geography, 2015). Human activities results in the contamination of surface as well as ground water sources. Some of the major sources of water pollution includes: release of untreated raw sewage from households and industries into waterways; dumping of chemicals and heavy metals into rivers; washing of agricultural run-offs into streams and rivers and groundwater sources; and discharge of other human waste into lakes, rivers, oceans and other water bodies.

(ii) Over-abstraction: This occurs when water is being used more quickly than it is being replaced. This situation occurs where the demand for water is more than its supply. Taking too much water out of an aquifer can limit future water supplies which will be a serious challenge for people in such environment.

(iii) Water transfer - Water transfer schemes is done to take care of water shortage. This is a system of transporting water from one river basin to another by constructing elaborate systems of pipes, canals and dredging over long distances.

2.4 Concept of Climate Change

Climate is the average condition of weather in a place over a period of thirty years. It is expressed as the average state described by temperature, rainfall, wind, sunshine and other climatic parameters (Ayoade, 2003). The World Meteorological Organization (WMO) recommended the use of 30 years to derive the climate of a place because it is believed that a period of 30 years is enough for estimating climate normal, whether of rainfall or temperature (Ayoade, 2003). Climate system is the totality of the atmosphere, biosphere, hydrosphere, geo-sphere and their interaction with human beings. Climatic variation is not universal, it occurs in both time and space. Therefore the nature and extent of global, regional and local variations in climate differs. The two terms used in describing the change in climate are: climate change and climate variability.

Climate change is the change in average weather conditions over a long period of time usually not less than 30 years. According to IPCC (2007), climate Change is 'a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer)'. The term, climate change is normally used when there is a prevailing change in the climate of a place over a long time. Climate variability on the other hand is defined as the variations in the mean state and other statistics of the climate on all temporal and spatial scales beyond that of individual weather events.

Over the past century, a gradual rise in global temperature has been observed. This noticeable change in climate started around the 1950s, with rapid warming of the Earth's climate system unlike the previous years or centuries (Pachauri *et al.*, 2014). The mean global earth temperature is said to have risen by 0.74°C during the last hundred years (1906-2005) (IPCC, 2007). Also, a global temperature rise of 0.13°C per decade has been noticed over the past fifty years which is double the decadal rise over the last 100 years (Solomon, 2007). This fast increase in the earth's temperature and the resultant warming of the earth's atmosphere is attributed to the increase in the emission of greenhouse gases into the atmosphere. The tremendous increase in the concentrations of green house gases since 1980s has triggered increase in global air temperature from around 1980s till date. This gradual warming of the earth is said to continue except drastic step is taking to address the ugly situation. The earth's mean temperature is projected to rise between the range of 1.5°C and 4.5°C by 2030, if the present trend of anthropogenic GHGs emissions is not reduced (Porter and Brown, 1991) in Ebele and Emodi, (2016).

2.4.1 Causes and consequences of climate change

The causes of climate change are classified into two basic factors: the natural process (Bio-geographical) and human activities (Anthropogenic). A schematic diagram showing the causal factors of climate change is presented in Figure 2.2.

The natural factors and its effects have relatively short term effects on climate (Ebele and Emodi, 2016). Hence, climate change and global warming results mainly from anthropogenic-driven emissions of greenhouse gases land-cover and land-use change. Human activities such as burning of fossil fuels, bush burning and deforestation have significantly increased the amount of greenhouse gases emitted to the atmosphere over the past decades (National Research Council, 2001). Carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) are the major green house gases (GHGs) and they respectively account for 80%, 14% and 6% of the total atmospheric concentrations of GHGs (SACAU, 2009).

The Anthropogenic-driven emitted greenhouse gases into the atmosphere increases the naturally existing concentration of these gases and thereby cause depletion of the ozone layer. This increases the amount of ultraviolet rays reaching the earth surfaces. Green house gases are good absorbers of heat. They are like a blanket over the earth's atmosphere absorbing the radiation coming from earth's surface, thereby keeping it warmer than it would be. The more the amount of GHGs in the atmosphere, the warmer the earth becomes, resulting into climate change.

The drastic changes in climate have a wide array of impacts on lives on earth. Notable among the effects of climate change are: shifting seasons, increasing temperature, rising sea levels, changing rainfall patterns, flooding, higher variability in storms and other extreme events. The developing countries suffer more from these adverse effects than the developed nations because of poor adaptation and lack of appropriate technology to mitigate its impacts (Ebele and Emodi, 2016).

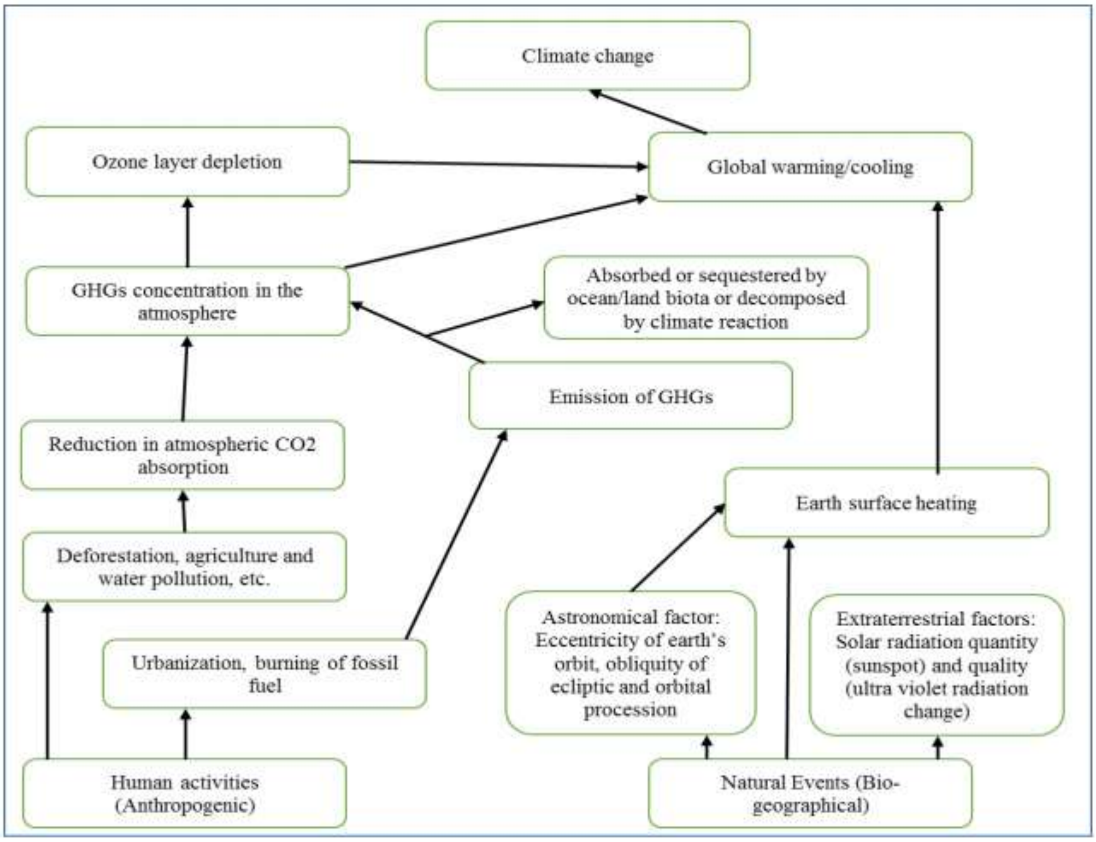

Figure 2.2: Causal factors of climate change
Source: Adapted from Odjugo, 2008

Nigeria as one of the developing nations in Africa is already experiencing the effects of climate change. Incidence of flooding is now a yearly occurrence in some states in the country. Besides, increasing temperatures, variation in rainfall patterns and shifting season have been reported across the country (Eludotin *et al.*, 2009; Ogungbenro and

Morakinyo, 2014; Akinsanola and Ogunjobi, 2014). According to Nigerian Meteorological agencies (NIMET, 2008) report on the onset and cessation of rainy season across the various locations of the country over the period of 1941 to 2000, few locations experience late onset of rainfall between 1941 and 1970, while many locations across the country experience late onset of rainfall from 1971 to 2000. Moreover, the study on the timing of cessation of rainy season in Nigeria revealed gradual change from "normal" between 1941 and 1970 while early cessation is recorded in many locations during the 1971 to 2000 period (NIMET, 2008). According to the report by the Department for International Development (DFID), climate change will cost Nigeria between 6% ($100 billion) to 30% ($460 billion) of her gross domestic product (GDP) by 2050 (UN FAO, 2009).

2.5 Concept of Temperature and Rainfall Trends

A trend is a long-term change (decrease or increase) in a time series. Temperature and rainfall trends therefore refer to the long time variation/change in temperature and rainfall over a particular area or region. In climatology, trend analysis is normally used to know how climate variables (for instance, temperature, rainfall, relative humidity), varies with time. Moreover, trend analysis helps in predicting the future behaviour of climate parameters (Ragatoa, *et al.*, 2018**)**. In the study of climate change and climate variability, temperature and rainfall are the two most studied parameters across the world (Fentahun and Gashaw, 2014; Camberlin, 2017). Also, one of the vital and attractive research areas in climatology is trend detection in temperature and rainfall (Amadi, *et.al* 2014). Temperature and rainfall changes are not uniform across the globe, as they vary with locations and seasons. Regional differences can be much larger, and substantial spatial and temporal variations may occur between climatically different regions (Yue and Hashino, 2003). This has necessitated researches on different spatial and temporal scales across the various locations and regions of the world. In studying temperature and rainfall trends, daily, monthly and annual data from reliable source(s) are normally used.

Trend analysis of temperature and rainfall has been carried out by researchers in many part of the world using different statistical analysis tools. Descriptive statistics (such as mean, median, standard deviation, coefficient of kurtosis and coefficient of skewness (Abaje *et.al*, 2010) has been widely used in many studied (Akinsanola, and Ogunjobi, 2014; Hayelom et al., 2017; Nyatuame, *et.al*, 2014). Others statistical analysis tools commonly employed in trend analysis include: Mann Kendall (MK) trend test (Ragatoa, *et al*., 2018), Modified Mann Kendall (MMK) (Hamed and Rao, 1998), Pre-Whitening (PW) methods (Bayazit, *et.al*, 2004), Standardized Anomaly Index (Abaje, *et.al*, 2010), Relative Seasonality Index (Abaje *et.al*, 2010) and Cramer's test (Abaje, *et.al*, 2010). Similarly, SPSS software is also use in analysing temperature and rainfall trends (Fentahun and Gashaw, 2014).

2.5.1 Variation of temperature and rainfall in Nigeria

The reality of climate change in the last few decades has drawn researchers' interest to the study of rainfall and temperature variation. Anuforom (2012) stated that annual rainfall amounts in Nigeria were generally higher than long term mean values.

In Nigeria, several other studies have been conducted on the rainfall and temperature variation in order to ascertain impact of climate change in the country. These studies vary in their area of coverage as some are limited to one or two location(s), while others cover many locations or climatic zones. The studies will be reviewed under the following group/sub-headings:

i. Studies on rainfall trends in Nigeria
ii. Studies on temperature trends in Nigeria
iii. Studies on rainfall and temperature trends in Nigeria

2.5.1.1 Studies on rainfall trends in Nigeria

Rainfall is a climate parameter that influences every aspect of the ecological system, flora and fauna inclusive. It affects human life and dictates the way and manner man lives (Obot *et al*., 2010). The study of rainfall is crucial because of the benefits of rainfall to man and other living things on earth. Apart from the advantageous aspect of rainfall, it can also be destructive in nature; as excess rainfall leads to natural disasters like floods and landslides (Ratnayake and Herath, 2005, Obot *et al*., 2010).

The study of rainfall trend is very important to Nigerians because of the reliance on rainfall for food production and other agricultural purposes. One of the earliest studies on rainfall trends in Nigeria was done by Adefolalu in 1986. The study examined trends in the rainfall pattern in Nigeria using data from twenty-eight meteorological stations for a period of seventy years (1911-1980). The results of the study revealed that there is an anomaly in the rainfall pattern across the country, with a decreasing dry season contribution to the total annual rainfall which may lead to a drier environment in the long term (Adefolalu, 1986). Some of the recent studies on rainfall trends and characteristics in the last two decades are discussed below.

Ayansina *et al*. (2009) studied the rainfall variability in Guinea savannah zone of Nigeria and found that there is continuous increase in rainfall variability in the zone. This variability is attributed to as an element of climate change. Eludoyin *et al*. (2009) also investigated monthly rainfall distribution in Nigeria between 1985 and 2004 and reported some fluctuations in most months within the studied period. Obot *et.al* (2010) examined the characteristics of total amount of annual rainfall in Nigeria using data from six locations selected across different region in Nigeria. The selected locations for the study are: Ibadan in the South West, Calabar in the South South, Enugu in the South East, Kaduna in the North West, Lokoja in the North Central and Maiduguri in the North East. In their study, Mann-Kendall test was used to test for significant trend in rainfall in the selected locations within a 30 years period (1978-2007). The results show that during the period of the study, there is no significant variation in the annual mean rainfalls in five out of the six locations. However, Maiduguri showed an increasing trend in the last sub period of (1988-2007) at a rate of 9.88 millimetre per year and a decreasing trend in the previous sub period. They suggested the need for continuous monitoring of the rainfall trends especially in the North Eastern part of the country.

Abaje *et.al.* (2010), investigated the trends in rainfall regime in Kafanchan, Kaduna state using thirty-five years (1974-2008) rainfall data. To identify trends, the rainfall series dataset was divided into 10-year overlapping sub-periods and the Cramer's test was used to compare the means of the sub-period with the average of the whole record period. The findings of the study revealed a decreasing trend of the annual rainfall from 1990 to 2008. Also, in the sub-period 1974-1983 and 1999-2008, the months of June and October respectively were observed to be appreciably drier. The decline observed in the annual rainfall is attributed to significant reduction in July to October rainfall.

Alli, *et.al (*2012) investigated the variation of rainfall over Nigeria, and their implications for agriculture and water resources. In this study, rainfall data of forty-seven years (1960 – 2006) from twenty stations across the country were analysed using the Mann-Kendall test. The result revealed dominant peaks in rainfall return at various rates. Decreasing trends of annual rainfall were reported in Benin, Yola, Maiduguri, Akure and Calabar at the rates of 0.03, 0.12, 0.75, 1.084 and 1.80 mm/month/yr, respectively with return periods between 1-2 years and 7-10 years. On the other hand, rising rainfall trends was observed in about 75 % of the locations with return period of dominant peaks varying between 1-2 years and 15 years. The findings showed different spatial effects on ecosystem and agriculture. The magnitude of the return period determined the level of the implications of these trends on agriculture and water resources in each location. However, the study further revealed that Bauchi and Minna cities are expected to experience serious desertification and complete depletion of underground water due to the effects of no change in trend of rainfall.

Suleiman (2014) investigated surface run-off response to rainfall variation over Bida Basin. The author analysed thirty years rainfall dataset between 1980 and 2009. The result indicated declining trend in rainfall over the period of the study. Also, the study revealed that the rainfall trend is in the form of alternating dry and wet years with strong seasonal variation.

Ogungbenro and Morakinyo (2014) studied rainfall change detection across various climate regions in Nigeria. The study used 90 years (1910-1999) from forty –four weather stations across the country. The result indicated common change points and transitions from dry to wet (upward shift) in all climatic zones. Also, significant rainfall changes over each zone is expected.

In 2016, Famine Early Warning Systems Network (FEWS NET), a USAID-funded programme in Nigeria analysed the rainfall pattern in Nigeria from 1981 to 2015. The satellite dataset used was retrieved from the archive of the Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS). The result of the analysis suggests little change in rainfall patterns over the last 35 years, outside of the northern region. In a more specific term, the findings of the study indicate that since 1980s:

i. The timing of the start of wet season has not change significantly.
ii. The timing of the end of season is prolonged by 5-15 days in the north region.
iii. The overall length of the season in the north region is lengthened by 5 – 20 days.
iv. There is an increase in the total rainfall across the country.
v. There is a moderate drying trend in parts of the central and southern regions.
vi. The change in total rainfall is less than 10% in most areas across the country (FEWS NET NIGERIA, 2016 report).

Nzoiwu *et al*., (2017) analysed rainfall trends and water balance characteristics in Akwa using monthly precipitation data between 1976 and 2015. The result indicated fluctuation in the length of raining season and variation in amount of rainfall. However, there is a steady increase in the total amount of annual rainfall between 1988 and early 2000s and backward shift in the beginning of raining season from March to February in some of the years during the last ten years of the study period.

Olarewaju *et al*., (2017) examined rainfall characteristics and flood incidences in Warri metropolis using 30 years rainfall data (1986-2015). The study revealed declining trend in rainfall amount over the study period and variation in pattern of average annual rainfall in the area under study. They observed that flood incidence in the metropolis is causes by poor urban planning practices, absence/blockage of drainage and overflowing of rivers due to heavy rainfall.

2.5.2 Studies on temperature trends in Nigeria

Temperature is a physical quantity that indicates the degree of hotness or coldness of a "body". Surface temperature is one of the commonly used climatic parameters for indicating climate change (Amadi *et al*., 2014). Changes in temperature affect the hydrological cycle processes directly or indirectly. Also, since temperature and water content are important physical indicators for plant growth, changing temperature patterns could have effects on soil and plant growth characteristics (Jackson *et al*., 2012). Changes in temperature pattern can lead to variation in precipitation trend, amount of soil moisture and groundwater reserves (Tshiala *et al*., 2011). Jackson *et al*., 2012 noted that there are limited studies on the trends of temperature in Nigeria, and therefore stressed the need for further studies on the subject matter. However, available studies on the monthly, seasonal and annual mean, temperatures trends in Nigeria will be discussed in this section.

Jackson *et al*., (2012) assessed the long term trends in the annual mean, minimum and maximum temperatures of Ibadan using forty eight years (1965-2013) dataset. The result of the analysis indicated upward drift in the air temperatures over the study period. The observed drift was said to be statistically significant with high coefficient of relationship for annual average and minimum temperatures, but no significant difference for maximum temperature. Industrialization and urbanization is attributed to the rise in temperature in the city.

Amadi *et al*., (2014) examined the long term trends in minimum and maximum temperature over twenty selected locations in Nigeria. Monthly mean minimum and maximum temperature data of sixty-two years (1950-1912) were used in the study. The analysis results indicated variation in temperature across the country with increase from south to the north. It further revealed that significant increasing trends were observed in the minimum and maximum temperatures in 17 and 16 locations respectively. This implies that temperature rise is experienced in more than 80% of the study location. Moreover, the study showed that higher trend coefficients were observed for the minimum temperatures than the maximum temperatures in most of the locations. The results show a general warming tendency across the study locations and by implication, a gradual rise in temperature in Nigeria.

Dammo *et al*., (2015) studied temperature trends over North-eastern zone (Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe) of Nigeria, using temperature data spanning 1981 to 2010. They analysed temporal and seasonal variation in the region using Mann-Kendall test. The results of their study revealed that temperature ranged between 20.2 - 31.8°C among the studied locations, and over months and years. They also reported that higher temperature was recorded in the month of April in comparing to the other months of the year. The annual and seasonal trends analysis, showed rising tendency in temperature in all the study area except for Taraba with negative trend. This indicates that Nigeria is also experiencing global warming.

Orisakwe *et al*., (2017), examined temperature trends in Abuja, using minimum, maximum and, mean temperatures data spanning over three decades (1983-2014). The results indicated a downward trend in maximum temperature between 1993 and 2013, and an upward trend in minimum and mean temperatures over Abuja. The study established the occurrence of a warming tendency in Abuja.

Ragatoa *et al*., (2018) investigated the temperature trends in various stations across different climatic zones of Nigeria. The data used spans thirty five years from 1981 to 2015. The study revealed that Nigeria is experiencing rise in the temperature in almost all the stations with the exception of Ikeja which show a decreasing temperature tendency. The mean temperature and Diurnal Temperature Range (DTR) found to be on increase in most of the study locations. The increase in the Diurnal Temperature Range is said to have negative impact human health and increase in the occurrence of extreme events weather in the country.

2.5.2.1 Studies on rainfall and temperature trends in Nigeria

A good number of researchers have attempted to study temperature and rainfall simultaneously across various locations in Nigeria. The characteristics and trends of these two climatic parameters are investigated to establish the presence of climate change and its extend in Nigeria. Some of the findings of these studies are discussed below.

Akinsanola and Ogunjobi (2014) investigated rainfall and temperature trends in Nigeria using thirty years data (1971-2000) from 25 synoptic stations. The result of the analysis of air temperature showed anomalies between -0.2 and -1.6 in the first decade (1971-1980), while most of the study locations were normal in the second decade (1981-1990), with the exception of five locations (Bida, Bauchi, Lokoja, Kaduna and Warri) that shows positive anomaly. The third decade (1991-2000) showed evidence of warming. The study further revealed increases in rainfall and temperature in most of the study locations.

Owolabi (2016) examined the rainfall and temperature variation in Ado Ekiti, Ekiti state capital using eleven years data (2001– 2011). The analysis results indicated that there is fluctuation in the rainfall and temperature recorded in the study area but no particular trend can is established during the study period. However, the last two years of the study shows increasing trend of rainfall and temperature. The study further revealed that over the 11 years period of the study, the lowest and highest total annual rainfall of 996.4 mm and 1549.4 mm were recorded in 2001 and 20102 respectively. Similarly, the lowest and highest total annual temperature of 280.4^{0}C and 319^{0}C were recorded in 2006 and 2011 respectively.

Ogunrayi *et al*. (2016) analysed the temperature and rainfall data in Akure (Ondo State capital) to understand the temperature and rainfall regimes of the area. Thirty-two years data spanning 1980 to 2011 was used for the study. In their finding, they reported that the study site is experiencing increase in temperature which poses a threat on human health in the area. The study further revealed that the rainy season length in the area is becoming longer than dry season period. This result shows a deviation from the normal which is an indication of climate change.

Emaziye, *et.al* (2012) studied rainfall and temperature trends and their future projection in Delta state. Descriptive statistics, trend analysis and growth model were employed for data analysis. The study revealed an increasing temperature trend and decreasing rainfall trend. Modelling of the future trends of temperature and rainfall shows an increasing trend for both parameters. This is said to have adverse effect on the agricultural production in the states and such the situation need to be monitored. Also, Ike and Emaziye (2012) examined trends of temperature and rainfall as well as their future projection in four selected states (Bayelsa, Cross River, Delta, and Ondo) in the Niger Delta region of Nigeria. The results indicated a fluctuation in rainfall pattern (decreasing and increasing trend), but escalating trend in average annual temperature. Modelling of the future trends of temperature and rainfall shows an increasing trend for both parameters in the region. The selected states in the region have similar trends of rainfall and temperature variation.

Adesina and Odekunle (2011) investigated the occurrence of climate change in Nigeria using long term temperature and rainfall data between 1961 and 2008. The study covers 28 locations across three climatic zones in Nigeria (Forest, Guinea Savanna and the Sudano-Sahelian). Their findings revealed an upward trend in minimum and maximum

temperatures across the zones between 1961 and 2007. Also, the result further showed different scenarios in the rainfall pattern across the various zones. However, analysis of the rainfall data indicates a declining trend from 1961 to 1983 and an upward trend thereafter till 2008 in all the zones.

Mangodo, *et.al* (2017) examined climatic trends in the Niger Delta region of Nigeria using 1951-2012 climatic data from five meteorological stations in the region. The result of the investigation showed that annual mean temperature in the region indicates an upward trend between 1951 and 2012. On the other hands, the result of the standardized anomalies of annual mean rainfall in the region indicated a fluctuating rainfall pattern. The study revealed the existence of climate change due to the warming tendency observed in the region.

Summarily, from the review of numerous studies across the various locations in Nigeria as express above, it can be concluded climate change is real Nigeria as revealed in declining rainfall amount and rise in temperature. Consequently, there is the need to develop the knowledge and skill for early warning about whether events. Also, the number of synoptic weather stations in the country needs to be increased in other to have sufficient up to date record of climate and weather indicators available and accessible to researchers and entire populace.

2.6 Implications of Rainfall and Temperature Variability on Water Resources

Global climate change is generally accepted by the scientist community across the world as a real problem that will alter the hydrological cycle in a many significant ways (World Resource Institute Report., 2002). The changing rainfall and temperature amount recorded across various locations around the globe has serious implication on the water resources available at such locations. Oguntunde *et al.* (2006) reported that understanding the nature and extend of variations of past and present hydro-climatic variables is vital to the future expansion and sustainable management of water resources in all regions. Some of the findings on the implications of rainfall and temperature trends on water resources at different locations are discussed below.

Alli *et al*., (2012) studied the effects of trends and cycles of rainfall on agriculture and water resource in the tropical climate of Nigeria. The study evaluated rainfall data of forty-seven years from twenty stations across the study area and observed that the implications of rainfall trends on agriculture and water resources vary from one location to another. The implications of rainfall and temperature variability across the study stations is summarised thus:

(i) Increase in rainfall and temperature trends, observed in Oshogbo, Sokoto, Yelwa, Warri and Port-Harcourt, is expected to lead to fair weather for Agriculture in these locations, with the exception of Warri, Ibadan and Port-Harcourt that are likely to experience flood due to excess rainfall.

(ii) Decrease in rainfall and temperature trends, observed in Akure and Maiduguri, is expected to lead to drought and shortage of moisture content in these locations.

(iii) Decrease in rainfall and increase in temperature trends, observed in Benin, Abuja, Lagos, Yola and Calabar, is expected to lead to desertification and high depletion of underground water in these locations.

(iv) Increase in temperature and zero trend of rainfall, observed in Bauchi and Minna, is also expected to lead to desertification and high depletion of underground water in these locations.

(v) Increase rainfall and decrease temperature trends observed in Enugu, Abeokuta, Iseyin and Ikeja, is expected to lead to likelihood of flooding in these locations.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Research Design

In this study, descriptive survey research design was used. Descriptive survey method is used to systematically describe an area of interest accurately and factually (Isaac and Michael, 1978). This method is used to study a group of items by collecting, analysing and interpreting data from a few people considered to be representative of the population.

3.2 Materials Required

The materials used for this study includes: Books, journal articles, published government and non-governmental reports, online articles and laptop computer for collation and analysis of data.

3.3 Sources of Data

Metrological data (rainfall and temperature) of thirty years (1989 – 2018) was used for this study. The data was obtained from the archive of National Aeronautics and space Administration (NASA). Also, water production trend was obtained from Niger state water board management, Chanchaga. The annual mean values of the temperature and rainfall data were evaluated from the monthly mean data.

3.4 Population of the Study

The study population includes all the residential households in Chanchaga LGA of Niger State and their water sources. The city has an estimated population of 201,429 people as at 2006 census (NPC, 2006).

3.5 Study Area

This study was carried out in Chanchaga LGA of Niger State. Chanchaga Local government area is part of Minna Metropolis, the capital of Niger State. Chanchaga local government area is located between latitude 9°35’00” to 9° 41’00” N and longitude 6° 25’00” to 6° 37’00” E. The town has a land area of about 72 square kilometres and an estimated human population of 201,429 as at 2006 census (NPC, 2006). Chanchaga local government area is located within the basement complex area of the country, which is characterized, by different forms of sedimentary rocks and alluvial deposit (Sule *et al*., 2014).

Chanchaga local government area has a tropical dry and wet climate characterized by double rainfall maxima. Rainfall occurs between April and November with high concentration in August. The city has an average annual precipitation of about 1300 mm. Temperature is usually high throughout the year. Maximum temperature of about 40^{o}C is recorded in February and March while, the temperature of about 30^{o}C is recorded around November and December (Ishiaku *et al*., 2014; Adegbehin *et al*., 2016). The in-habitants of Chanchaga are mostly government workers, traders and students. A map of the study area is presented in Figure 1.1

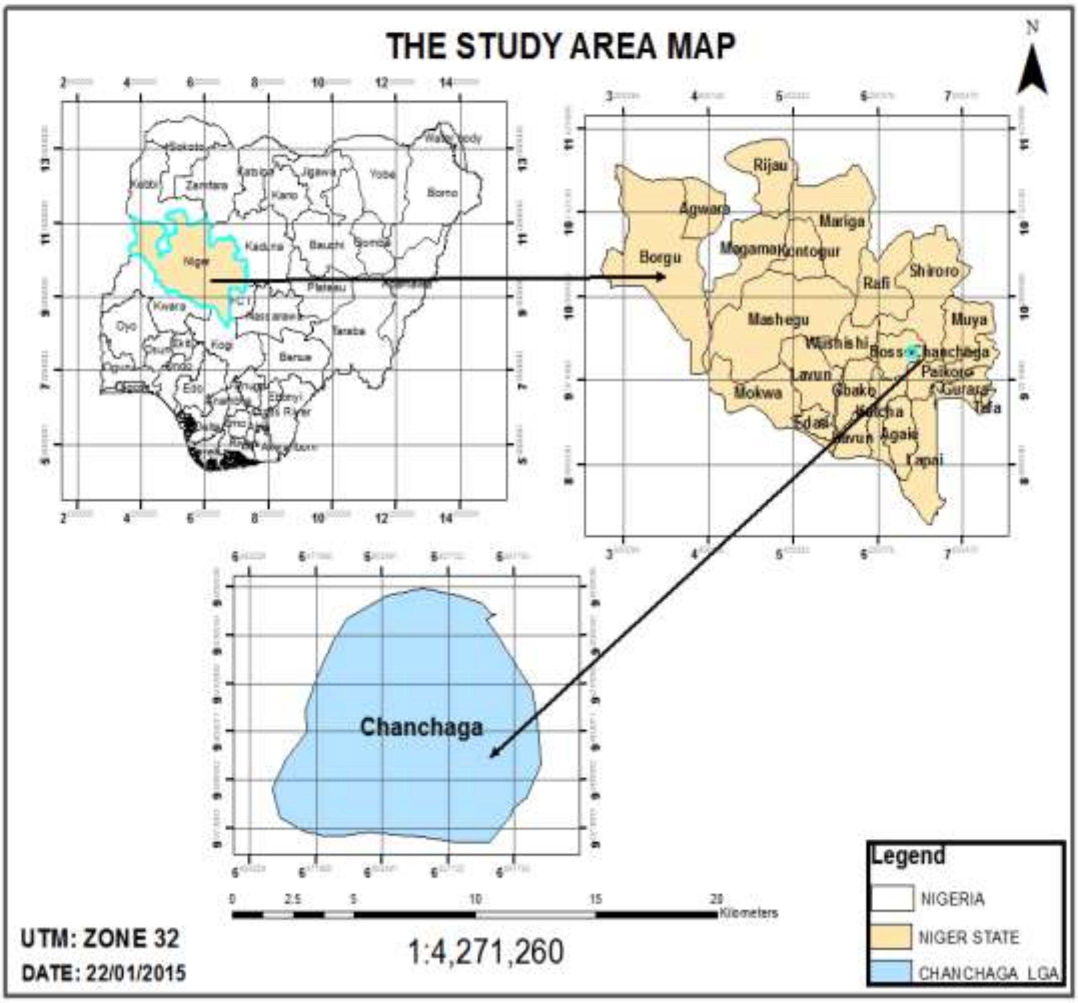

Figure 1.1: Map of the study area

3.6 Sample and Sample Techniques

Two hundred households were selected as sample for this study. The sampling technique used for this study is the stratified/random sampling technique. The stratified sampling technique was used to stratify the area into zones based on existing quarters. The following quarters were selected within the local government area: Sauka-Kahuta, Barkin Sale, Gurara, Tunga and Dutsen Kura. After stratification, 200 households were randomly selected for questionnaire administration from the indentified quarters.

3.7 Research Instrument and Data Collection

Primary and secondary data was used in this work. The primary data was used for the analysis of implication of rainfall and temperature trends on portable water supply. Structured questionnaires were used in the collection of the primary data. Two hundred (200) copies of questionnaire were administered to households within the study area for data generation on the portable water supply and implication of rainfall and temperature variability on it. The secondary data used are monthly mean rainfall and temperature for Minna for a period of 30 years and water production trend in Chanchaga branch of Niger state water board management.

3.8 Description of Data Analysis

Quantitative monthly and annual mean data of rainfall and temperature collected from the National Aeronautics and space Administration was analysed to illustrate the variability in the monthly, annual and seasonal rainfall and temperature data. Descriptive statistics such as the mean, standard deviation, coefficient of skewness, coefficient of Kurtosis and coefficient of variation was computed from the climatic data using Microsoft Excel.

Coefficient of skewness (Z_1) and Coefficient of Kurtosis (Z_2) was computed to test for normality of the time series data. These statistical tools have been used in many works involving analysis of time series data (Uduak and Ini, 2012; Akinsanola and Ogunjobi, 2014). These statistics was used to test the null hypothesis that the samples came from a population with a normal distribution. Transformation would be required to normalize the data if the value of Z_1or Z_2 is greater than 1.96. This shows that a significant deviation from the normal curve is indicated at 95% confidence level.

To determine rainfall and temperature variability, the Standardized Anomaly Index (SAI) and Coefficient of Variation (CV) were used. SAI gives an area average index of relative rainfall yield based on the standardization of rainfall totals. It also helps in the determination of the dry (positive values) and wet (negative values) years in the record (Abaje *et. al*, 2010). SAI is expressed by the equation:

$$SAI = \frac{x - \bar{x}}{\sigma} \qquad 3.1$$

Where:

SAI = standardize anomaly index

x = annual rainfall/temperature totals

$\bar{x}$ = mean of the entire time series data

σ = standard deviation from the mean of the time series data.

Coefficient of Variation (CV) is one of the two most widely used measures of variability (Uduak and Ini, 2012). This measure of dispersion is given by equation 3.2:

$$CV = \frac{\sigma}{\bar{x}} \times 100 \qquad 3.2$$

Standard deviation σ is defined by:

$$\sigma = \frac{[(x - \bar{x})^2]}{n} \qquad 3.3$$

Moreover, Microsoft Excel was used to plot the linear trend so as to further examine the variation in the rainfall and temperature data set.

Finally, quantitative data obtained from the questionnaire survey was computed and analysed for frequency distribution and percentages using Microsoft excel software.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The rainfall and temperature data collected from NASA are collated and analysed to investigate rainfall and temperature variability in Chanchaga LGA of Niger State. This is done in an attempt to provide answer to research question one, "What is the trend of monthly and annual rainfall and temperature in Chanchaga LGA?". The result is presented for discussion in graphs and tables below.

4.1 Rainfall Variation and Trend in Chanchaga

The monthly variation in rainfall is presented in Figures 4.1 and 4.2, while Figure 4.3 presents the annual variation and trends in rainfall in Chanchaga LGA for the period of thirty years (1989-2018).

The result in Figure 4.1 shows a gradual increase in rainfall from February to a peak value of 282.05 mm in August, and then a gradual decrease to November. The months of December and January are completely dry with no rainfall amount recorded. The months of May to October are known for rain (wet season) but, July, August and September are characterised with heavy rainfall in Minna metropolis. Rain water is normally available for domestic use during the wet season. The amount of rainfall between the months of November and April is usually insignificant, as such; these months are classified as dry season months. This result is agreement with reported period of the onset and offset of rainfall in Minna which is April and November respectively (Ishiaku *et al*., 2014; Adegbehin *et al*., 2016).

From Figure 4.2, similar monthly mean rainfall pattern is observed in the last three decades from 1989-2018. There is no significant change in the seasonal monthly mean rainfall trend except for very slight decrease in some month during the last twenty years of the study period (1999-2018).

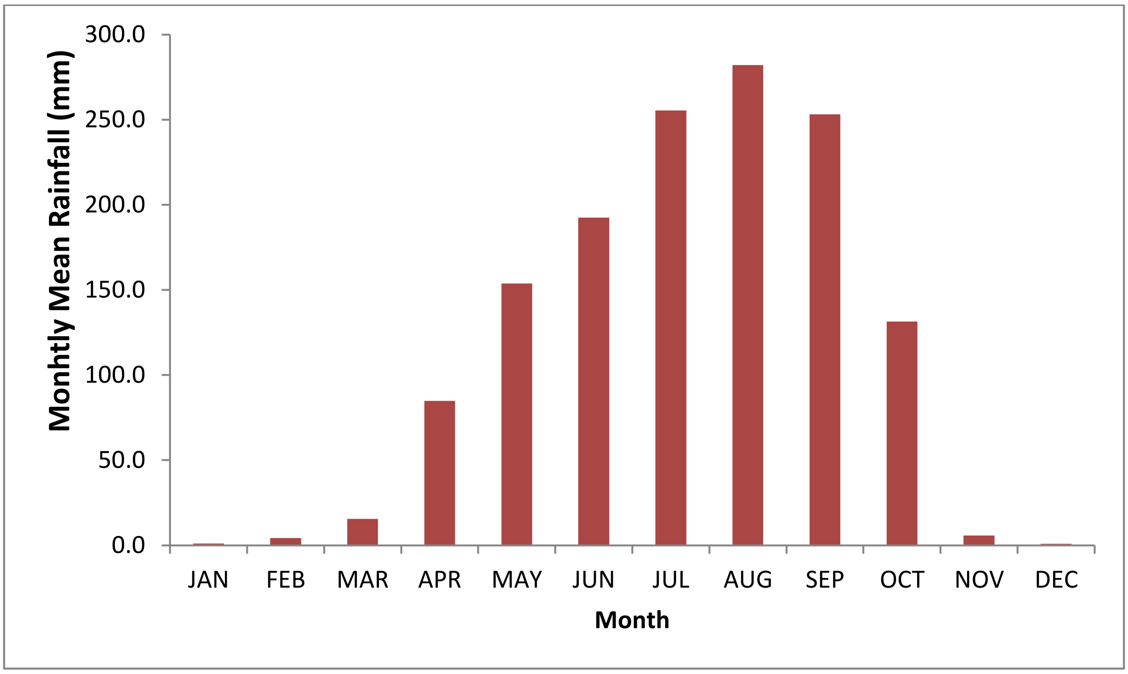

Figure 4.1: Monthly rainfall variation for Chanchaga LGA

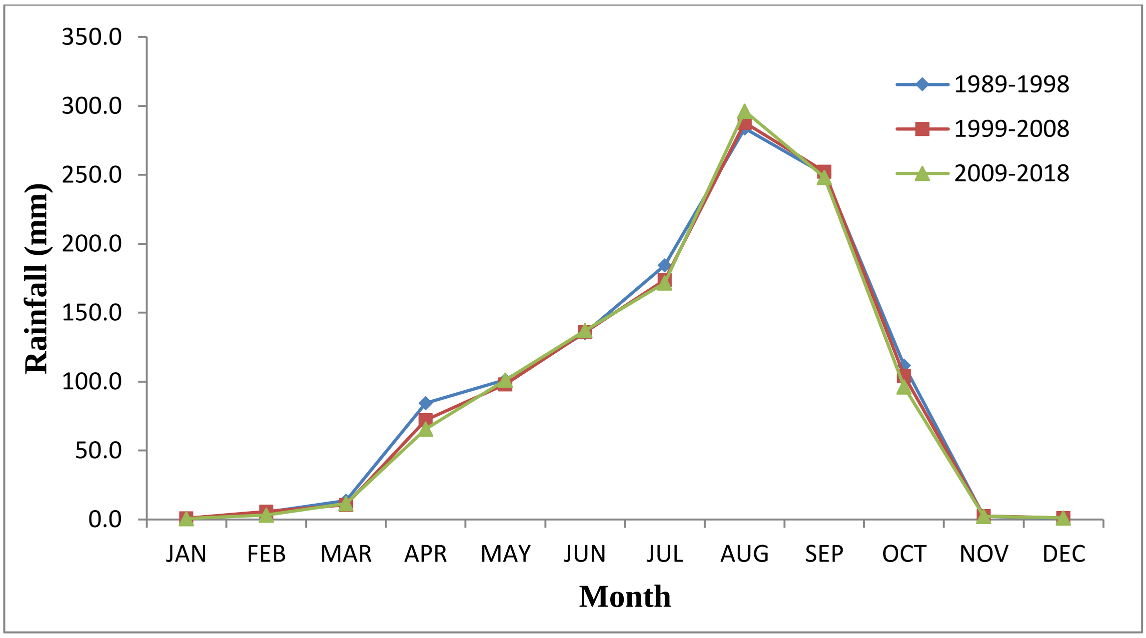

Figure 4.2: Seasonal variation in monthly rainfall over Chanchaga LGA for three decades (1989-2018)

Figure 4.3 shows the inter-annual rainfall variability over Chanchaga LGA during the thirty years study period (1989-2018). The trend indicates a fluctuating in annual rainfall values and general decline in rainfall values over the study area. Over the study period, the highest (2094.92 mm) and lowest (148.51 mm) annual rainfall were recorded in 1994 and 2011 respectively. In the last one decade (2009-2018), the highest annual rainfall of 1594.22 mm was recorded in 2012. This was the year that Niger state and many other states in the country witnessed serious flooding (Emberga, 2014). Moreover, it can be observed from Figure 4.3 that the value of the annual rainfall has been similar in the last three years (2016-2018). However, the annual rainfall over Chanchaga local government shows a fluctuating and decreasing trend in recent time. The negative trend line obtained further give credence to this result. The trend line equation indicates that the annual rainfall value is decreasing at the rate of 19.72 mm per year during the thirty years study period. This result corroborates previous research conducted over Minna by Akinsanola and Ogunjobi, 2014.

Figure 4.4 presents the standardized anomaly index for rainfall over Chanchaga LGA for the study period. The standardized rainfall deviation shown in Figure 4.4 reveals that; 1999, 2001, 2004, 2005, 2006, 2011, 2013, 2014 and 2015 are years with below normal rainfall with 2011 showing lowest negative rainfall anomaly. The other years show above average rainfall with 1994 showing the highest positive rainfall deviation.

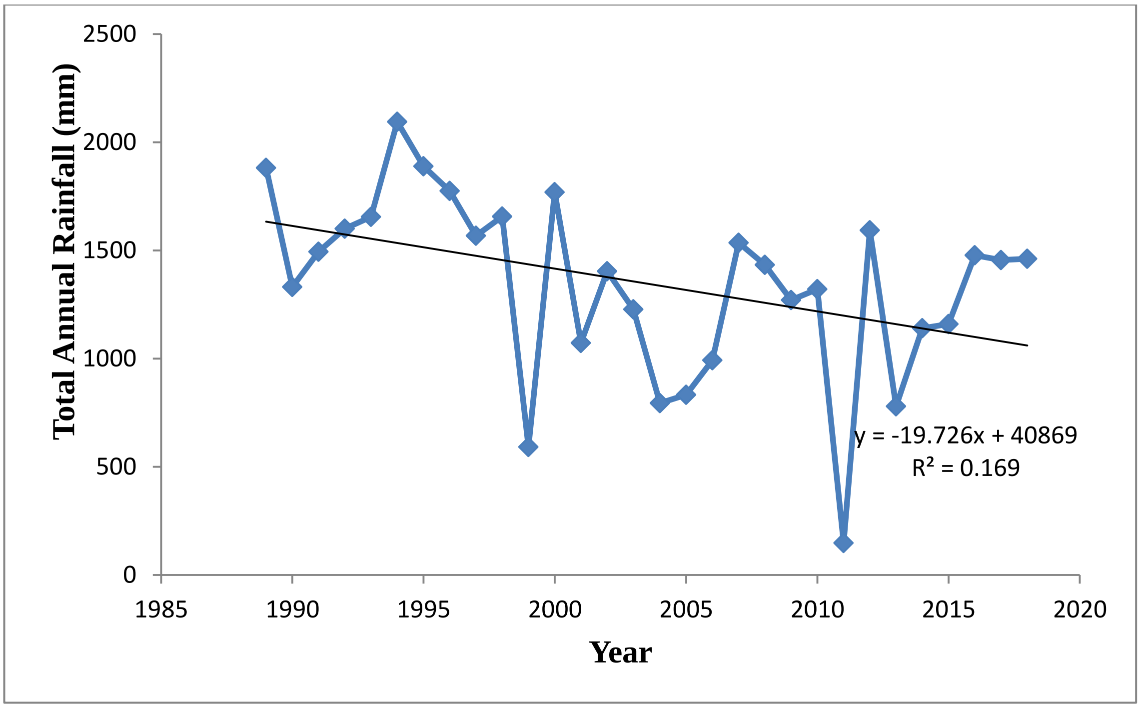

Figure 4.3: Annual rainfall variation and trend in Chanchaga LGA

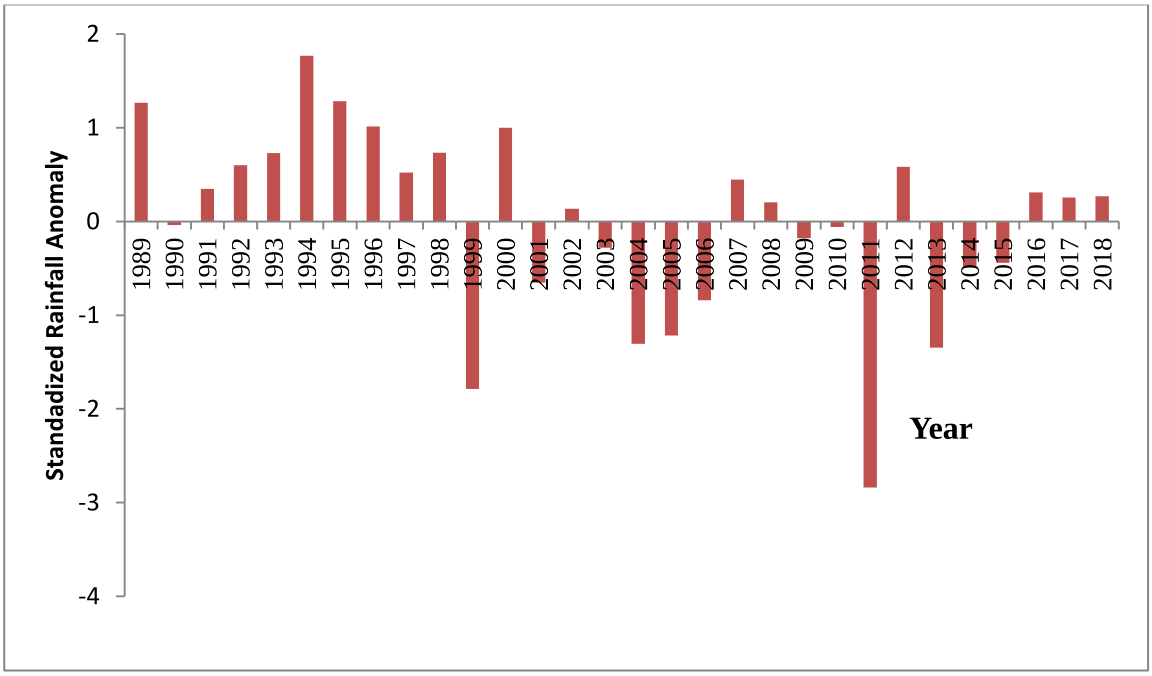

Figure 4.4: Standardized Rainfall Anomaly index over Chanchaga LGA

Tables 4.1 and 4.2 present monthly and annual summary of descriptive statistics of rainfall data respectively. The descriptive statistics of monthly and annual rainfall presented in Tables 4.1 and 4.2 respectively include: mean, minimum, maximum, standard deviation, coefficient of variation (CV), coefficient of skewness (Z_1) and coefficient of kurtosis (Z_2).

From the analysis in Table 4.1, the monthly mean rainfall varies between 0.9 mm in December and 282.1 mm in August. This corresponds to the month with the lowest and highest standard deviation.

Table 4.1: Monthly rainfall for Chanchaga

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TOTAL	33.3	128.7	464.3	2545.2	4610.9	5772.3	7665.1	8461.6	7596.2	3945.3	174.3	27.4
MEAN (mm)	1.1	4.3	15.5	84.8	153.7	192.4	255.5	282.1	253.2	131.5	5.8	0.9
MIN (mm)	0.0	0.0	0.2	3.1	41.8	71.6	98.7	88.5	107.2	44.3	0.0	0.0
MAX (mm)	18.6	27.5	83.7	183.2	270.2	403.3	470.4	461.0	424.7	333.3	25.3	10.7
CV(%)	308.8	160.4	114.7	56.5	39.5	42.0	36.2	33.4	28.0	48.2	113.4	224.9
STDEV	3.4	6.9	17.7	47.9	60.8	80.8	92.4	94.1	70.9	63.3	6.6	2.1
SKEWNESS	4.9	2.3	2.2	0.3	-0.1	0.7	0.2	-0.2	-0.2	1.2	1.3	4.0
KURTOSIS	25.6	5.3	6.6	-0.7	-0.9	0.1	-0.3	-0.3	0.4	2.3	1.3	18.1

Table 4.2: Annual rainfall for Chanchaga

YEAR	ANNUAL (mm)	MEAN (mm)	MIN (mm)	MAX (mm)	STDEV	CV(%)	SKEWNESS	KURTOSIS
1989	1882.30	156.86	0.00	392.77	153.06	97.58	0.29	-1.68
1990	1331.66	110.97	0.03	245.64	100.62	90.67	0.05	-1.92
1991	1493.89	124.49	0.03	315.49	120.71	96.96	0.33	-1.61
1992	1601.72	133.48	0.00	335.88	133.44	99.97	0.32	-1.77
1993	1655.99	138.00	0.00	392.76	139.34	100.97	0.57	-1.07
1994	2094.92	174.58	0.00	424.74	167.10	95.72	0.21	-1.84
1995	1889.56	157.46	0.00	390.73	149.24	94.78	0.43	-1.29
1996	1775.95	148.00	0.00	377.35	145.67	98.43	0.40	-1.60
1997	1568.58	130.72	0.00	295.40	115.63	88.46	0.19	-1.62
1998	1657.09	138.09	0.00	319.67	132.29	95.80	0.10	-1.88
1999	592.39	49.37	0.00	134.01	51.34	104.01	0.51	-1.36
2000	1769.69	147.48	0.00	470.39	164.81	111.75	0.88	-0.29
2001	1072.31	89.36	0.00	206.44	88.57	99.12	0.18	-2.08
2002	1404.78	117.07	0.00	269.86	105.87	90.44	0.10	-1.69
2003	1228.88	102.40	0.53	287.15	99.02	96.70	0.51	-0.96
2004	795.48	66.29	0.00	177.31	64.96	97.99	0.27	-1.49
2005	833.18	69.43	0.00	283.72	84.77	122.10	1.61	2.83
2006	992.46	82.70	0.00	408.29	120.05	145.16	2.13	4.85
2007	1535.87	127.99	0.00	447.21	147.93	115.58	1.12	0.42
2008	1434.36	119.53	0.07	461.01	148.96	124.62	1.31	1.05
2009	1271.54	105.96	0.00	307.10	101.63	95.92	0.42	-0.65
2010	1322.15	110.18	0.74	304.80	111.60	101.29	0.57	-1.13
2011	148.51	95.71	0.02	268.55	100.71	105.22	0.56	-1.24
2012	1594.22	132.85	0.04	345.62	132.84	99.99	0.32	-1.65
2013	779.58	64.96	1.98	172.78	60.50	93.12	0.65	-1.03
2014	1140.97	95.08	0.00	288.62	97.78	102.84	0.84	-0.08
2015	1160.64	96.72	0.00	307.20	122.36	126.51	1.02	-0.67
2016	1479.03	123.25	0.00	331.85	125.99	102.22	0.55	-1.21
2017	1455.52	121.29	0.00	331.39	132.89	109.56	0.43	-1.82
2018	1461.35	121.78	0.00	338.81	128.32	105.37	0.47	-1.51

It can also be observed that the monthly rainfall coefficient of variation falls between 28.0 – 308.8%. According to Hare (2003), the degree of variability of rainfall events is classified depending on the value of coefficient of variation as less when CV < 20%, moderate when CV is between 20 – 30%, high when CV >30%, very high when CV>40% and extremely high when CV>70%. Based on the above classification, the observed CV indicates that there is extremely high monthly rainfall variation between November and March, while the variation is very high in April, June and October, high in May and August and moderate in September (Figure 4.1). From Table 4.2, the values of the annual CV fall between 88.46% in 1997 and 126.51% in 2015. These values are above 70%, therefore, this indicate that there is extremely high annual rainfall variability over the study area within the thirty years study period.

Coefficients of skewness and kurtosis were computed to test whether the series rainfall dataset follow a normal distribution. Skewness is a measure of symmetry while, kurtosis is a measure of data peakedness or flatness of curve relative to a normal distribution. The values of the coefficients of skewness for the monthly and annual dataset follow normal distribution with the exception of the values for the months of December – March (Table 4.1) and value for year 2006 (Table 4.2) which is above 1.96. The month and year with the most evenly skewed distribution are May with a value of -0.1 (Table 4.1) and 1990 with a value of 0.05 (Table 4.2) respectively. Similarly, the values of the coefficients of kurtosis show that the data follow normal distribution except for the months of October, December – March and in the year 2005 and 2006. The coefficients of kurtosis for the annual rainfall data are positive for year 2006 – 2008, and negative for the rest of the study years. This indicates peaked distributions for the year 2006 – 2008 and flat distributions for the rest of the study years.

4.2 Temperature Variation and Trend in Chanchaga

The variation in monthly mean air temperature over Chanchaga is presented in Figures 4.5 and 4.6, while Figure 4.7 presents the annual variation and trends in air temperature over Chanchaga Local Government Area for the period of thirty years (1989-2018).

The result in Figure 4.5 shows a slight variation in the average monthly temperature over the study area. The graph shows double maxima with peaks at April and October. The temperature gradually increases from January to a peak value of 27.92^{0}C in April, and then decreases steadily to 24.31^{0}C August. This is follow by another steady increase to a peak in October and then, a gradual decrease to the lowest value in December. The highest (27.92^{0}C) and lowest (22.86^{0}C) temperature values were recorded the months of April and December respectively. The graph further reveals that the warmest months in the study area are March and April with air temperature of 27.77^{0}C and 27.92^{0}C respectively. This corroborates the assertion by Orisakwe *et al*., (2017) that, the month of March and April are pre-monsoon seasons, during which the effects of the cold tropical continental (cT) air-mass has weakened, leaving the atmosphere dry and warm with high temperature. It is also noted that the coolest months are the months of December and January with temperature of 22.86^{0}C and 23.14^{0}C.

The seasonal variation of air temperature over Chanchaga LGA shown in Figure 4.6, reveals that the monthly temperature distribution have similar trend with slight increase in temperature over the last two decades. There is notable change in monthly mean temperature in the dry season months between November and April during the second and third decades (1999-2018) compare with the first decade (1989-1998).

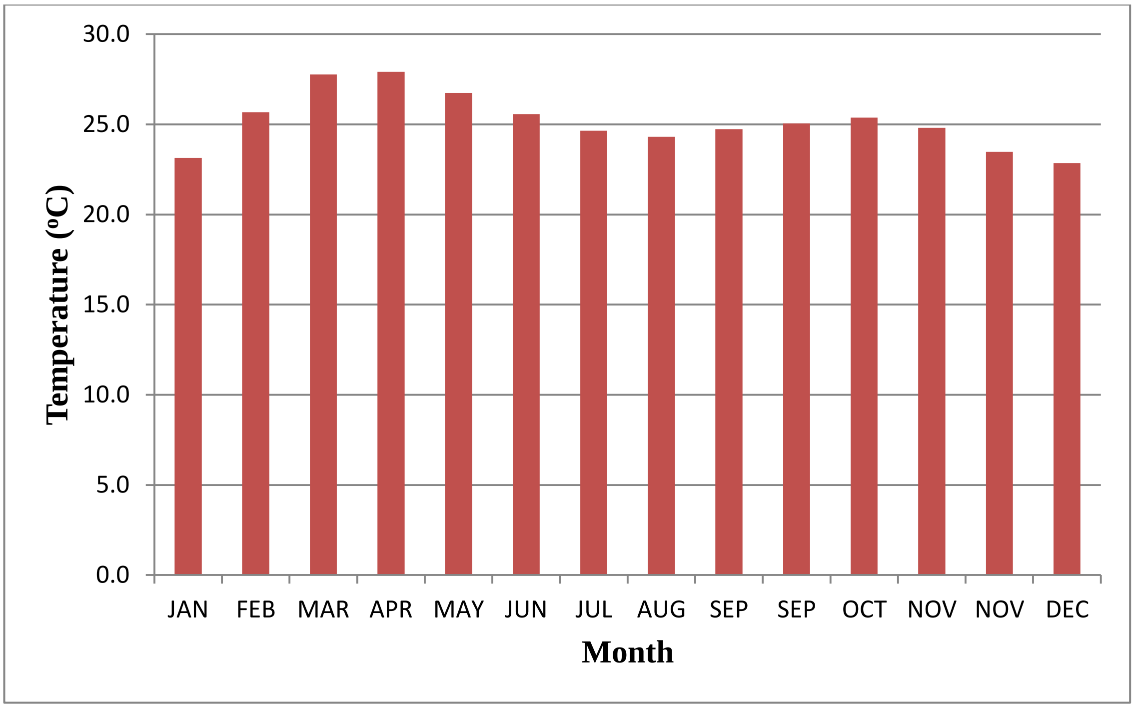

Figure 4.5: Monthly temperature variation for Chanchaga, Minna

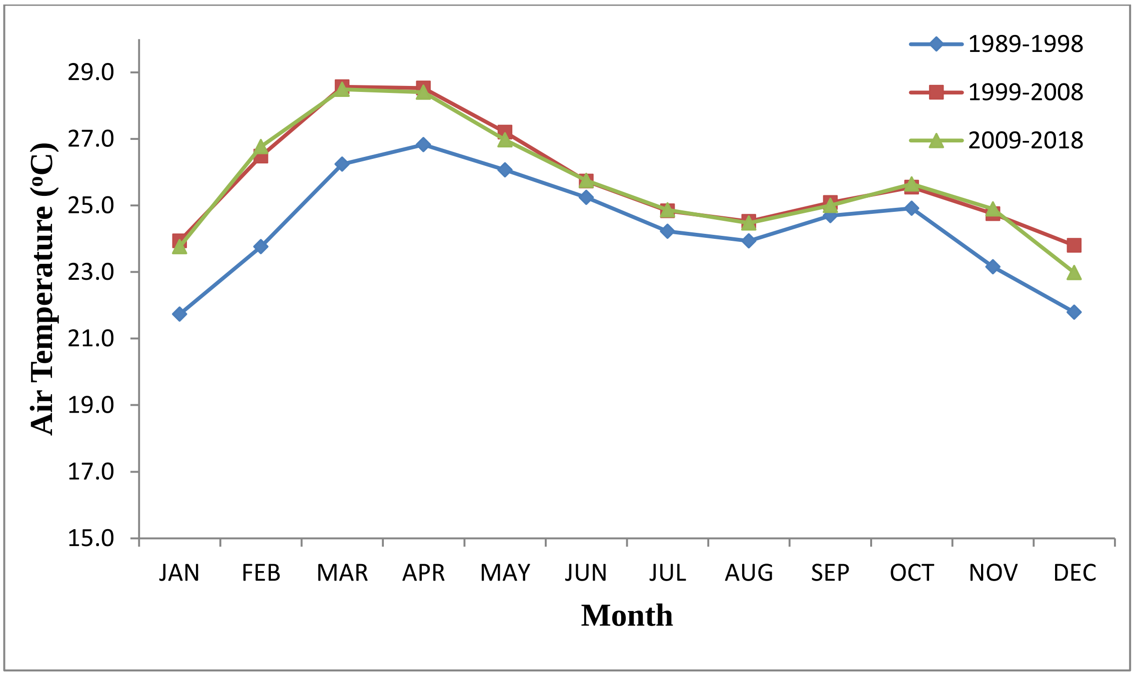

Figure 4.6: Seasonal variation in monthly temperature over Chanchaga LGA for three decades (1989-2018)

Figure 4.7 shows the inter-annual mean air temperature variability over Chanchaga Local Government Area during the thirty years study period (1989-2018). The curve indicates fluctuation in annual mean temperature values and general increase in temperature values over the study period. Over the thirty years study period, the highest annual mean temperature of 27.18^{0}C and lowest value of 23.94^{0}C were recorded in 1989 and 2005 respectively. In the last five years (2014-2018), there is a gradual decrease in the mean annual air temperature within the study area. However, the trend line obtained from the graph indicates a gradual rise in temperature over the over the study location. The positive slope of the trend line equation further gives credence to this result. The trend line equation indicates that the mean annual temperature value is increasing at the rate of 0.061^{0}C per year during the thirty years study period. The rise in mean annual temperature recorded is an indication of climate change over the study area. This result is in agreement with other researchers that reported rise in annual average temperature in Nigeria and other regions around the globe (Karmaker and Shrestha, 2000; Jackson *et al*., 2012; Akinsanola and Ogunjobi, 2014; Wuebbles *et al*., 2014; Dammo *et.al,* 2015).

The standardized anomaly index for temperature over Chanchaga local government area is presented in Figure 4.8. The standardized rainfall deviation shown in Figure 4.8 reveals that over the thirty years study period, the highest positive and lowest negative temperature anomaly were recorded in 2005 and 1989 respectively. It can also be deduced from the anomaly index that, negative temperature deviation with below normal temperature was observed in the first decade (1989-1998) of the study period. However, positive temperature anomaly with above normal temperature is predominantly observed in the last two decades between 1999 and 2018. This indicates that there is rise in mean annual temperature over the study area since 1999.

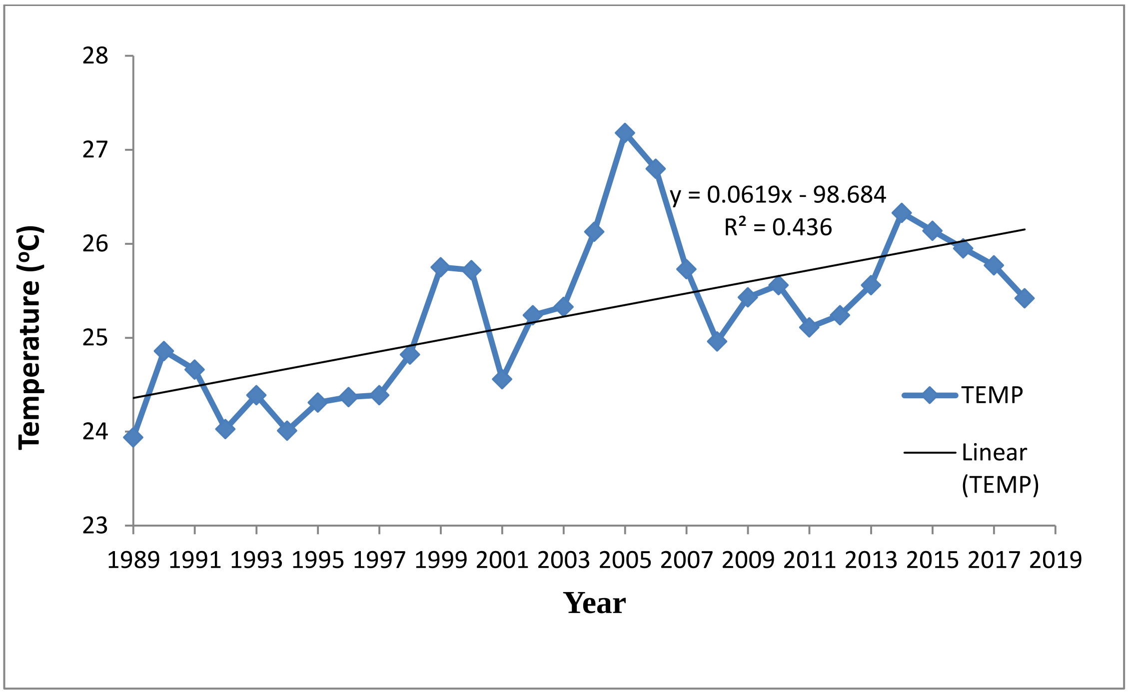

Figure 4.7: Annual mean temperature variation and trend over Chanchaga LGA

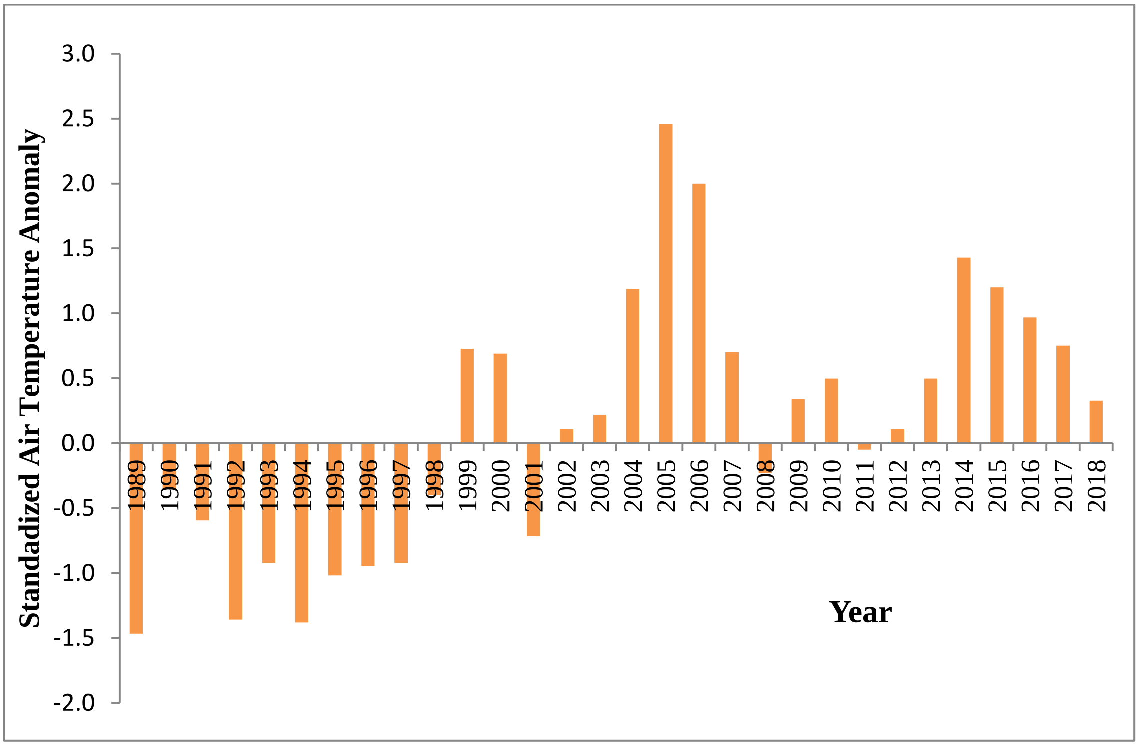

Figure 4.8: Standardized Air Temperature Anomaly index over Chanchaga, Minna

Tables 4.3 and 4.4 respectively present monthly and annual summary of descriptive statistics of temperature data set. The descriptive statistics of monthly and annual temperature presented in Table 4.3 and 4.4 include: mean, minimum, maximum, standard deviation, coefficient of variation (CV), coefficient of skewness (Z_1) and coefficient of kurtosis (Z_2).

From Table 4.3, the analysis of the thirty years temperature data show that the highest mean, minimum and maximum air temperature were recorded in April, April and March respectively. Also, the lowest mean, minimum and maximum air temperatures were respectively recorded in December, January and August. The maximum deviation in the monthly data distribution was obtained in February. Figure 4.3 also revealed that the monthly temperature coefficient of variation falls between 1.02% in September and 8.68% in January. According to Hare (2003) classification of coefficient of variation value as earlier stated, the CV monthly values are less than 20% in all the months of the year. Based on this result, the observed CV indicates that there is less variability in the monthly mean temperature over the area of study. The values of the coefficients of skewness and kurtosis for the monthly data follow normal distribution since there is no value above 1.96. The month with the most evenly skewed distribution is February with a value of 0.11 (Table 4.3)

Table 4.3: Monthly temperature for Chanchaga

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN (^{O}C)	23.14	25.67	27.77	27.92	26.74	25.57	24.64	24.31	25.05	25.37	23.48	22.86
MIN (^{O}C)	19.32	21.67	25.38	25.99	25.81	24.79	23.78	23.32	24.53	24.14	21.54	19.79
MAX (^{O}C)	28.18	30.00	30.48	30.08	29.14	26.80	26.02	25.28	25.63	26.28	27.01	27.30
STDEV	2.01	2.17	1.45	1.18	0.82	0.50	0.48	0.43	0.26	0.54	1.45	1.74
CV (%)	8.68	8.46	5.22	4.22	3.08	1.95	1.97	1.76	1.02	2.11	6.18	7.61
SKEWNESS	0.60	0.11	0.23	0.54	1.08	0.89	0.73	-0.39	0.21	-0.27	1.30	0.88
KURTOSIS	0.57	-0.63	-0.97	-0.84	1.12	0.26	0.85	0.63	0.55	-0.42	2.29	0.57

Table 4.4: Annual temperature for Chanchaga

YEAR	MEAN(°C)	MIN(°C)	MAX(°C)	STDEV	CV(%)	SKEWNESS	KURTOSIS
1989	23.94	19.32	26.94	2.06	8.62	-0.77	1.14
1990	24.86	23.3	27.29	1.09	4.39	0.78	1.07
1991	24.68	20.98	27.21	1.84	7.46	-0.48	-0.12
1992	24.04	20.85	27.01	1.99	8.26	-0.08	-0.78
1993	24.40	20.3	26.63	1.78	7.29	-1.18	1.63
1994	24.01	19.79	26.64	1.97	8.22	-0.63	0.47
1995	24.31	21.54	26.61	1.65	6.81	-0.32	-1.15
1996	24.37	21.54	26.56	1.62	6.63	-0.46	-0.39
1997	24.38	21.65	25.99	1.60	6.57	-0.97	-0.61
1998	24.83	21.41	27.67	1.88	7.59	-0.42	-0.22
1999	25.76	22.54	27.64	1.53	5.95	-0.63	0.17
2000	25.72	20.99	29.77	2.61	10.13	0.03	-0.43
2001	24.55	20.49	27.18	1.87	7.63	-0.66	0.77
2002	25.25	21.75	28.58	1.93	7.65	-0.05	-0.15
2003	25.35	22.7	27.62	1.65	6.51	-0.27	-0.81
2004	26.13	24.35	28.86	1.42	5.43	0.93	0.28
2005	27.21	25.28	30.34	1.98	7.27	0.71	-1.21
2006	26.82	23.81	30.04	2.21	8.24	0.30	-1.32
2007	25.75	22.24	29.34	2.20	8.56	0.45	-0.63
2008	24.96	21.4	27.69	1.88	7.55	-0.09	-0.38
2009	25.44	23.56	27.54	1.13	4.45	0.42	-0.08
2010	25.58	22.29	28.27	1.71	6.69	-0.10	-0.24
2011	25.12	21.89	27.68	1.84	7.31	-0.40	-0.34
2012	25.26	22.05	27.97	1.75	6.94	0.06	-0.37
2013	25.57	23.13	27.37	1.26	4.95	-0.29	-0.37
2014	26.35	24.28	29.47	1.74	6.61	0.59	-0.88
2015	26.17	20.79	29.67	2.67	10.19	-0.36	-0.16
2016	25.96	23.05	30.48	2.15	8.30	0.90	0.50
2017	25.78	23.27	29.89	1.99	7.73	1.23	0.85
2018	25.44	21.49	28.86	2.18	8.57	-0.21	-0.02

From Table 4.3, the analysis of the thirty years annual mean temperature dataset show that the highest mean (27.21^{0}C), minimum (25.28^{0}C) and maximum (30.48^{0}C) air temperature were recorded in 2005, 2005 and 2016 respectively. Also, the lowest mean (23.94^{0}C), minimum (19.32^{0}C) and maximum (25.99^{0}C) air temperatures were respectively recorded in 1989, 1989 and 1997. The maximum deviation value of 2.67 in the annual data distribution was obtained in the year 2015.

The annual temperature coefficient of variation for the thirty years study period presented in Table 4.4 falls between 0.19% in 2015 and 4.39% in 1990. According to Hare (2003) classification of coefficient of variation value as earlier stated, the CV annual values are less than 20% across the thirty years study period. Based on this result, the observed CV indicates that there is less variability in the annual mean temperature over the study area.

Coefficients of skewness and kurtosis were computed to test whether the series rainfall dataset follow a normal distribution. Therefore, the values of the coefficients of skewness and kurtosis for the annual data follow normal distribution since there is no value above 1.96. The year with the most evenly skewed distribution is year 2000 with a value of 0.03 (Table 4.4).

Kurtosis is a measure of data peakedness or flatness of curve relative to a normal distribution. The coefficients of kurtosis obtained for the annual temperature data indicates flat distributions for most of the study years as shown by negative coefficient of kurtosis values.

4.3 Portable Water Supply and Trend of Water Production in Chanchaga LGA

To answer research question two, "What is the source(s) of portable water supply and trend of water production in Chanchaga Local Government Area?" and research question three, "What is the implication of rainfall and temperature variability on portable water supply in Chanchaga?", two hundred (200) questionnaires were administered for data generation in five selected locations in Chanchaga LGA of Niger State. Forty questionnaires each were administered in Sauka Kahuta, Nyikangbe, Tunga, Barki Sale and Dutsen Kura quarters. A total of one hundred and eighty-five (185) out of the two hundred administered questionnaires were retrieved and data generated from the questionnaires were analysed and presented in tables and graphs below.

Table 4.5 presents the duration of stay of the respondents in the area of study. From the Table, only 5.95% of the respondents have live in their area for less than one year. About 30% of the respondents have live in the study area for more than 10 years, while 64.33% have stay in the study location for more than 3 years. This shows that majority of the respondents have good knowledge of the water supply and climatic condition of their environment. The respondents' gender is presented in Table 4.6. From the Table, 40.54% of the respondents are male while the remaining 59.46% are female.

Table 4.7 presents the educational level of the respondents. From Table 4.7, only 2.16% of the respondents have no formal education. About 30.81 % of the respondents are first degree graduate, 37.30% have either National Certificate in Education (NCE) or National Diploma (ND), 27.03% are secondary lever and 2.70% have completed primary school education. This data shows that the respondents educated enough to understand the contents of the questionnaires. The age group of the respondents is presented in Table 4.8. The minimum age of the selected respondents is fifteen years.

Table 4.5: Duration of stay of the respondents in the study area

DURATION OF STAY	SAUKA KAHUTA	NYIKANGBE	TUNGA	BARKI SALE	DUTSEN KURA	TOTAL RESPONSE	% RESPONSE
< 1 year	3	1	2	3	2	11	5.95
1-3 years	8	11	3	10	23	55	29.73
3-5 years	13	20	4	9	3	49	26.49
5-9 years	4	2	-	4	3	13	7.03
>10 years	10	4	30	8	5	57	30.81
TOTAL	38	38	39	34	36	**185**	100.00

Table 4.6: The gender of the respondents

SEX	SAUKA KAHUTA	NYIKANGBE	TUNGA	BARKI SALE	DUTSEN KURA	TOTAL RESPONSE	% RESPONSE
Male	18	7	24	18	8	75	40.54
Female	20	31	15	16	28	110	59.46
TOTAL	38	38	39	34	36	185	100.00

Table 4.7: Educational Level of the respondents

EDUCATIONAL LEVEL	SAUKA KAHUTA	NYIKANGBE	TUNGA	BARKI SALE	DUTSEN KURA	TOTAL RESPONSE	% RESPONSE
Graduate	16	11	9	12	9	57	30.81
NCE/ND	11	12	14	6	26	69	37.30
Secondary	9	13	16	11	1	50	27.03
Primary	1	2	--	2	--	5	2.70
No formal education	1	--	--	3	--	4	2.16
TOTAL	38	38	39	34	36	185	100.00

Table 4.8: The respondents' age group

AGE (YEARS)	SAUKA KAHUTA	NYIKANGBE	TUNGA	BARKI SALE	DUTSEN KURA	TOTAL RESPONSE	% RESPONSE
15-19	5	5	7	13	4	34	18.38
20-29	8	21	23	7	6	65	35.14
30-39	15	6	5	5	25	56	30.27
40-49	8	5	4	7	1	25	13.51
Above 50	2	1	-	2	-	5	2.70
TOTAL	38	38	39	34	36	185	100.00

4.3.1 Portable water supply sources in Chanchaga LGA

Table 4.9 presents the various water sources available in Chanchaga Local Government Area of Niger State as compiled from the five selected quarters within the study area.

Table 4.9: Sources of water available in the study locations

WATER SOURCES	SAUKA KAHUTA	NYIKANGBE	TUNGA	BARKI SALE	DUTSEN KURA	TOTAL RESPONSE	% RESPONSE
Borehole	22	29	7	9	12	79	42.70
Hand pump	-	1	8	3	1	13	7.03
Tap	7	3	22	10	3	45	24.32
Hand dug well	9	5	2	12	20	48	25.95
Stream/ River	-	-	-	-	-	0	0.00
TOTAL	38	38	39	34	36	185	100.00

From Table 4.9, four main water sources were identified within the study area. These are Borehole, Hand pump, Tap and Hand dug well. In this study, Stream or River was not identified as one of the water sources in the study area. The analysis in Table 4.9 further reveals that, the main water source of the residents in Chanchaga Local Government Area is either privately owned or commercial Boreholes (42.70%). This is followed by Hand dug wells (25.95%), Tap water (24.32%) and Hand pumps (7.03%). Also, it can be deduced from Table 4.9 that, the main water source in Suaka Kahuta and Gurura is boreholes, in Tunga is tap water, while that of Barkin Sale and Dutsen Kura area is hand dug wells. The results agree with the study by Ishiaku *et al*., (2014) which indentified boreholes, well water and water from vendors as the main alternative water sources in Minna. Tap water availability in Gurara and Dutsen Kura is very poor. The tap water penetration result for Dutsen Kura in this work (8.3%) is lower than the value reported for Dutsen Kura Gwari (33.3%) by Adegbehin *et al*., (2016).

The main households' source(s) of drinking and domestic water for the study area was investigated and the results presented in Figures 4.9 and 4.10.

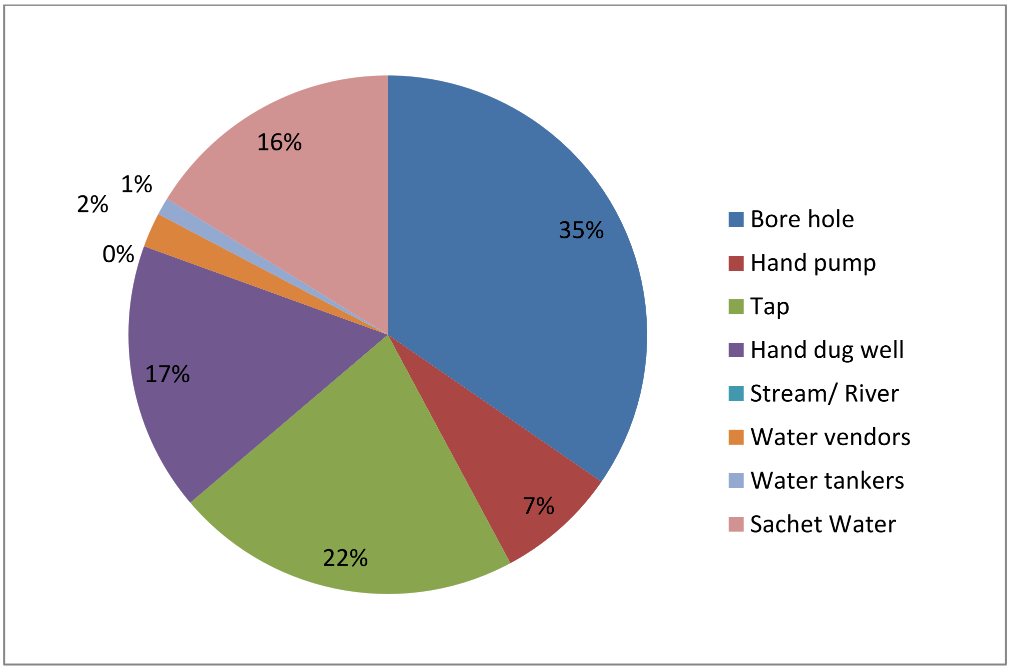

Figure 4.9: Households main source of drinking water in Chanchaga LGA

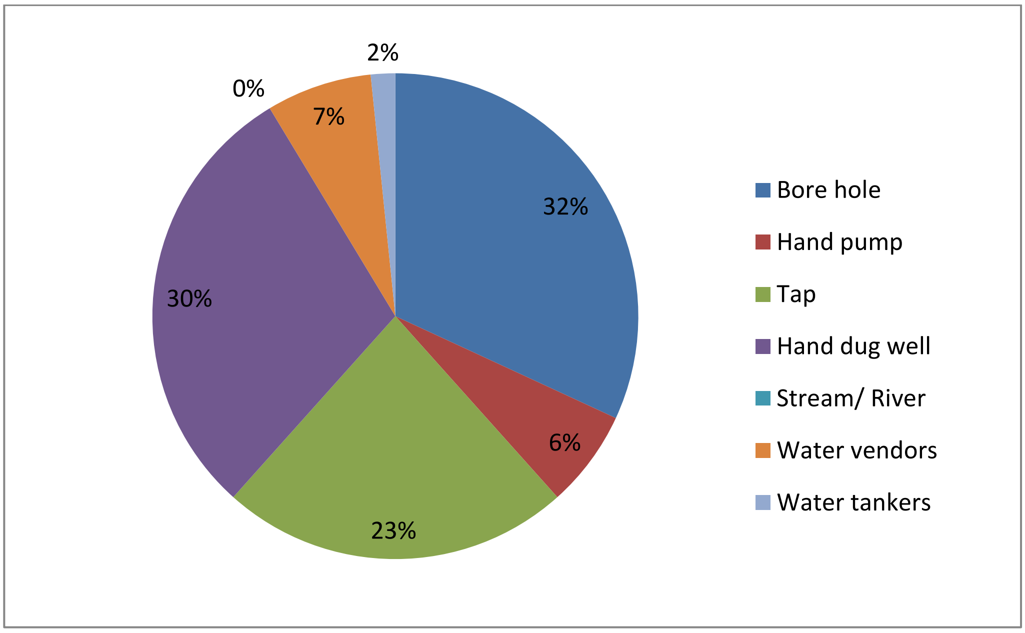

Figure 4.10: Households main source of domestic water supply in Chanchaga LGA

From Figure 4.9, the main sources of drinking water identified are borehole water (35%), tap water (22%), well water (17%) and sachet water (16%). The percentage of people drinking water from water tankers and other water vendors is very small. Similarly, from Figure 4.10, the main sources of domestic water supply identified in the study area are boreholes (32%), hand dug wells (30%) and tap (23%). Others water sources for domestic use include water vendors (7%), hand pump (6%) and water tankers (2%). A good number of households in the study area depend on well water either for drinking (17%) or for domestic use (30%) as shown in Figures 4.9 and 4.10. This indicates that those people may not have water supply all round the year as well water supply is seasonal in Minna. Most wells are said to dry up during the dry season in Minna metropolis (Adegbehin *et al*., 2016).

Tables 4.10 and 4.11 present the result on water availability in the study area. From Table 4.10, 41.62 % of the respondents indicated that they have regular water supply throughout the year, while 58.38% do not have regular water supply in some period of the year. Table 4.11 presents the extent of water scarcity across the twelve months of the year. From the result (Table 4.11), the rate of water scarcity is high between the month of November and April. This represents the dry season months, with no rainfall and high temperature. Most of the wells in the study area are said to be dry during this period thereby leading to water scarcity. Also, the lack of water from wells may put pressure on the other available sources of water during the dry season months.

Table 4.10: Water availability from the main source throughout the year

WATER AVAILABILITY	SAUKA KAHUTA	NYIKANGBE	TUNGA	BARKI SALE	DUTSEN KURA	TOTAL RESPONSE	% RESPONSE
Yes	11	14	26	15	11	77	41.62
No	27	24	13	19	25	108	58.38
TOTAL	38	38	39	34	36	185	100.00

Table 4.11: Trend of water scarcity

MONTH	SAUKA KAHUTA	NYIKANGBE	TUNGA	BARKI SALE	DUTSEN KURA	TOTAL RESPONSE	% RESPONSE
Jan	3	2	5	4	2	16	10.53
Feb	5	11	2	2	3	23	15.13
Mar	9	4	2	6	2	23	15.13
Apr	3	-	-	3	22	28	18.42
May	3	-	-	2	-	5	3.29
Jun	-	-	-	1	-	1	0.66
Jul	-	-	3	-	-	3	1.97
Aug	-	1	3	-	-	4	2.63
Sep	1	-	1	-	-	2	1.32
Oct	1	7	2	1	1	12	7.89
Nov	3	5	2	5	2	17	11.18
Dec	4	2	1	9	2	18	11.84

Perception of the respondents on climate variability on water supply in Chanchaga Local Government Area was examined with questions 11, 12 and 13 of the questionnaires. The results are shown on Tables 4.12, 4.13 and 4.14.

Table 4.12: Change in quantity of water supply in the past decade

WATER VARIABILITY	SAUKA KAHUTA	NYIKANGBE	TUNGA	BARKI SALE	DUTSEN KURA	TOTAL RESPONSE	% RESPONSE
Yes	29	26	27	22	29	133	71.89
No	9	12	12	12	7	52	28.11
TOTAL	38	38	39	34	36	185	100.00

Table 4.13: Nature of the change observed in water supply

WATER VARIABILITY	SAUKA KAHUTA	NYIKANGBE	TUNGA	BARKI SALE	DUTSEN KURA	TOTAL RESPONSE	% RESPONSE
Increase	5	7	10	9	23	54	40.60
Decrease	15	9	9	10	4	47	35.34
Irregular	9	10	8	3	2	32	24.06
Total	29	26	27	22	29	133	100.00

Table 4.14: Cause of the observed change in water supply

	SAUKA KAHUTA	NYIKANGBE	TUNGA	BARKI SALE	DUTSEN KURA	TOTAL RESPONSE	% RESPONSE
Climate change	15	6	18	13	25	77	57.89
Population increase	14	20	9	9	4	56	42.11
TOTAL	29	26	27	22	29	133	100.00

From Table 4.12, 71.89% of the respondents indicated that there is notable change in water supply in the study area in the past decade, while 28.11% of them did not observed any significant change in water supply in their locality. Among the respondents that observed changes in their water supply, 40.60% of them reported increase in water supply, 35.34% reported decrease in water supply and 24.06% indicated irregularity in their water supply (Table 4.13).

From Table 4.14, the cause of the observed change in water supply was attributed to climate change by 57.89% of the respondents, while 42.11% of them associated it with increase in population in the study area. This result clearly shows that there is notable change in water supply in the study area over the past decades and the change is partly attributed to climate change and partly to high influx of people to the study area. The change in water supply due to climatic change can be explained in line with the results of this work. From sections 4.1 and 4.2, the results show that there is decreasing rainfall trend and increasing temperature trend respectively. This implies that there will be high evapotranspiration of surface water sources and high depletion of ground water which are the sources of portable water supply. Therefore, climate change can lead to decrease in portable water supply.

4.3.2 Tap water production trend from Chanchaga water board plant

To further evaluate the impact of rainfall and temperature variability on portable water supply in Chanchaga local government LGA, data on tap water production from Chanchaga plant of Niger State water cooperation was collected from Niger State water board management (NSWBM). Chanchaga plant of Niger State water cooperation supplies tap water to Chanchaga local government and some other parts of Minna metropolis. As at the time of data collection, Chanchaga plant only has two functional pumping machines with code names “Impresit” and “Biwater”. The data available as at the time of collecting data was daily water production “High Lift” of the pumps for about two months (19th May, 2019 - 21st June, 2019. The data collected for May and June was analysed and presented in Figures 4.11 and 4.12 respectively.

From Figures 4.11 and 4.12, the daily water production from Chanchaga plant for the months of May and June show a fluctuating pattern. The two pumping machines have different capacity. Impresit has a higher capacity the Biwater. The total quantity of water pumped out by the two machines per day varies as shown in Figures 4.11 and 4.12. However, from the available data, the average daily water production for the months of May and June are 22470.65 m^3 and 26298.72 m^3 respectively. From this analysis, the impact of rainfall and temperature variability on tap water production cannot be ascertained due to the limitedness of the available data.

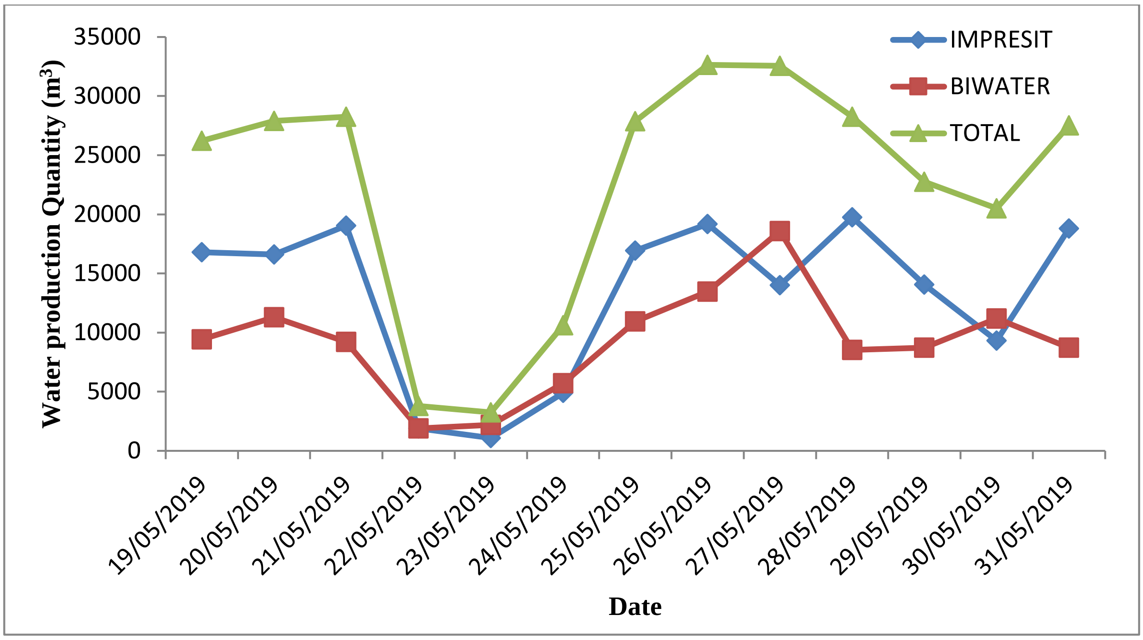

Figure 4.11: Daily water production quantity for the month of May

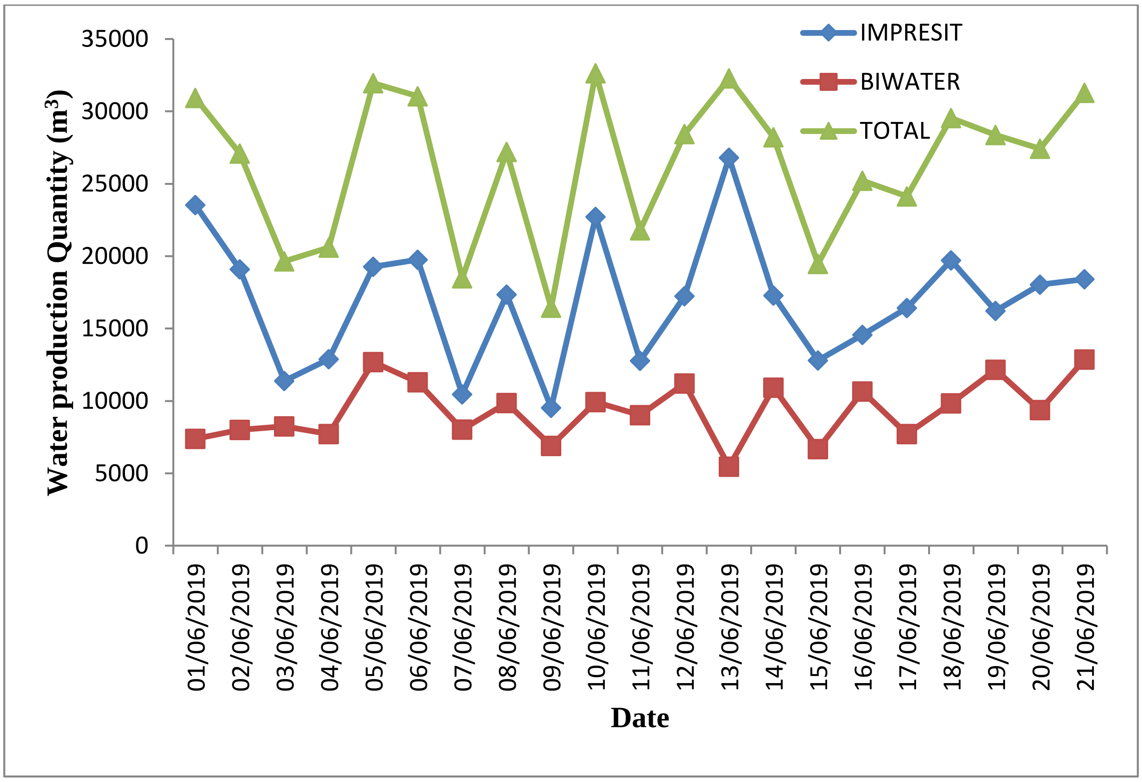

Figure 4.12: Daily water production quantity for the month of June

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In line with the aim of this study, investigation of rainfall and temperature variability and its impact on portable water supply in Chanchaga LGA of Niger State has been carried out. Thus, the following conclusion can be made from the results and findings of this research.

There is extremely high variability in the rainfall distribution in the study area. Significant monthly rainfall amount is observed between April and October with the highest value recorded in August. The mean annual rainfall show a fluctuating pattern with a decreasing trend at the rate of 19.72 mm per year during the thirty years study period. There is no notable seasonal variation in the rainfall pattern over the study period.

The analysis of the air temperature data indicates that there is less variability in the temperature distribution over the study area. The monthly mean air temperature data over the study area shows a slight variation with double maxima at April and October. The annual mean temperature during the study period shows a fluctuating pattern and general rising trend. The mean annual temperature value is increasing at the rate of 0.061^0C per year during the thirty years study period. The seasonal variation of air temperature in the study area reveals similar monthly temperature distribution trend, with slight increase in temperature over the last two decades (1999-2018).

Investigation into portable water sources in the study revealed that Borehole, Hand pump, Tap and Hand dug well are the main water sources in the selected locations.

Nevertheless, the main sources of drinking water identified in the study area are borehole water, tap water, well water and sachet water while, the main sources of domestic water supply identified are boreholes, hand dug wells, tap and vendors. The daily water production from Chanchaga plant for the months of May and June show a fluctuating pattern. The pipe borne water supply to the study area is not sufficient as many people depend on alternative water sources for drinking and domestic use. Therefore, there is need for increase in tap water pipe network and water supply to cope with increase in population in Chanchaga LGA of Niger state.

Finally, the decrease trend in rainfall and increase trend in temperature reported in the study area is a strong indication of the evidence of climate change. This change becomes noticeable in 1999 as indicated by the temperature data. This evidence is supported by previous studies that reveal the manifestation of climate change in Nigeria (Akinsanola and Ogunjobi, 2014; Dammo, Abubakar and Sangodoyin, 2015). Also, this study clearly shows that there is notable change in portable water supply in the study area over the past decades and the change is partly attributed to climate change and partly to the rising population growth in the study area. The change in water supply due to climate change can be explained in line with the results of this work. The decreasing rainfall trend and increasing temperature trend observed in the study area will lead to high evapotranspiration of surface water sources and high depletion of ground water which are the sources of portable water supply. Hence, government need to put in place strategies to mitigate the impact of climate change on water supply system in the study area.

5.2 Contributions to Knowledge

At the end of this research, the following contributions to knowledge have been made:

(i) This work has been able to establish the manifestation of climate change in Chanchaga LGA of Niger state.

(ii) Specifically, the work has been able to identify a declining trend in rainfall and a rising trend in temperature in the study area.

(iii) Also, in this study, the various water sources available for drinking and domestic use in the study area have been outlined and the extent of shortage in tap water supply in the selected locations has been identified.

5.3 Recommendations

The following recommendations for further study are made based on the findings of this research:

(i) Rainfall and temperature variability should be investigated in other local government areas of Niger State.

(ii) Water availability and its impact on human and agricultural production should also be investigated in other local government areas of Niger State.

(iii) Rainfall and temperature variability should be investigated in other states in Nigeria where corresponding researches have not been done to detect the presence of climate change.

(iv) Investigation of people perception on climate change and adaptive strategies to the changing climate should also be studied across the various locations in the country.

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APPENDIX A

QUESTIONNAIRE

Dear Respondent,

I am a postgraduate student of Federal University of Technology, Minna. As part of requirements for the award of Master of Technology (M.Tech) in Environmental Management, I am conducting a research work on 'Impact of Rainfall and Temperature Variability on Portable Water Supply in Chanchaga LGA, Minna, Niger State.

Your cooperation is therefore solicited in answering the questions contained in this questionnaire. The questions and your response therein are meant for academic purpose and will be holistically and confidentially treated as such.

NOTE: Please, tick (√) in the appropriate box

Section A: Demographic Data of Respondents

1. Where do you live?

   I. Sauka Kahuta ( ) II. Barki Sale ( ) III. Nyikangbe ( ) IV. Tunga ( )

   V. Maitumbi ( )
2. How long have you been in the Area?

   I. Less than one year ( ) II. 1-3years ( ) III. 3-5years ( ) IV. 5-9 years

   V. Above 10years ( )
3. What is your sex?

   I. Male ( ) II. Female ( )
4. What is your Educational Level?

   I. Graduate ( ) II. NCE/ND ( ) III. Secondary ( ) IV. Primary ( )

   V. No formal education ( )
5. Where does your age bracket falls?

   I. 15-19 ( ) II. 20-29 ( ) III. 30-39 ( ) IV. 40-49 ( ) V. Above 50 ( )

Section B: Portable Water Supply

6. Which of the following source(s) of water is/are available in your locality?

   I- Bore hole ( ) II- Hand pump ( ) III- Tap ( ) IV- Hand dug well ( )

   V- Stream/ River ( )

7. What is your household main source of **drinking water**?

   I- Bore hole ( ) II- Hand pump ( ) III- Tap ( ) IV- Hand dug well ( ) V- Stream/ River ( ) VI. Water vendors ( ) VII. Water tankers ( ) VIII. Sachet Water ( )

8 What is your household main source of **domestic water supply**?

   I- Bore hole ( ) II- Hand pump ( ) III- Tap ( ) IV- Hand dug well ( )
   V- Stream/ River ( ) VI. Water vendors ( ) VII. Water tankers ( )

9. Is water available from your main source throughout the year?

   I. Yes ( ) II. No ( )

10. If No, which months of the year do you experience water scarcity?

   I-January ( ) II- February ( ) III- March ( ) IV-April ( ) V- May ( )
   VI-June ( ) VII-July ( ) VIII-August ( ) IX-September ( )
   X-October ( ) XI-November ( ) XII-December ( )

Section C: Perception of households on climate variability on water supply

11. Is there change in quantity of water supply in the past decade?

   I. Yes ( ) II. No ( )

12. What is the nature of the change?

   I. Increase ( ) II. Decrease ( ) III. Irregular ( )

13. What cause the observed change?

   I. Increase of temperature/decrease of rainfall ( ) II. Population increase ( )

APENDIX B

Department of Geography,

Federal University of Technology,

Minna, Niger State,

20thth June, 2019.

The Manager,

Niger State Water Board Management,

Chanchaga, Minna.

Sir,

REQUEST FOR DATA

I hereby write to request for data on **water production trend** for my master's research titled, "**Analysis of rainfall and temperature variability on portable water supply in Chanchaga Local Government Area of Niger State**."

I am **Olomiyesan Atinuke Omolola** of the department of Geography, Federal University of Technology, Minna.

Detail of the required data is a follow:

Location: Chanchaga, Minna

Parameters: Monthly water production trend

Year: 10 years (2007-2018)

Please, find attached my letter of introduction from the department.

I shall be very grateful, if my request is favourably granted.

Yours faithfully,

Olomiyesan, A. Omolola