# HOUSEHOLD VULNERABILITY AND ADAPTATION TO WATER STRESS INDUCED BY CLIMATE VARIABILITY ON DOWNSTREAM KADUNA RIVER BASIN

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**MTECH/SNAS/2013/4212**

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**NIGERIA**

**SEPTEMBER, 2015**

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**THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (MTECH) IN CLIMATE CHANGE AND ADAPTED LAND USE**

**SEPTEMBER, 2015**

## DECLARATION

I hereby declare that this thesis titled: “Household Vulnerability and Adaptation to Water Stress Induced by Climate Variability on Downstream Kaduna River Basin” is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has been duly acknowledged.

OKAFOR, Gloria Chinwendu ……………………

MTECH/SNAS/2013/4212 SIGNATURE AND DATE
FEDERAL UNIVERSITY OF TECHNOLOGY,
MINNA, NIGERIA.

## CERTIFICATION

This thesis titled: "Household Vulnerability and Adaptation to Water Stress Induced by Climate Variability on Downstream Kaduna River Basin", carried out by OKAFOR, Gloria Chinwendu (MTECH/SNAS/2013/4212) meets the regulations governing the Award of Master of Technology in Climate Change and Adapted Land Use, and is approved for its contribution to scientific knowledge and literary presentation.

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|---|---|
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| Dean of Postgraduate school | Signature & Date |

# DEDICATION

This work is dedicated to my mother, Mrs Okafor Cordelia Ifeoma for her love and support in my life.

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## ABSTRACT

Water stress is one of the risks climatic variations poses to livelihoods and challenge that is confronting all continent of the World. This study aimed at investigating household vulnerability and adaptation to water stress induced by climate variability on Downstream Kaduna river basin. The study sites; Shiroro, Gbako and Lavun LGA were selected purposively while random sampling was adopted to select 200 households. Historical records of hydro-climatic data were collected from NIMET and Shiroro Hydro-electric Power Station. The research employed qualitative data collected through stakeholders' participatory survey to explore vulnerability through its three determinants: exposure to a stressor (water stress and climate variability), sensitivity to stress, and adaptive capacity of households. Interviews at the household levels, focus group meetings and site visits were conducted to assess the prevailing conditions in six communities and to develop a profile of water stress and how this was altered by climatic variations. Statistical tests were used to assess the significance of trends and questionnaire data were analysed using SPSS IBM 20 and MS Excel 2013. The results indicate that for the period 1975 to 2014 at 95% significance level, rainfall in the Kaduna river basin has no distinctive significant trend at annual and seasonal scale, but the temperature in the basin show obvious upward trends particularly during the rainy season. An overall increasing trend is prevalent in runoff series into the Shiroro reservoir which are the result of the combined effects of rainfall and temperature changes in the basin. In addition, the survey in six communities suggests that households are vulnerable to climate variability induced water stress with low current coping capacity. The study revealed that households have both individually and collectively employed strategies to minimize water-related vulnerabilities such as soil and water conservation practices, diversification and migration to nearest towns. Household adaptation techniques to water stress induced by climate variability in the study area are temporal indigenous coping strategies usually adopted during periods of stress to offset growing vulnerability. The study demonstrated how an understanding of the local household vulnerabilities will enable the recognition of early indicators of water and food insecurity in addition to the occurrence of extreme events. In general, vulnerability of households has decreased across villages due to differences in sensitivity to stress, livelihood options and infrastructure. Therefore, there is the need to have robust coping and adaptation measures to deal with the variations in the climate system.

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| | |
|---|---|
| CMI | Climate Moisture Index |
| FAO | Food and Agricultural Organization |
| FMWR | Federal Ministry of Water Resources |
| IPCC | Intergovernmental Panel on Climate Change |
| ITCZ | Inter-tropical Convergence Zone |
| NEEDS | National Environmental Economic and Developmental S |
| NRDC | Natural Resources Defense Council |
| NSBS | Niger State Bureau of Statistics |
| NSPC | Niger State Population Commission |
| NWRMP | National Water Resources Management Planning |
| PHCN | Power Holding Company of Nigeria |
| SPSS | Statistical Packages for Social Science |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNFCCC | United Nation Framework on Climate Change Convention |
| WASCAL | West African Science Service Centre on Climate Change and Adapted Land Use |

## CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Study Background

Freshwater sustains life on earth and associated socio-economic processes but when its availability is disrupted, it threatens both the ecosystems and human well-being. Water is an essential instrument of livelihood support. The fourth Intergovernmental Panel on Climate Change (IPCC) assessment reported change in the global climate, with resulting effect on the global hydrological cycle and negative impacts on the availability of water and its demand (IPCC, 2007). Consequently, this negative impacts are anticipated to affect biophysical, socio-ecological and economical systems including their processes.

The worsening climatic variations poses to lives and livelihoods, the water stress challenge that is confronting all continents of the World (Vörösmarty, Douglas, Green and Revenga, 2005). The shift in normal availability water resource regarding the amount, intensity, timing, and duration that affects human and economic activities have been defined as water stress by Acosta-Michliketal, Kelkar and Sharma (2008). It also refers to the withdrawal/availability of total surface and groundwater which include the water needed for domestic, industrial and irrigation purposes.

Furthermore, scientific literatures suggest that the changing world's climate has considerable effects on water resources which impacts livelihoods' of people particularly in arid and semi-arid areas such as Nigeria. Availability of water or actual per capita renewable water resources is on the decline influenced by variations in rainfall and pressures from the rapidly growing population, among others. There is high variability of water resource availability in time and space (Postel and Ehrlich, 1996). Climate and hydrological model outputs in combination with socioeconomic information on basin scale reveals that larger percentage of the world's population is at present facing water stress and increasing water demands (Praskievicz and Chang, 2009). With growing world's population which means demand for more water, by 2025 it is projected that the demand for water will exceed the availability by fifty-six percent (World Water Organization, 2010) and water use will increase by about 50 percent. United Nations News Service (2009) also reported that 1.8 billion people particularly those in Asian and African continents will experience severe water scarcity by 2025. Over 25 percent of the present African population experiences high water stress, mainly due to increased water demand (IPCC, 2007) and about 69 percent live under conditions of relative water abundance and rely on water resources that are limited and highly variable (Vörösmarty *et al.*, 2005). In Nigeria, the population growth rate remains about 3 percent per annum, while water consumption is projected to be 24,140mm$^3$ by 2020 (NWRMP, 1995).

Furthermore, climatic fluctuations intensify the vulnerabilities of rural people to high natural variability and anticipated future change in climate. The vulnerability analysis on climate change impact carried out on different sectors in Nigeria illustrates that the water sector is highly vulnerable to the manifestations of climate change and variability, with specific on fresh water supply (Adesina, Odekunle, Balarabe, Dami, Bulus, Ambio and Gworgor, 2010; Oladipo, 2008). Although well above the 1,000 threshold typically used to define water scarcity, Nigeria is considerably below the Sub-Saharan Africa average of about 6,500 (Cervigni Raffaello, Riccardo Valentini, and Monia Santini, 2013). With less than 40% of the Nigeria's population having access to potable water, a substantial percentage at risk of water stress. Local water availability is subject to climatic variations and uncertainties in terms of rainfall and temperature (Beck and Bernauer, 2001).

Virtually, in several parts of Nigeria, water shortage as a result of variations in the availability of water both in time and space has become an annual occurrence (NEEDS, 2010), with agriculture accounting for more than 80% of water withdrawals in the country, using both surface and groundwater resources. Other sectors such as hydro-electric power generation and water transportation have also been negatively impacted due to frequent low in-flow to the dams (NEEDS, 2010).

Changes in climate in conjunction with the changes in physiographic characteristics of river basins could influence the streamflow. Despite some uncertainties, models discloses that some pronounced changes in amount and the occurrence of runoff will follow reasonable changes in climate variables. Also, it is well well-known that substantial changes in rainfall can have proportionate effect on runoff (Gleick, 2000). Kaduna River supports downstream water supply with highly variable climate and topography. Variability in the Climate system and hydrological processes in the basin adds new challenges in the management of water resources.

The decline in water quality is compounding the scarcity of water in most developing countries. Changing patterns of rainfall and runoff as a result of climatic variations exacerbates this situation. Thus, the failure to predict as well as manage water quality and quantity and the associated impacts from climatic variability (including extreme events) will impose huge costs on many economies in the developing world. If model results on climate change due to increasing emissions of greenhouse gases are correct, these impacts will only increase in the coming years. In this circumstance, scarcity of fresh and portable water in many rural areas of Niger State and environ especially in the dry season (Ibbi and Nmadu, 2012) will continue to magnify under the conditions of climate deviations unless substantial measures are introduced. Therefore, certain level of adaptation to climatic variations is inevitable. This will require scientific research on the trend of climatic and hydrological processes and understanding of vulnerability of households in the basin to enable the development of local adaptation and mitigation strategies as well as support sustainable land and water development. The uncertainty about future course of climate change is posing serious challenges on the nature of change and the associated consequences, preventing people at different levels from making critical decisions that are necessary to adapt. Moreover, the current rapidly growing economies, population growth and urbanization urge for sustainable water resources development and secured food supplies in the basin.

## 1.2 Problem Statement

Climate change is already affecting poor people and communities around the globe. A growing number of evidences suggest that, climatic anomalies in the form of rainfall variability and rising temperatures have been observed over northern Nigeria in the last 40 years with consequences of persistent droughts, dust storms and killer floods (Ekpoh and Nsa, 2010). Located in the north-central part of Nigeria, Kaduna River, upon which the Shiroro dam is built, majorly for power supply to Nigeria and neighboring countries is particularly vulnerable to climate variability impacts because of its dependence on rainfall and current high levels of water stress. The River is subject to great seasonal fluctuations depending on the main rainy period from June to September. Consequently, there is decrease in reservoir inflow which may lead to shortage of water for hydropower generation in future, domestic uses and other negative impact of climate variability on the water resources (Eze, 2006; Salami, Sule, and Okeola, 2011).

Furthermore, the Kaduna basin is a typical example depicting interdependencies of upstream and downstream water users through the water and sediment fluxes linking Jos, Kaduna and Niger States. Thousands of people in the upstream and downstream of the river are reliant on the water availability. Rain-fed and irrigated agriculture is the mainstay and the primary livelihood of the locals living within the watershed. The population in the watershed is facing many problems. Poverty and limited development is common in many parts of the basin. Climatic and hydrological extremes such as floods and droughts hit the basin population severely and regularly. The soil erosion upstream contributes to lower rate of food production due to lower soil fertility in the rain-fed catchments. Pressures on the water resources such as variability of rainfall, prolonged dry season, environmental changes and population growth will result in serious consequences for the many rural poor in the basin. These pressures will be exacerbated by potential changes in climate and extremes. Water authorities also find it difficult to meet the demands of many communities in Niger State (Ibbi and Nmadu, 2012). Besides, the available land and water resources in Niger State are not utilized effectively to improve the livelihood and socioeconomic conditions of the inhabitants.

### 1.3 Justification

Certain hydro-climatic studies have been piloted on different river basins in Nigeria to support the improvement of basin management but only a few have emphasized the impacts of water stress and climate variability jointly. Assessing long term variability of hydro-climatic variables on Kaduna river basin is necessary to better inform policies and strategies to aid sustainable water resources management in the basin.

At the same time, there is a knowledge gap with respect to climate impact on water availability on different temporal and spatial scales in the basin; owing to inadequacies in observations and models, and this requires identifying processes that shape vulnerability and adaptive capacity of the local population. To contribute to data-base development and research on climate change impacts and responses in the study location, indigenous knowledge on recent climate variability and adaptation is important. Under these circumstances, vulnerability assessment of household in the basin to water stress induced by climatic variations offers good opportunities for gaining further insights on livelihood responses to climate variability with an aim to determine the constraints and implications of these responses to adapting to current changing climate in the basin for future action.

### 1.4 Aim and Objectives of Study

The main thrust of this study is to determine the degree of exposure of rural households' downstream Kaduna river basin, their sensitivity and adaptive mechanisms to water stress induced by climatic variations. The study therefore, attempts to address the following specific objectives:

i. To analyze historical trends and variability of runoff, rainfall, and temperature records in the Kaduna river basin for the period 1975 to 2014.
ii. To examine the vulnerability of households downstream of the basin to water stress induced by climatic variability.
iii. To investigate households' responses or adaptation mechanisms to Climatic Variability and Water Stress.

### 1.5 Research Questions

Based on the study objectives, the study tried to answer the following research questions;

i. What are the historical trends and variability of runoff, rainfall, and temperature data over the Kaduna river basin? Do temporal trends of climate variables explain the trends in hydrological variables?

ii. What are the observed climate variability and water stress threats households' downstream Kaduna river basin are exposed to?

iii. How does water stress induced by climate variability impact on households livelihoods?

iv. What are the major current households' responses at the study site to deal or cope with climatic variations and water-stress impacts? Are their responses only temporary coping measures, or in the long run help households adapt? What are the constraints to adapt to water stress in the area?

### 1.6 Study Site

#### 1.6.1 Location of study

Kaduna River is one of the tributaries of River Niger in Nigeria originating from the Jos Plateau flowing through Kaduna town into Niger State, where it meets the Niger River at Nupeko. The downstream basin of the river is situated on the eastern part of Niger state (also known as Power State) comprises of Shiroro reservoir watershed and stretches to Lavun in Niger state. Geographically, it lies between latitudes $09^{O}$06'32.64''N and $10^{O}$30'12.64''N, and longitudes $05^{O}$30'39.34''E and $07^{O}$04'44.34''E (Figure 1.1). The Shiroro dam reservoir (320 km2), was built primarily for purpose of supplying needed energy to power the country's growing economy about 500 MW commissioned in 1990.

The choice of the area as study site is due to the fact that Shiroro and its downstream area is densely populated and sometimes identified with low water availability or water stress.

### 1.6.2 Climate

The general climate of the study area is characterized by distinct dry and wet seasons, with rainfall occurring in the rainy season for about five to six months. The climate in this region is strongly governed by the Tropical Monsoon that brings about moist, warm air in the rainy season and dry, cool air during the dry season. This drives the region's rainfall regime and influences the hydrology of the Kaduna basin. The basin has an annual rainfall ranging between 1,110 mm and 1,500 mm which generally decreases from the south to the north with an annual evaporation loss between 2480 m and 4350 m (Adie, Ismail, Muhammad and Aliyu, 2012; Umoh, 1995; Suleiman, 2013).

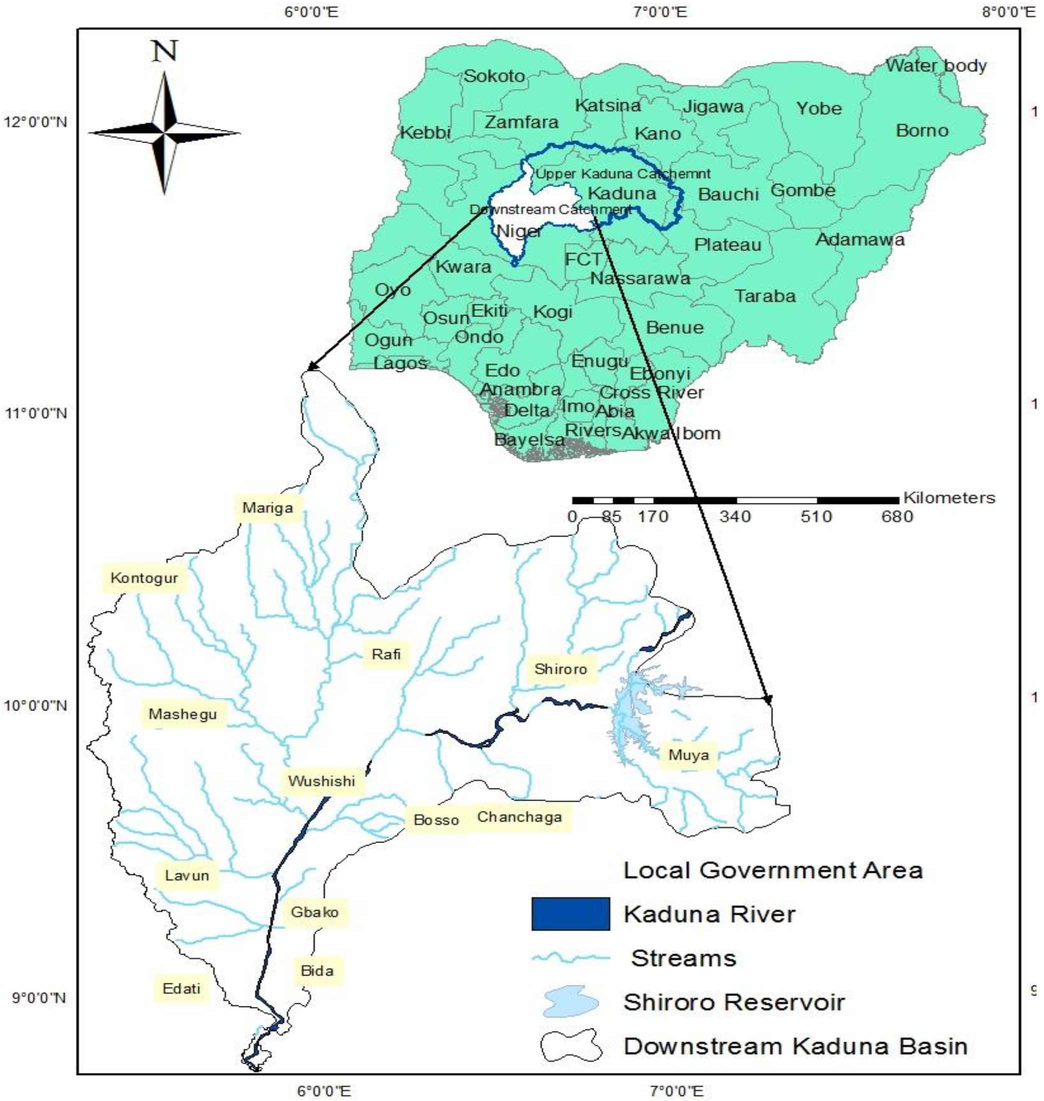


Figure 1.1: Downstream Kaduna River Basin Location in a Map of Nigeria

The months of July, August and September are the heaviest rainfall periods and consequently significant reservoir inflow yield (Suleiman and Ifabiyi, 2014). However, rainfall is available for only 96 days. Annual average daily temperatures are relatively high throughout the year varying between $27^0$C and $35^0$C (Suleiman and Ifabiyi, 2014). The creation of the Shiroro reservoir has led to a change of climatic conditions in and around the reservoir area such as higher humidity and remarkable cool zone in the reservoir area, while the southern part is warmer (Sanyu and Sunmiko, 1995).

### 1.6.3 Geology and Drainage

The study location is characterized by highly variable topographic structure and low relief lying ranging from 150 m to 300 m above sea level at an altitude of 500 feet (NSBS, 2011) which strongly influences the local climate variables and their spatial variability. This gives rise to many of the seasonal streams (Aliyu, 2001), with a highly dendritic pattern of drainage. Flow regime downstream Shiroro dam exhibits a single peak which falls between August and September (Suleiman and Ifabiyi, 2014). Comparable to rainfall, runoff also depicts large seasonal fluctuations described by a peak in August and a trough in March pursuing the seasonality of rainfall in the basin. The basin is vulnerable to seasonal flooding resulting from the annual migration of the Inter-Tropical Convergence Zone (ITCZ) and its accompanying rainfall instability (PHCN, 2010). This will have an impact on the socio-economic development and the environment in the upper and middle part of the study area which are the basis of agricultural and industrial development in Niger State.

### 1.6.4 Soil, Landuse and Vegetation

This region is an area of Guinea Savannah sustained by annual burning. The land is made up of two major rock formations, the sedimentary and pre-Cambrian basement complex rocks. The dominant soils are broadly categorized as Ferric Luvisols, Ferric Acrisols and Ferric Cambisols (Ojanuga, 2006). The soils are poorly drained, characterized by considerable variations in physical composition (Aregheore, 2006) and generally poor away from the river alluvium. Soils are mainly characterized by clay soil mixed with small quantity of sandy soil. Predominant landuse and land cover in the basin are cultivated farmlands mainly rain-fed crops, forest, rocks, bare soil, settlements and water body. Vegetation found here consists of economic trees like mangoes, Dogoyaro

(*Azadiracta indica*), and some stunted acacia trees, grasses with scanty scrubs. Most land cover have been cleared for intensive farming.

### 1.6.5 Population

According to the 2006 Census Figures for Niger State, the study site is among the most populated area in Niger State; Shiroro (235,404), Gbako (127,466), Lavun (209,917), with relative high poverty rate and of the most underdeveloped parts of Nigeria (National Population Commission, 2006; NSBS, 2012). The downstream of Shiroro hydro-dam inhabited mostly by farmers and fishermen. They are mostly agriculturists who cultivate a variety of crops such as grains, roots and tubers, legumes and vegetables, among them are guinea corn, maize, groundnut, millet, sorghum, upland rice, soy beans, yam and cassava. They have utilized the upper floodplains for swamp rice cultivation as well as sugarcane production (Eze, 2006). Inhabitants in the area engage in other economic activities including manufacturing, petty trading and service. More importantly, Kaduna River serve as a main source of drinking water supply for a large population and sustain multiple economic activities including fishing, transport of local produce and recreation at the study site.  Both tribal and other local communities, living immediately around the river course depend very much on the natural water resources for their lively needs such as fishing, irrigation/fadama farming, and cattle rearing.

## 1.7 Scope

Combining statistical methods and vulnerability-based framework, the study investigated how households are experiencing and responding to climate variability and water stress, what is supporting or constraining their capacity to respond, in downstream Kaduna river basin at Shiroro reservoir in the past 40years (1975 - 2014). The underlying hypothesis is that regional changing climate patterns exacerbates existing water stress in Kaduna River basin, Nigeria, which is currently pressured by an inadequate demand/need-supply ratio.

## 1.8 Limitations of the Study

With respect to the specific research questions to be addressed and among other multiple aspects such as, the relevant spatial and temporal scale of analysis, data used and method considered, some major limitations to the study are as follows; this study was limited to 25 year period of runoff data from 1990 to 2014. This will limit the discussion on compares' of runoff and climate variables to the years available. Though quality data control is carried out, the entire possibility of hundred percent correction rate is not guaranteed. Also time constraint, and inadequate resources will limit the study to sample population which is not necessary a representative of the whole downstream population.

# CHAPTER TWO

## 2.0 CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

Present study investigates vulnerability and household responses to water stress induced by climate variability. Quite a number of researches have been done on vulnerability, adaptation, climate variability and water stress. As a preliminary step in this study, this chapter briefly reviews existing interpretations, concepts and frameworks of these important subjects.

### 2.1 Conceptual Framework

#### 2.1.1 Climate and Hydrological Variability

In recent years, investigations on present and probable future climatic change patterns and their impacts on water resources have become of great interest in different parts of the world because of their serious effects imparted on both human society and the natural environment. Temperature and rainfall are fundamental components of climate, therefore, the analysis of changes in these climatic variables represents an important task in detecting climatic changes. Climate is not a static feature but is continuously evolving on a variety of temporal and spatial scales as a result of a complex system of internal dynamic interactions. Climate variability refers to variations in the mean state of the climate on all temporal and spatial scales in terms of average temperature and rainfall, or an alteration in frequency of extreme weather conditions. Examples of changing climate phenomena include extended droughts, floods, and conditions that result from periodic El Niño and La Niña events. Climatic variations or fluctuations are rather the shifts in the values of these climatic elements.

While variations or fluctuations occur in a short term periods, trends, climatic cycle or change are detected only over longer periods of time. Hydrological and climatic variability are caused by multiple reasons. Variability can be as a result of the internal processes occurring within the climate system or variations in natural or anthropogenic external forcing. Studies showed that anthropogenic climate change, modification in land use/clover, abstraction or change in water use are the main contributing factors for the alteration of hydrological and climatic variability **(**Pagano, Garen, Sorooshian, 2004**).**

Climatic variations are expected to produce reductions in water availability, accessibility, supply in Africa and many parts of the developing world will experience large increase in relative water demand (Arnell, 2004; IPCC, 2007). The most important impacts of future climate variations on society will be the changes in water availability and impacts on water balance would differ for different areas, particularly in lowland areas and floods due to possible heavier rainfall (World Bank, 2010). Rainfall variability, for example, linked to changes in atmospheric circulation and sea-surface temperature patterns in the tropics determine and affect the availability, quality and quantity of fresh water.

### 2.1.2 Water Stress in Climate Variability Context

Water is central to the wellbeing of human society. As such it must be available in sufficient quantities to meet consumption and social needs. Where there is imbalance between water demand and needed and available water consumed for meeting the need, the condition is termed Water stress (UNESCO, 2009). It is an indication of the presence and consequence of water shortage and/or scarcity. Pereira et al., (2002) defined water stress is analogous to the term “drought”. Griffina, Montza, Arrigob (2013) study in the Lower Cape Fear River basin point out water stress as a result of warming climate and increased demand. This can be seen in growing conflicts among water-users, irregularity of water sources, crop failures and food insecurity.

Water is unevenly distributed in space and time; its accessibility is dependent on rainfall variability and water shortages in lakes dams, rivers for domestic, irrigation as well as industrial purposes are likely created by changes in temperature (Ishaku and Majid 2010). While water demand is also increasing rapidly, total water supply may be at risk due to increasing agricultural intensification and urbanization, even in areas projected to increase in annual runoff. Variability of rainfall and runoff, uncoordinated water resources development and population growth in Kaduna basin result in more demand for water thereby subjecting water resources in the basin to stress.

Arnell (2004), using consistent climate and socio-economic scenarios concludes that by the 2020s, about fifty-three to two-hundred and six million people will fall into water-stressed category and about three-hundred and seventy-four to a thousand-six hundred and sixty-six million people in the world are projected to experience increases in water stress. Idogho and Yahaya (2012) attempts determination of water-stressed ratio using Integrated Water Measurement Tool considering water availability, access to safe water and water use to identify the most water-stressed area in Ondo-State Western Nigeria. The study did not take into account environmental factors and socioeconomic factors that could influence water stress. Water stress is determined in this study using the availability, access and use of water by household. Most water stressed areas in this study is identified based on exposure and sensitivity to water stress. High water stresses may include flood, droughts, erosion, and landslides (Xu and Daniel, 2011).

### 2.1.3 Vulnerability Conceptual Issues, Definitions and Causes

A wide range of descriptions for vulnerability exists mostly on the contexts of their origin (UNFCCC, 2011; Adger, 2006; Bohle, Downing and Watts, 1994) or context of study Nelson, Kokic, Crimp, Meinke and Howden (2010) pinpointed that definitions of vulnerability differ from conceptual frameworks, however, clarity and understanding of vulnerability when spoken or written about in context of climate change is however essential (Eakin and Luers, 2006). Vulnerability can be conceptualized in many ways which differ mainly due to different interpretations of vulnerability analysis (Fellmann, 2001; O'Brien et al. 2004, Madu, 2012).

The scientific international body taxed with climate change issues, IPCC's definition of vulnerability in context of climate change specifically highlights three components of vulnerability namely; exposure (E), sensitivity (S) and adaptive capacity (AC) (IPCC, 2007). The exposure of a system to threat depends on its location and the degree of climatic stress. It can be denoted as long-term change or variations in climate, including the degree and regularity of extreme events (IPCC 2001). Smit, Burton, Klein and Wandel (2000), terms sensitivity as the degree to which a system is affected by, or respond to climate risk. Also the sensitivity of a system doesn't often depend on a single system characteristic but on multiple factors and their interactions. Water resources are affected by climate change through changes in precipitation and temperature. Hence, causes climate change vulnerability include insufficient water supply and undesirable water quality. Adaptive capacity of a system to climate change is its ability to moderate or reduce potential harm, take advantage of opportunities or to cope (IPCC, 2000; Smit and Pilifosova 2001). Thus, the adaptive capacity of any society invariably describes its knowledge, their ability to reduce vulnerability in order to cope better with the changes in the environment external conditions. Households or community adaptive capacity can be described by their socio-economic characteristics such as access to financial, technological and information resources.

The economist Sir Nicolas Stern (2006) in his review and Eboh (2009) concludes that developing countries are most vulnerable to climate change because of their geography, high population growth, low incomes, low technological and institutional capacity to adapt to rapid changes in the environment, as well as their greater dependence on climate-sensitive natural resources sectors such as water and agriculture. This is because of the agriculture predominance in their economies, scarce capital available for adaptation measures, their warmer baseline climates, and their heightened exposure to extreme events.

Vulnerability can be said to be affected by both physical and socioeconomic characteristics such as age, culture, resource tenure regimes, and gender, implying that it specific to place, time and the perspective of those assessing it (Adger, 1996, Turner et al., 2003a, Madu, 2012). It is commonly regarded in climate change vulnerability literatures, differences in degrees of vulnerability with respect to sectors, place and social groups (IPCC, 2001; Bohle, et al., 1994). This is partly due to unequal changes in rainfall and temperature occurrence with unevenly distribution of climate change impacts, resources and wealth around the globe (TERI, 2007; IPCC, AR5; Antwi-Agyei, Dougill, Fraser and Stringer, 2012).

Vulnerability is also determined by the local institutional, environmental, political, and market context. The implication of this is that vulnerability will be governed by the exposure-sensitivity and the capacity of affected societies to cope or adapt in long-term (NEST, 2004). Majority of the States in Nigeria have low vulnerability especially rural households in the northern States because of greater exposure to climate induced environmental hazards and low adaptive capacity which results from rural poverty, inadequate healthcare, education systems and poor infrastructure (Madu, 2012). Thus it is important to analyse the variables of vulnerability within an understanding of the local context.

Preston and Stafford-Smith (2009) pointed out that present and future timescales are important and valid to determine degree of vulnerability. However, socio-economic factors can strongly modify the climatic impacts of climate change (Carter, Jones, Lu, Bhadwal, Conde, Mearns, O'Neill, Rounsevell, and Zurek, 2007; Polsky, Neff and Yarnall, 2007), which implies that future vulnerability also critically depends on present adaptation processes (Downing and Patwardhan, 2005; Carter *et al*., 2007). As a result, broad knowledge of vulnerability can be obtained by essentially associating current and future time, biophysical and socio-economic determinants. There are, however, three conceptual methods to analysing climate change vulnerability, which includes; integrated assessment methods, socioeconomic and biophysical methods.

The vulnerability of households in this study is conceptualized based on their adaptive capacity, sensitivity, and exposure – combination of both socioeconomic and biophysical approaches. This reflects the integrated approach to vulnerability analysis as shown in equation 2.1 (Füssel, 2007; Füssel and Klein, 2006).

$$Vulnerability, V = f(A, E, S) \qquad (2.1)$$

Where; f = function, A refers to adaptive capacity, E refers to exposure and S refers to sensitivity.

The three independent overlapping elements is governed by local conditions (Johnston and Williamson, 2007). For this study, these elements have been related (directly and indirectly) with the individual household's characteristics, resources availability and use.

IPCC also stressed that climate impacts are locally specific but there is limited knowledge level of specificity, thus, global knowledge needs to be downscaled. Consequently, household is then selected as the main unit of analysis for this because sensitivity is reflected in this type of livelihood activity and major decisions about adaptation to climate variability and livelihood processes are taken at this level (Thomas *et al*., 2007).

### 2.1.4 Overview of Adaptation

Vulnerable communities have long employed local coping measures and changed livelihood strategies in response to environmental stress, example being climate variability and change. The term coping is sometimes used as a synonym for adaptation, but coping measures are usually short-term responses to avert immediate threats. While adaptation requires adjustments in practices, to continuous or permanent changes. There exists various approaches to adaptation ranging from modifying threats to preventing effects and to accepting the loss.

Indigenous strategies to cope with climatic variability vary geographically and between social-religious-cultural settings, in addition to temporal scales (TERI, 2007). Studies have identified climatic properties of most important in the environment and in different sectors, therefore have proposed adaptive responses types that can be anticipated (Kelkar, Narula, Sharma, Chandna, 2008). While some authors argued that attention should be given to adaptation to current climate (Burton, 1997), it has also been noted that the way people adapted to socioeconomic and environmental changes in the past have major implications for both their current and future vulnerability and adaptive capacity (Zheng *et al*., 2013).

The capacity of communities to cope with the effects of climate change on different economic sectors and human activities is essential in planning adaptation. Adaption measures at different levels, to reduce the magnitude of these impacts and their consequences for livelihoods, should be planned, implemented and need to be further supported and strengthened where necessary. Given the uncertainties about future climate under various scenarios, efforts to assess adaptation options and preferences to current climate can be useful and a crucial step in reducing vulnerability as improved adaptation to climatic variations (Olmos, 2001). This study explores coping strategies or adaption measures employed by rural households in response to reduce vulnerability to water stress and climate variability.

## 2.2 Review of Pertinent Literature

### 2.2.1 Trends of Hydro-Climatic Variables

With anticipated changes in the global climate system, trend detection in hydro-climatic data has received a great deal of attention of recent. The trends of observational and historical hydro-climatic data reflects variations in climate and are generally used to determine appropriate adaptation strategies and also in the planning and designing of water resources projects. Understanding the variations of rainfall, temperature and runoff at the basin scale is very important to study the impacts of climate change on water resources and hydrological processes. Substantial efforts have been devoted to the study of hydro-climate variables (Sirak Tekleab Gebrekristos, 2015; Oyerinde, 2014; Nenwiini and Kabanda, 2013; Salarijazi *et al.*, 2012; Obasi and Ikubuwaje, 2012; Chen *et al*., 2007; Omar, 2006).

Studies have suggested variations in temperature and rainfall. For example, in 2009, Nigeria meteorological agency NIMET predicted variations in annual rainfall from 400-1200 mm over northern Nigeria, while the southern parts, will experience rapid increase from 1,200 to 2,800 mm, denoting high surface runoff and its resultant environmental vulnerabilities such as flooding. Adakayi (2012) examined variations in rainfall and temperature in parts of Northern Nigeria and results indicate that on the basis of years (1970s and 1980s) showed lower temperatures and rainfall while the periods (1990s and 2000s) revealed higher temperatures and rainfall. The study recommends that more attention should be paid to regional studies of current climatic behaviors in various regions of Nigeria. Ayinde, Ojehomon, Daramola, and Falaki (2013) analyzed the trend of climatic variables in Niger State, Nigeria, to determine the factors affecting the output of rice in the State. Their result reveals that there is variation in the trend of the climatic factors with effect on rice production. Nenwiini and Kabanda (2013) observed that rainfall is highly variable within local settings. With the aim of detecting spatio-temporal trends, statistical analysis of hydro-meteorological variables at Shiroro dam was carried out by Suleiman and Ifabiyi (2014). Their results indicate a significant positive uptrend in rainfall during the study period which is reflected in the surface runoff yield into the Shiroro dam.

Recently, Okunlola and Folorunso (2015) analyzed rainfall series in selected States of Nigeria geo-political zones. Their study indicated an increasing trend in the rainfall series with the rate of change highest in South-South zone. Tekleab (2015) showed that trends and change point times varied considerably across stations and catchments with respect to temperature and runoff series, respectively in the Upper Blue Nile. Abaje, Ishaya, and Usman (2010) analyzed rainfall data from 1974 – 2008 (35 years) over Kaduna state. The results of the Standardized Anomaly Index (SAI) revealed that rainfall yield is declining in the study area.

Despite the recent progress, hydro-climatic investigations and hydrological studies in Nigeria are still relatively scanty and mostly in small river basins especially in northern Nigerian basins. In fact, most of the previous studies have focused on temporal and spatial trends (Akinsanola and Ogunjobi), magnitude and frequency of rainfall and runoff occurrence for various return periods (Dike and Nwachukwu, 2003), response patterns of hydrological parameters (Ifabiyi, 2013), effects of climate change (Ayinde, Ojehomon, Daramola and Falaki, 2013; Obasi, and Ikubuwaje, 2012), and flood analysis (Garba *et al.*, 2013).

Understanding the spatial and temporal variability of rainfall and runoff is challenging and requires high quality observed datasets. Over the country, extensive studies of hydrological phenomena have been limited because the spatial distribution of rain gauges is not adequate enough to allow the description of local and large-scale hydrological phenomena. The problems of scarce hydro-climatic data and limited hydrological studies are also applicable in the Kaduna basin. Ifabiyi (2013) studied 30 hydro-climatic variables generated from 30 sub basins of the Upper Kaduna Catchment covering 1979 - 1989

(11years period). The research revealed that behavior of hydrological variables in the tropics and indeed, in Nigeria is largely misunderstood as different basin variables explained response patterns of individual flow types. In the research, factor regression method was used to identify the most significant factors that explained each of these components in the Upper Kaduna catchment (UKC).

A number of statistical analysis such as Mann-Kendall, Sen's Slope, reduction method, standardized anomaly indices (SAIs), simple and multiple regression analysis (MRA) have been used to assess fluctuations and trends analysis of hydro-meteorological variables with the purpose of studying the climate change impact on runoff (Salami *et al*., 2015; Karmeshu, 2012). Statistical approach was deployed by Akinsanola and Ogunjobi (2014) in their study investigated rainfall and temperature variabilities in Nigeria from 1971-2000. Their results indicated statistically significant increase in air temperature in vast majority of the country and decrease in rainfall which may be due to failure of rain-producing mechanism such as ITD, AEJ, and TEJ within the year of consideration.

One non-parametric tests, the Mann–Kendall (MK) test, is widely used for detecting a trend in hydro-climatic time series (Hirsch, Slack and Smith, 1982; Chen *et al*., 2007; Yue and Wang, 2004**).** Mann-Kendall, Regression, and reduction pattern methods have been employed by Salami, Sule, and Okeola, (2011) to analyze reservoir inflow and temperature data obtained from Kanji Hydropower station. Their result showed slight decrease in reservoir inflow, which may lead to shortage of water for hydropower generation in future. At 5% significance level, the modified Mann-Kendall test was run by Karmeshu (2012) and revealed increasing statistically significant trends in temperature and rainfall for 9 states in the Northeastern U.S for the time period, 1900 to 2011.

In general, the investigations of trends of hydro-climatic variables at sub-catchment level and the implications on watersheds in previous studies were largely unexplored, though it is a very relevant issue for sustainable use of water resources. Therefore, first specific purpose of present study is to identify existing hydro-climatic trends and variation for Kaduna river basin at sub-catchment level with focus on its impact on water availability.

### 2.2.2 Stream flow trends and climate linkages

The hydrological cycle is intimately linked with changes in atmospheric temperature and radiation balance. For effective management and utilization of scarce water resources, knowledge of this relationships is a pre-requisite to understanding effects of trends and links to supply and use of water in the basin. Temperature and rainfall are fundamental components of climate and pattern of changes can affect the ecosystems and human welfare. Also, variations in climate in conjunction with the changes in the physical environment of the catchment could influence the stream flow. Salarijazi *et al.* (2012) reported that in spite of wide range human induced changes, stream-flow series is more affected from the watershed rainfall time series variations.

A growing number of evidences suggest that changes in climatic variables cause a tremendous fluctuation in runoff (Salami, Mohammed, Adeyemo, Olanlokun, 2015; Yurong Hu, 2014; Chen *et al.*, 2007). Associations between stream flow and climatic variables at Kizilirmak river basin in Turkey was studied by Dadaser-Celik and Dokuz, (2012). The study conducted at the annual and seasonal timescales indicated that the relationships between rainfall, temperature and stream flow are most prevalent. The linkages between hydrological and climatic variables were also explored by Yurong (2014) for better understanding of the nature of recent observed hydrological changes.

Salami *et al.* (2015) concluded that the variation in runoff are contributed by temperature, rainfall and evaporation in their assessment of climate change impact on runoff in the Kainji lake basin using statistical methods. In addition, Sang, Xu, Zhang, and Wang (2012) observed that similarity of rainfall and runoff always followed a linear distribution, and the next annual similar relationship of rainfall and runoff could be predicted. The trend of annual mean similarity also reflected the impact of external environment changes on hydrology and water resources system.

Largely due to local and regional differences and limitations, there still exists substantial uncertainties in the description of climate variability induced trends of hydrological variables (Sang, Wang, Li, Liu, and Liu, 2012). Variability in rainfall pattern over northeastern Nigeria was studied by Ishaku and Rafee Majid (2010) with the aim of assessing its impacts on access to water supply. Their result indicates that rainfall in the study area is not only dependent on distance from the coast but also on some other climatic factors such as relief, solar radiation and temperature among others. Therefore, understanding climate and hydrological variability is vital for society and ecosystems, particularly with regard to complex changes affecting the availability and sustainability of surface and ground water resources (US Geological Survey, 2009). Thus, this study attempts to study rainfall, temperature and runoff to see their impacts on water availability downstream Kaduna basin.

### 2.2.3 General Climate Variability Impacts

The world is projected to become increasingly water stressed under climate impacts and population growth. Climate, water resources, biophysical and socioeconomic systems are interconnected in complex ways, so a change in any one of these induces a change in another. Notably, climate variability is likely to accelerate the global hydrological cycles, a greater increase is expected in extreme rainfall as compared to the mean (Ekpoh and Nsa, 2011) and higher temperatures will increase evaporation. The rates of water loss by evapotranspiration in a tropical country like Nigeria is enormous, so the effectiveness of rainfall is considerably reduced especially in the drier Northern parts of the country (Ayoade, 1975).

With respect to climate change, changes in temperature, evaporation and rainfall influence the distribution of river flows and groundwater recharge (Kundzewicz *et al*., 2007). Allexandrov and Genev (2003) investigated climate variability and change impact on water resources in Bulgaria and showed that recent detected decreasing trend in water resources will continue in the future due to warming and rainfall declines. For hydrological variables such as runoff, non-climate related factors may play an important role locally such as changes in rate of withdrawal but river runoff will increase on global scale because of the increased rainfall and the reduced transpiration (Nohara, Kitoh, Hosaka and Oki, 2005).

Evidence from observational records and climate projections indicates water resources are vulnerable and have the potential to be strongly impacted by climate change and variability, with wide-ranging consequences for human societies and ecosystems (Bates, Kundzewicz, Wu and Palutikof, 2008). Hydro-climatic changes have significant impacts on the ecosystems and local populations. The livelihood and socioeconomic aspects of the rural poor are expected to be adversely affected owning to negative impact of climate variability on streamflow and water availability. Changes in the mean temperature, rainfall patterns and variability can possibly extend dry seasons, or lead to increase in instances of dry spells and drought thereby increase the severity of water stresses. Heat wave incidents can result from increase in temperature and cause illness or even death in susceptible populations. Increasing rainfall trends and higher peak flows can contribute to increase in the frequency of floods adversely affecting human settlements and livelihood. Conversely, low minimum flows will impact the use of water for power generation, irrigation and public water supply while variations in rainfall and evaporation may also affect groundwater levels and water quality.

### 2.2.4 Climate Impacts on Water Resources in Kaduna Basin

The climate variability impact on water resources in the Kaduna river basin is likely to put wide ranging effects on the environment, biodiversity, and socio-economic conditions of the catchment. The construction of Shiroro dam reservoir to supply hydroelectric power for the Nigeria in Kaduna River Basin causing changes of watercourse and hydrologic regime, soil erosion, sediment deposition, water pollution, loss of biodiversity, and other water-related issues have attracted attention of recent.

Under the impact of changing climate on water resources, Haruna, Abubakar, Rabia, Saminu, Abdullahi, Faustinus, (2006) observed an increase in the magnitude and frequency of flooding events, a reduction in soil storage throughout the summer and autumn months as well as increase in base flow, round storage and runoff potential of aquifers located along Kaduna River. Folorunsho, Iguisi, Mu'azu and Garba (2012) also applied Adaptive Neuro-Fuzzy based Inference System (ANFIS) model to forecast runoff in River Kaduna but did not account for potential changes in climate and its variability nor discuss the implications of the prediction.

In an attempt to examine the response of Benue river runoff, in Yola, to climate change using 49 years period climatic (rainfall and temperature) and hydrological data (river runoff), Adelalu (2012) observed both total runoff and rainfall decrease with the rate of decrease of rainfall about 14 times that of runoff. The study further revealed that 24 percent and 31 percent association strength to the variation of runoff is contributed by rainfall and temperature respectively and 50% water variability in the state. In spite of the considerable investment of Niger State government over the years on water supply, a large p0pulation still does not have access to water in adequate quantity and quality (Ibbi and Nmadu, 2012).

Certainly, assessment of vulnerability of households in the Kaduna basin, especially downstream users and their need to adapt to water stresses caused by climate variability is crucial. Thus, the first priority of research on hydrology should be on development of coping measures to climate variability impacts, to assist communities dependent on agriculture for their livelihood especially in semi-arid areas of the country.

### 2.2.5 Vulnerability Assessments of Climate Variability

Due to complexity in vulnerability assessment, climate system itself and water resources management, not many studies of vulnerability assessment of climate variability and water resources are available to date. Researchers have both highlighted the need for vulnerability assessment and discussed particular ways of conducting it (Carter *et al*., 1994; Smit, Burton, Klein, and Street, 1999).

Assessments either focus on a geographic area and related c0mmunities, or a particular natural system and socioeconomic characteristics. Southwest Pacific vulnerability to climatic and socioeconomic stresses such as population growth, inappropriate land use practices, were examined by Birk (2014). The study finding revealed that some non-climatic stresses are more important factors of local vulnerability than climate change and sea-level rise in the area. Finally, the study discussed adaptations options pertinent to different time scales.

They also focus on specific climatic stresses (desertification, changing rainfall patterns, drought, and flood) considering impacts and vulnerability in more than a single sector such as agriculture or at more than one particular level. Kelkar *et al.*, (2008) in the Lakhwar watershed India assessed their vulnerability and adaptive capacity to water stress and identified highly stressed micro-watersheds. The study highlighted the discrepancies between policy recommendations and local needs.

Furthermore, at different scales (global, regional, national and local) a variety of methods and tools have been applied to assess impacts and vulnerability in climate-sensitive sectors and examined the implications of climate change to inform adaptation decision at specific levels. Climate vulnerability assessment of Kangpara Gewog, Trashigang was evaluated to report local climate variability and trends, as well as socioeconomic and ecological conditions by Royal Society for Protection of Nature, (2012). Using both primary and secondary data sources collected through administration of a structured survey questionnaire at household level and reviewing of past studies on climate change, the study concluded that the Gewog is exposed to natural and climate related disasters such as erratic rainfall and drought.

Also, a number of other indices have been developed with different set of parameters/indicators or through defining an index. To mention but a few:

- Climate Vu1nerability Index (Smit and Pilifosova 2001);
- Live1ihood Vu1nerability Index (LVI) (Antwi-Agyei, *et al.*, 2012),
- Live1ihood Effect Index (LEI) (Urothody and Larsen 2010),
- Social Vu1nerability to C1imate Chanqe (SVA) in Africa (Vincent's (2004).

Combining socioeconomic and biophysical indicators, an index was also developed to examine vulnerability to climate change in 7 regions in Ethiopia (Deressa, Hassan and Ringler, 2008). Some of these indices as reported by Antwi-Agyei *et al.*, (2012) are predefined or theoretical and do not acknowledge local level perception of communities on vulnerability to climate variability. Even though, such assessments at national level provide basis for comprehensive work, their spatio-temporal assessments for smaller areas is inadequate. Consequently, the different soci$_0$economic and bi$_0$physical indicators are classified into adaptive capacity, sensitivity, and exp$_0$sure based on the IPCC definition of vu1nerability (IPCC, 200l). From this, one can identify several indicators that may contribute to vulnerability. These includes; natural hazards, livelihood strategies, and socioeconomic characteristic.

Assessments of climate vulnerability are usually aimed at informing the development of policies that reduce the risks associated with climate impacts. Oginni and Adebamowo (2013) assessed the vulnerability of men and women in Nigeria to prompt actions towards adaptation methods. The study revealed that climate change impacts were widely felt and recognized with rural men and women continually struggling to make adjustments to their livelihoods. The study suggests the need to integrate climate change sensitivity into all sectors and empowering the vulnerable especially the women. On the basis of survey carried out using interviews with selected key stakeholders and documentation by Fatile, Adejobi and Olorunnimbe (2012). They argued the need to develop appropriate strategies to mitigate the impacts of vulnerability to climate change and conflict management in Nigeria.

### 2.2.6 Adaptation to Climate Variability Impact and Water Stress

Vulnerability requires an adaptation strategy or coping mechanism. The key objective in vulnerability assessment is to assist rural poor to adapt to stresses (Huq, 2007). The local community is knowledgeable of the change and variations in climate respectively. Oginni and Adebamowo (2013) argued that the resource-dependent rural communities constantly struggle to make modifications to their lives to survive. Moreover, Rishi, Omprakash, and Mudaliar (2010) noted that there is a pressing need to address issues related to climate change adaptation, vulnerability, and coping in the developing nations as these regions have the largest deficiencies in adaptive capacity.

The perception and adaption measures to long-term changes in climate of smallholder farmers Free State Province in central South Africa as examined by Gandure, Walker and Botha (2010) reveals rainwater harvesting techniques as the most popular strategy used and are externally supported and sustained. Obiora (2014) investigated the survival strategies used by the women farmers in Benue State to coping with flood incidence induced by climate change. The study reported that respondents resorted to begging alms and migration to neighboring communities as means of adaptation. The study suggests government and NGOs to economically help empower the women.

Previous studies have emphasized the role of livelihood diversification as a means of adaptation for rural households (Ellis and Allison, 2004). However, specialization has been identified as economically more attractive but require access to education, irrigation, and/or transport (Eriksen, Brown and Kelly, 2005) which may not readily be available for rural households. Oyerinde *et al*., (2014) observed that social and environmental factors determines impacts of climate change in the communities and can introduce differences in perception despite identical observations. Wiltshire *et al.*, (2013) suggests that opportunities to alleviate some of the increases in water-stress, may hinge on adaptation measures being taken to exploit increased runoff through increased storage of seasonal flows.

Clearly, while much previous work has been done investigating vulnerability and adaptation to climate variability. In the reviewed studies, study focus were on climate change impacts with few on jointly study of climate variability and water stress. The main methods of assessing vulnerability applied from these studies under integrated approaches were questionnaire interviews, semi-structured interviews, focus groups and participatory observations, and supplemented by mapping exercises and topographic transects. Time lines of socio-economic and environmental changes were also developed. Results with regards to water stress are few and indicates variability across regions and dependence on the methods considered, the data used and the scale of relevance selected. Likewise, it is anticipated that water resources in Nigeria would be extremely vulnerable under climate change scenarios, and as a result, water and food security of the country will be at risk. Despite being highly vulnerable, very little efforts have so far been made to understand potential of water resources adaptation in Nigeria.

# CHAPTER THREE

## 3.0 RESEARCH METHODOLOGY

To examine vulnerability and adaptation to water stress induced by climate variability among the communities living downstream of Kaduna River watershed, the study employed Statistical and Stakeholders' Participatory Approach. This chapter outlines the research design, method employed and data analytical techniques that were used in achieving the objectives of the research.

### 3.1 Collection of Hydro-meteorological Data

Data records employed for study are both primary and secondary data. The following long term secondary hydro-climatic data of 40 years were used in the study analysis.

- Historical records of Daily Minimum and Maximum Temperature data for two (2) stations (Minna and Bida) from 1975 to 2014, and
- Daily Rainfall data for two (2) stations measured in millimeters for the period 1975 to 2014 were obtained from Nigerian Meteorological Agency Abuja, and hydrometric stations near/covering the sample villages.

The stations with their locations in the basin and their elevation, latitudes and longitudes are listed in Table 3.1.

Similarly, Hydrological data set (runoff) for one gauging station in the Kaduna river basin (see also Table 3.1) for different periods; 1990 to 2014 (available length of records) was provided by Shiroro Dam Hydro-Electric Power Station in Niger State. This station was established in 1990, mainly responsible for collecting basic hydrological data and providing services for the operation of Shiroro reservoir.

**Table 3.1: The hydro-meteorological stations in the Kaduna basin used for the study**

| Station | Type of Data | | Location |
|---|---|---|---|
| | Rainfall | Temperature | |
| Minna | 1975 - 2014 | 1975 – 2014 | 09°39'07''N, 06°27'44''E, 254m |
| Bida | 1975 - 2014 | 1975 – 2014 | 09°10′00''N, 06°20'00''E, 143m |
| | Runoff | | |
| Shiroro HEP | 1990 - 2014 | | 09°56'32.64''N, 06°48'44.34''E, 397m |

Source: Author

**3.2 Study Population and Sampling Technique**

The population of study comprises of households downstream Kaduna River within Niger state. The three study sites; Shiroro, Gbako and Lavun Local Government Areas were purposively selected on the basis of location on the course of Kaduna River; the upper, middle and lower slope positions of Shiroro reservoir. They are located at different elevations, hence vary in terms of environmental conditions, level of rurality as well as access to infrastructure, goods and services. Six communities in the three sites, and two from each of the local government areas were selected for survey based on water scarcity, communities with high population density and economic and agricultural activities. The selected communities were Isogi, Dadi, Wuya, Gbadafu, Galadima kogo, and Mutumdaya. They represent typical rural village types in Niger State. Effort was made to select villages with at most minimum of 30 – 50 households to get a realistic sample size, with the households sample weighted with household number and represents about 65% of the households in each of the villages.

**Table 3.2 Sample distribution**

| LGA | Villages interviewed | Number of households | Households interviewed (n=200) | Location |
|---|---|---|---|---|
| Shiroro | Galadima Kogo<br>Mutumdaya | 85<br>30 | 55<br>20 | 09°59′32.33″N, 06°48′07.34″E |
| Gbako | Wuya<br>Gbadafu | 45<br>55 | 30<br>40 | 09°08′33.47″N, 05°49′15.43″E |
| Lavun | Tsoegi Tako<br>Dadi | 55<br>30 | 30<br>25 | 08°58′28.83″N, 05°51′19.67″E |

*Source: Author*

A total of 200 randomly selected households across the chosen local government areas were considered for the study. Galadima Kogo and Mutumdaya are part of a cluster of villages in Shiroro local government. The total number of households in the communities were about 85 and 30 of which fifty-five (55) and twenty (20) were interviewed. Wuya and Gbadafu in Gbako local government, with total number of households as hundred and ten (110), of which seventy (70) were surveyed.

## 3.3 Physical site visit

Site visit and transect walk were undertaken in six villages to assess the available water sources, land use, socio-economic status, access to infrastructure within the area. Personal observations and photographs, were taken where necessary, to substantiate the observations made.

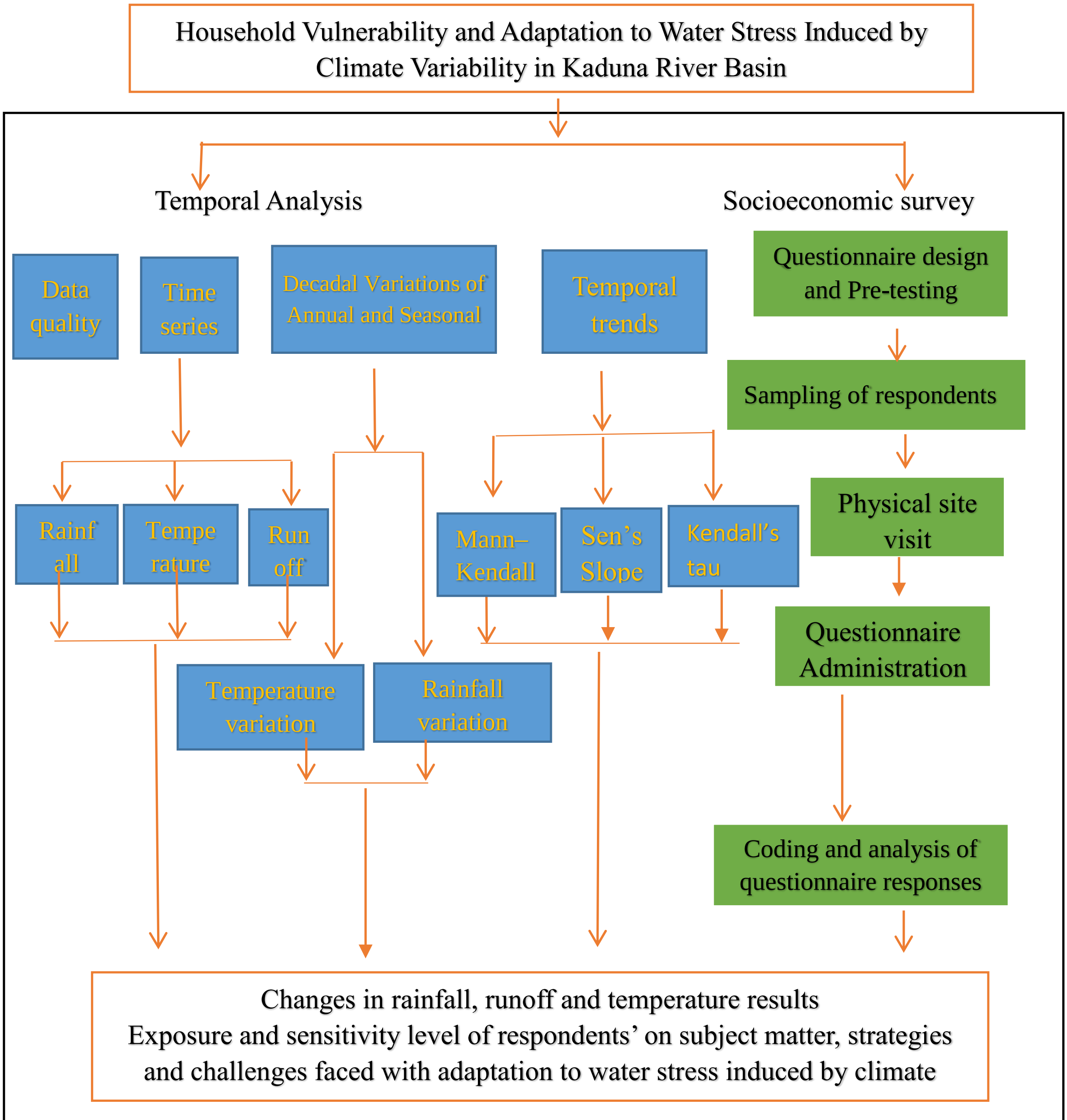


Figure 3.1: Methodology flowchart

### 3.4 Statistical methods

Generally, there are few hydrometric stations that measure daily rainfall and daily river runoff in the basin, resulting in scanty hydrological data for the basin. The stations selected have less than 5% of the daily values missing in each year. Other indices of these data were calculated and used which include monthly, annual and seasonal values, as well as decadal averages. Visual inspection have been used to detect outliers and interpolation from data of the nearest high correlating neighboring stations were used to fill in gaps observed in the data.

To analyse temporal variations in trends of data time series, three statistical methods were adopted in this study:

1) The Mann Kendall approach, non-parametric trend detection test initially developed by Mann (1945), which was later derived by Kendall in 1975 in testing for non-linear trends.
2) Sen's Slope to estimate the trend magnitude
3) Trends in streamflow and their association with the climate trends are explored using Kendall's tau to show correlation in the time series.

Available data periods used in are given in Table 3.1 and trends evaluated in different times with length of available records.

### 3.4.1 Mann-Kendall test

The Mann Kendall (MK) test is extensively used non-parametric tests for trends in hydro-climatic time series (Yue and Wang, 2004; Love, 2013; Hu, 2014). The Mann-Kendall test most generally said to test for if X data values exhibit monotonic change with time. It is applied to data that are not normally distributed, frequently found in climatological or hydrological analysis (Hu, 2014, Yue and Pilon, 2004) but there must be no serial or auto correlation in the data series.

According to this test, let a time series $X_{1,} X_{2,} X_{3,} \dots, X_n$ data points of n and $X_i$ $and$ $X_j$ as subsets of the data in the procedural Mann Kendall test calculation, where $i =$

$1,2,3,\ldots n-1, j=i=i+1, i+2, i+3, \ldots n$. The data series are ranked and successively compared. If a value in the time series from a period is greater than a va1ue fr0m a previously time period, the $M$ value is raised by 1. Conversely, if value of the late period is lesser than that tested earlier, $M$ is reduced by 1. The gross result of all such increases and reductions produces the final the test statistic $M$ given by the formula:

$$M = \sum_{i=1}^{n} \sum_{j=i+1}^{n} sgn\,(X_j - X_i) \quad (3.1)$$

$$sgn\,(X_j - X_i) = \begin{cases} 1, if\ (X_j - X_i) > 0 \\ 0, if\ (X_j - X_i) = 0 \\ -1, if\ (X_j - X_i) < 0 \end{cases} \quad (3.2)$$

Where $X_j$ and $X_i$ represent annual values of the data in years $j$ $and$ $i$ such that $j$ is greater than $i$.

For $n < 10$, the $|M|$ value is directly linked to hypothetical distribution developed by Mann-Kendall. Employing the two tailed-test for α=0.05 probability level, the null hypothesis, $H_0$ is rejected against the alternative hypothesis, $H_1$. Therefore, if the $|S|$ equals or exceeds a stated value $S_{\alpha/2}$ (+1.96), where $S_{\alpha/2}$ is the smallest S which has the likelihood less than $\alpha/2$ to occur in the situation of no existence of trend.

$$H_0: Prob\ [Xj > Xi] = 0.05, \text{ on time } Tj > Ti \quad (3.3)$$

$$H_1: Prob\ [Xj > Xi] \neq 0.05 \text{ (2-sided test)} \quad (3.4)$$

For n values ≥ 10 approximately, the statistic S is normally distributed. Under the null hypothesis of no trend and independence of the series terms, the variance of the Mann-Kendall statistic is computed as:

$$Var\ (S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} ti(i)(i-1)(2i+5)}{18} \quad (3.5)$$

for which $t_i$ represents the size of ties to i and extent and m number of tied groups. The summation formula in the equation can be used only when the series comprises of tied values. A significant trend is statistically evaluated using the Z value.

$$Z_K = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}}, for\ s > 0 \\ 0, \qquad for\ s = 0 \\ \frac{S+1}{\sqrt{VAR(S)}}, for\ s < 0 \end{cases} \tag{3.6}$$

The MK statistic Z is the normal, standard variate with mean equals 0 and variance equals one. In this study, trends have been estimated at 5% level of significance (the corresponding threshold value of $\pm 1.96$). This denotes that the null hypothesis is rejected when $/Z_K/ > Z_{\alpha/2}\ or\ (Z_{1-\alpha/2})$, in equation (3.4) at α level of significance, where $Z_K$ is the standard normal variate. If $Z_K$ is +, it indicates increasing trend but when negative shows decreasing trend.

### 3.4.2 Sen's slope estimator

The magnitude of trends is computed using a median centred slope estimator as proposed by Sen (1968) and extended by Hirsch *et al*. (1982). The slope estimation is given by:

$$Q_i = \frac{Xj - Xk}{j - k}, for\ all\ k < j\ and\ i = 1, \ldots N, \tag{3.7}$$

Where Q = slope between data points $X_j, and\ X_k$, $X_j$ data values at time j, $X_k$ = data values at time k. N = $\frac{n(n-1)}{2}$ for single observation in each time period or N < $\frac{n(n-1)}{2}$, where $1 < k < j < n$, and n is the total number of observations for each period. The N values of $Q_i$ are ordered from the least to highest and median is the Sen's estimator of slope as:

$$Q_{med} = \begin{cases} Q\{\frac{N+1}{2}\}, \quad when\ N\ is\ odd \\ \frac{Q\left(\frac{N}{2}\right)+Q\{\frac{N+2}{2}\}}{2}, when\ N\ is\ even \end{cases} \tag{3.8}$$

The $Q_{med}$ sign reflects data trend, while its value indicates the steepness of the trend.

### 3.4.3 Kendall's tau

Kendall's tau test measures correlation that indicates the level of relationship between variables and have been employed to show correlation in the time series. The aim of corre1ation analysis is to determine whether the trends in runoff are attributable to climate variability. The Kendall's tau technique (non-parametric) described in Gocic and Trajkovic (2013) was employed in testing the relationship between runoff, rainfall and temperature series. In common with other measures of corre1ation, Kenda1l's tau coefficient, denoted with 'b', allows to measure on scale of $-1\ to\ +1$ The degree of relationship (positive) between two ordered variables indicates that the levels of the variables increases concurrently whereas a negative correlation is an indication that as one variable is decreasing while the second increases. It is well-suited for variables which exhibit skewness around the general relationship. Unlike the Gamma coefficient, the Kendall's tau allows to take ties into account.

## 3.5 The Survey Method

To determine vulnerability, survey was done with the aid of questionnaire (semi-structured) comprising open and closed questions addressing climate trends and variability, water stress and adaptation responses. This was administered on 200 randomly selected households to collect rural household data and household adaptation strategies; both farming practices and non-farming responses in the face of water stress, based on indicators grouped at local government level. Household questionnaire (see Appendix A) were designed and tested (using expert opinion and 10 households in Bosso), and through a face-to-face interview, they were administered from April to May, 2015. The respondents were from three different Local Government Areas (see Fig. 1.1) determined from purposive sampling (location along the Kaduna River and its tributaries).

The required information on vu1nerability due to climate variabi1ity revolves around various dimensions as consistent with literature (Adger 2006; IPCC, 2007a; Smit and Wandel, 2006) summarized as exposure, sensitivity and adaptive capacity. Exposure variables include information on rainfall variability and temperature and runoff changes while sensitivity variable include effect of climate variability, water availability, drought and flood. Adaptive capacity was determined by site characteristics, socioeconomic profile, livelihood strategies (diversification, irrigation and planting twice per year), Social group, house types and access to information and/or resources (awareness of climate change, farmland and assistance). The institutional, economic and physical aspects of water resource and its management system are contributing factors to vulnerability. To address them, indicators that are most relevant with local conditions were identified (listed in Table 3.2) used to investigate the exposure, sensitivity and adaptive capacity selected based on literature recognition and availability. These were used to investigate vulnerability of households to water stress and corresponding adaptation responses.

**Table 3.3: Indicators of household vulnerability and water stress as used in the study**

| Vulnerability Dimensions | Components | Indicators |
|---|---|---|
| Exposure | Rainfall, temperature and river runoff | Observed trends and occurrence |
| Sensitivity | Degree of climate variability, water stress, and extreme events such as Flood and drought | Awareness, perception, effect of climate variability, level of water availability and water shortage. |
| Adaptive capacity | Socio-demographic characteristics, livelihood strategies and adaptive measures employed | Level of education, size of household, income diversification, access to resources, measures in agriculture, water supply and flood control |

*Source: Author*

In line with the methodology, the questionnaire consisting of 50 questions was divided into four sections (see Appendix A). The section A gives an overview of the respondent's background and households characteristics and resources (occupation, houses, land, crops and livestock). This was used to create vulnerability profiles, help in the understanding of the socio-economic relations in the households and comparing households across case study sites. Section B aimed at analysis of climate trend and variability with questions regarding their perceptions, awareness and knowledge level of changes in temperature, rainfall and river runoff in the area over the past 5 - 10 years. Section C is on assessment of water availability in the villages; water stress in terms of flood and drought and their perceived impacts of climate variability on water resources and livelihood challenges. This was used in analyzing the extent to which households are exposed to water stress. Section D addressed responses in relation to climate variability and water stress in households like coping actions; social network, and access to resources and information. Questions (semi-structured) and response options were modified to use locally appropriate terms and concepts and to enable balance between optimization of vulnerable peoples' opinion and quantification of impacts.

### 3.6 Focused Group Meetings

Group discussions were held in the selected villages from the catchment to elicit community perceptions on climatic variability in the basin, learn about factors impacting livelihoods overtime and the adaptation of the local population to those variations. The groups consist of people differentiated according to age and gender to ensure triangulation of the key issues emerging from the household questionnaire and validity of the data.

### 3.7 Data Analysis and Presentation

In this sub-section, explanation of statistical analysis performed on the hydro-meteorological data collected, and quantitative analysis and qualitative judgements of socioeconomic data collected from questionnaire were described.

#### 3.7.1 Statistical Hydro-climatic Data Analysis

Statistical techniques such as the time series analysis using Microsoft excel, to show the rainfall, runoff and temperature patterns from 1975 to 2014. To detect significant periods in hydro-climatology, the rainfall, runoff and temperature were analyzed at annual and seasonal timescales because the variables exhibit substantial dependence over a series of space and time basis (Katz *et al*., 2002). Essentially, during the series analysis, autocorrelation effect, defined as the relationship of a variab1e with itse1f over successive time intervals, should be taken into account before checking for trends. This increases the likelihoods of detecting significant trends. However, a positive autocorrelation or serial correlation (which is usually present in time series of climate data), if present, makes this test unreliable. So the serial correlation in the residuals of the annual temperature, rainfall and runoff series when testing the statistical significance of trends was checked using Durban Watson method at $\alpha = 0.05$ significance level. Taking account the effect of autocorrelation, Von Storch (1995); Wang and Swail 2001, Yue *et al*. (2002), Zhang and Zwiers (2004) recommended pre-whitening the series to remove serial correlation prior the Mann-Kendall method is applied. This procedure have been applied by Hu, 2014; Yue and Pilon (2004). Based on effective sample size (ESS), Hamed and Rao in 1998 proposed a modified Mann Kendall test which calculates serial correlation between the ranks of the data after taking out the apparent trend. This method, to an extent, still have much higher rejection rate as demonstrated by Yue *et al*. (2002b). To correct the data for serial autocorrelation, the procedure as described in Yue and Wang (2004) was used in this study. The advantage of this method used is its performance when there are both a trend and an autocorrelation. The statistical Mann-Kendall test was performed in Excel (XLSTAT 2012- Excel extension software). The null hypothesis for hydro-climatic variables was tested at 95% confidence level for the three stations and linear trend lines plotted in Microsoft Excel 2013.

### 3.7.2 Socio-economic Data Analysis

Data obtained from the questionnaires were coded and subsequently analyzed using a combination of the SPSS software package, version 20 and Microsoft Excel 2013; and compared with the respective hydro-climatic observations. Most of the collected data were of qualitative nature and necessitated use of qualitative data analysis. The key analyses carried out were descriptive statistics and frequency analysis and using "COUNTIF function" of the Excel to collect questionnaire results into simple and clearer dataset. Results were presented using frequency and univariate analysis charts, tables and graphs to show the socio-economic life of the people.

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSIONS

In this chapter, the main findings of the study are presented. The major findings presented are trend analysis of hydro-climatic data, peoples' perception on climate variations, vulnerabilities and adaptation strategies adopted by the households to cope with the impacts of climate variability induced water stress. Prior to evaluating and inter-comparing the series, it is helpful to assess the pattern of the individual hydro-climatic variables using time series plot. For a proper utilisation of scarce water resources under varying climate, assessment of vulnerability, adaptation and flood impacts, relevant facts about temperature, rainfall and runoff for the whole basin must be known. The rainy and dry season months in the study refers to April to October and November to March, respectively.

### 4.1 Hydro-climatic Trends

#### 4.1.1 Rainfall Pattern

In this subsection, the evidence of trends in rainfall was reviewed and time series analysis was carried out using the trend lines with respect to the mean value. This to discern if there exist trends (increasing or decreasing) in the rainfall records during the forty (40) years. The rainfall data showed large disparities in average monthly rainfall patterns over downstream Shiroro reservoir. There are distinct dry and rainy seasons which occurs for about five and seven months respectively. Figure 4.1 showed that the maximum seasonal rainfall for the study period occurred in 1995 – 2004 decade with a value of 2556.95 mm.

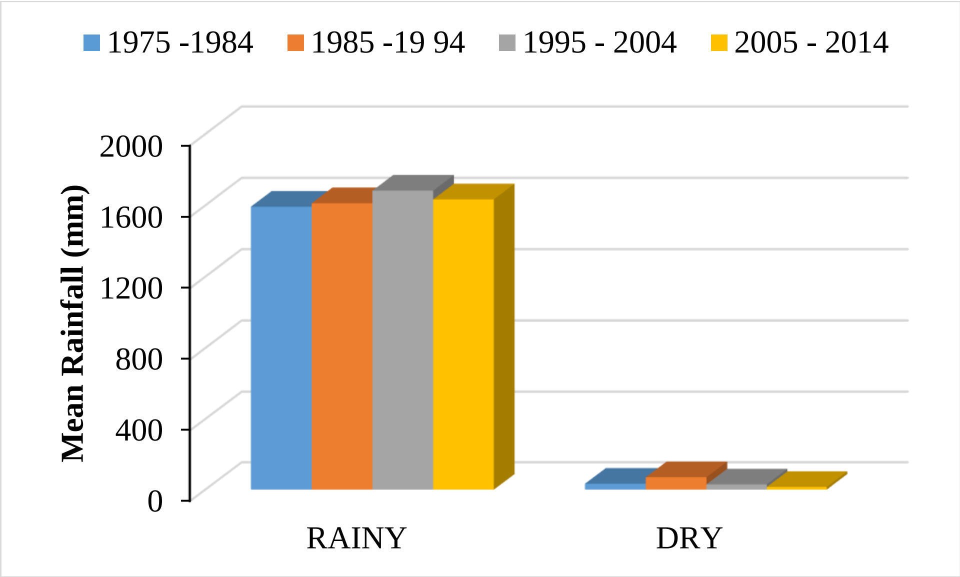


***Figure 4.1:*** Average seasonal rainfall (1975 - 2014) for downstream Kaduna River in decades

When compared in decades, the results show that the dry season was decreasing especially in 2005 – 2014 decade and increasing in rainy season. The mean yearly pattern of rainfall in the study area shows obvious oscillation and instability (Figure 4.2). The polynomial trend line indicates variation in rainfall totals showing dry and wet periods. Significant wet years can be seen in 1978, 1991, 1994, 2001, 2008 and 2012 while 1981, 1983, 1987, 2002, 2011 and 2013 can be seen as the driest years in the area. Wet years obviously brings the risk of flooding.

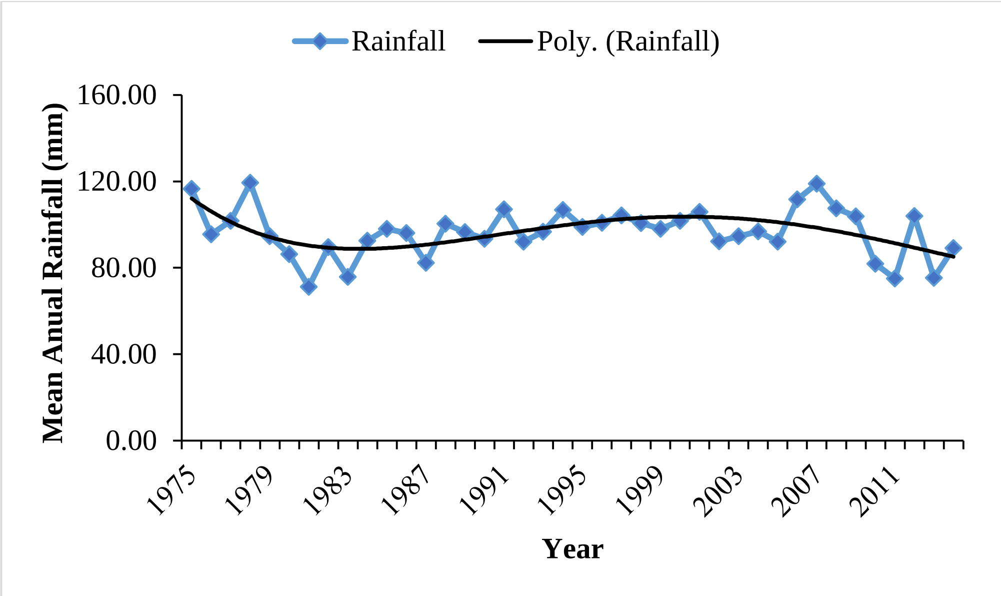


Figure 4.2: Annual Rainfall Pattern downstream Kaduna River (1975 – 2014)

The analysis reveals a variable rainfall pattern with obvious decreasing trend in the 2005 – 2014 decade. Rainfall is highly variable within local settings (Nenwiini and Kabanda, 2013). The observed variability in seasonal rainfall in this study was in line with the study conducted by Suleiman and Ifabiyi (2014). They found that variability is greater between the months of May to October of which coincides with the rainy season. Similar observations in irregular pattern of annual rainfall were made by Eze (2006). The study suggests a slight increase in rainfall amount from irregular rainfall pattern over the Kaduna River catchment at Shiroro Local Government Area as indicated from the significant wet periods were observed from this study.

### 4.1.2 Runoff pattern

Similarly, the maximum mean seasonal runoff at Shiroro reservoir for the study period (1990 – 2014) has occurred in 2005 - 2014 decade with a value of 310.05 cubic metres. Figure 4.4 illustrates the mean seasonal runoff which showed an increasing pattern.

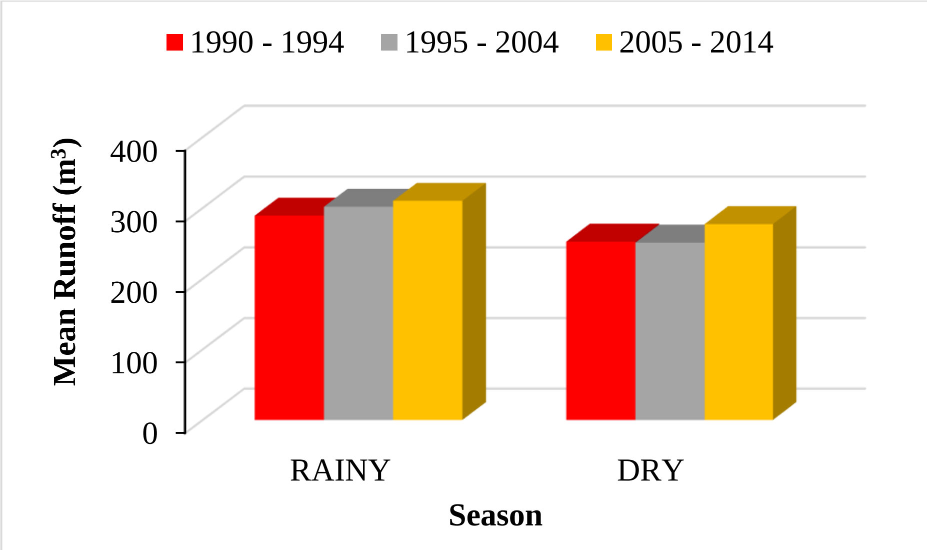


Figure 4.3: Mean seasonal runoff in Kaduna Basin River at Shiroro reservoir gauging station

Figure 4.4 shows the variable increasing pattern of mean annual runoff at Shiroro at the rate of 1.618 cubic metre per year. The peak runoffs happened in 1992, 1998, 2001, 2006 and 2012 for every five years while 2005 and 2008 show extreme minimum runoff at Shiroro reservoir. Significant peak periods can be seen in 1992, 1997, 1998, 1999, 2001, 2003, 2004, 2006, 2010, 2011, 2012 and 2013 years while 1993 - 96, 2004 and 2014 can be seen as the years with low runoff peaks in the area.

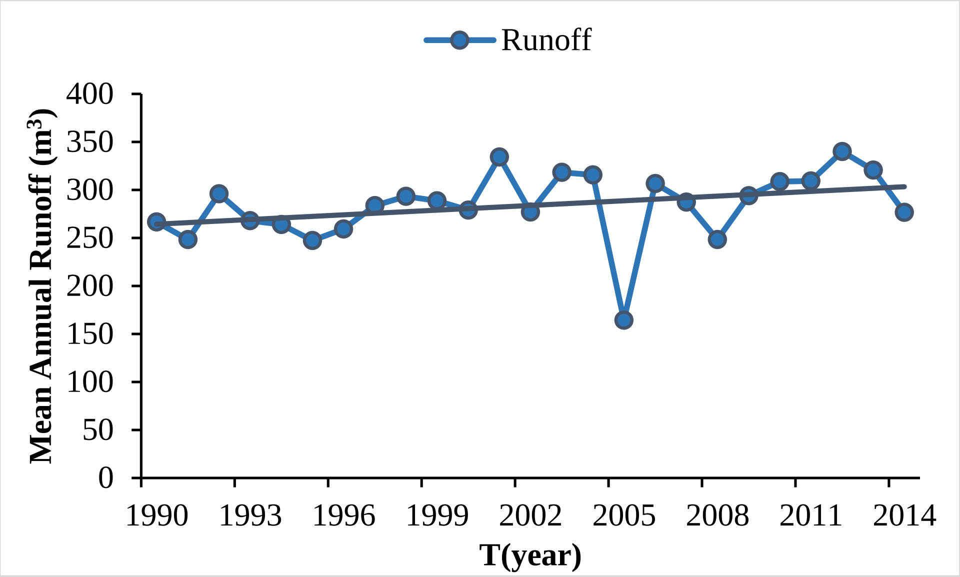


Figure 4.4: Observed river runoff pattern at the outlet in Shiroro reservoir (1990-2014).

From the runoff result, increasing tendency has been observed which is supported by runoff analysis performed by Fan, Chen, Li, Wang and Li (2011). Conversely, the frequency, amount and the duration of rainfall events determine the trend of hydrological events such as river runoff and flood. The observed significant wet years and slight increase in rainy season rainfall amount follows the flood events that occurred in the area in the years 1998, 2003 and 2012 agrees with the work of Eze (2006) and Adakayi (2012). These authors reported similarities in flood events and significant wet years. Both rainfall and runoff have strong inter-annua1 and intra- annua1 variabi1ities corroborating the work by Oladipo (1993a). The variability in runoff is higher than that found in rainfall owing to annual runoff influence by both annual variability and amount of rainfall (Peel, McMahon, Finlayson and Watson, 2001).

### 4.1.3 Temperature pattern

The seasonal analysis of the mean temperature for the area shows an increasing trend in rainy season while the dry season shows a decreasing trend (Figure 4.5).

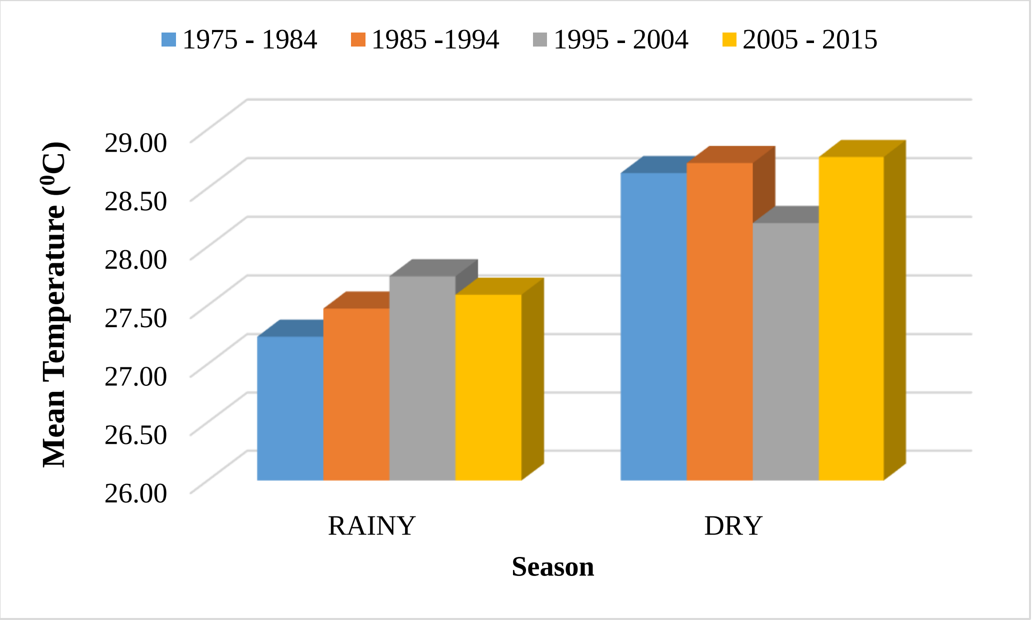


Figure 4.5: Seasonal mean temperature in decades (1975 - 2004)

Variations in mean annual and seasonal temperature pattern are clearly seen. Figure 4.6 shows that the mean annual temperature pattern is increasing with maximum value of 28.87°C in 1987 followed by 1998. The monthly maximum temperature (in July) and minimum temperature (in January) are 27.4°C and 19.49°C, respectively. The warmest period occurred in 1985 – 1994 decade (similar to dry years in the 80's found in rainfall) but the coolest years were in 1974, and 1994. The results of the temperature analysis indicates increasing trend in annual mean temperature while decreasing high temperature events are pronounced in dry season than in rainy season.

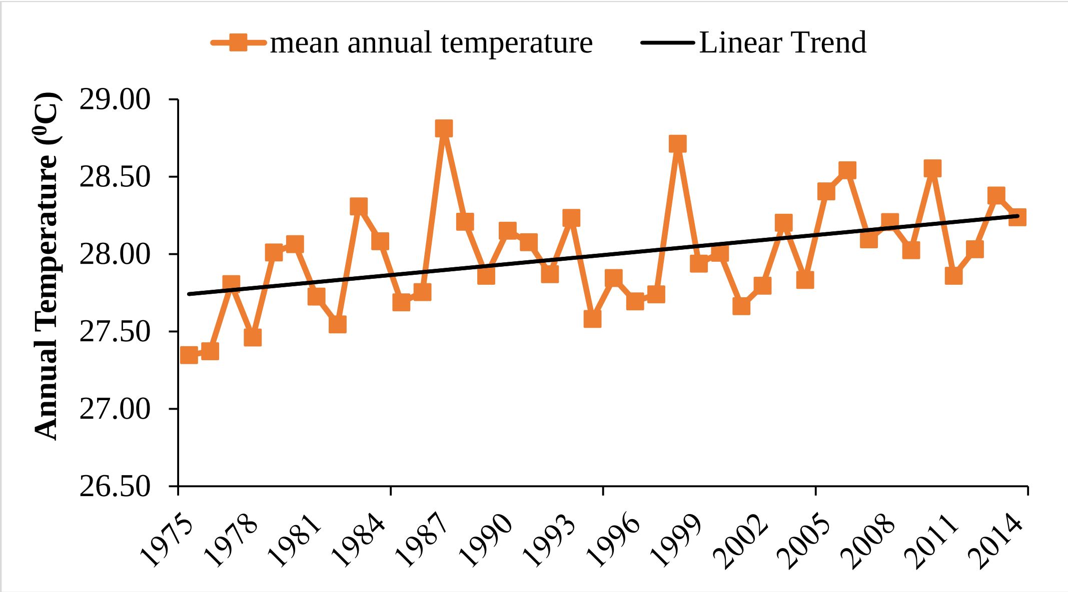


Figure 4.6: Annual Temperature Pattern downstream Kaduna River (1975 – 2014**)**

Overall, there is large intra-annual variation of the rainfall and runoff between 1975 and 2014. Rainfall variability can be related to the movement of the inter-tropical convergence zone (ITCZ) as controlled by the monsoon trade winds movement. The intra-annual variabilities of these hydro-climatic variables play a key role in determining the characteristics of a given climate. The results have proven that the river's natural flow (surface runoff) is very sensitive to precipitation and temperature variations. Further analysis showed that the increasing temperatures observed are consistent with increasing temperatures, over Africa since 1960s, as reported by Bates *et al*. (2008) and evidence of warming observed across the globe. An increase in temperature with increased or decreased rainfall and runoff leads to water stress which impacts on livelihoods. For example, water scarcity is expected to reduce soil moisture levels. Where this occurs in combination with high temperatures, might develop a hard soil layer which will limit infiltration, and most importantly in areas with poor vegetation cover or high rates of surface water evaporation. Cases when intense rainfall does occur, high rates of surface runoff may contribute to flash floods and limit the capacity of land and soils to regulate water supplies more evenly.

## 4.2 Annual and Seasonal Rainfall, Runoff and Temperature Decadal Variations in Kaduna River Basin

In order to study the decadal variations of historical rainfall, runoff and temperature, the mean annual and seasonal values for the entire period of study (1975–2014) and for each decade (1975 –1984, 1985– 1994, 1995–2004 and 2005–2014) were calculated and compared. Results of the analysis were shown in Tables 4.2 and 4.3, and plotted as shown in figures. 4.7 to 4.11.

**Table 4.2: Rainfall (mm) and Temperature (°C) variations as compared with the long-term mean (LM) at Minna and Bida stations**

| Station | Period | 1975 –1984 | | 1985– 1994 | | 1995–2004 | | 2005–2014 | |
|---|---|---|---|---|---|---|---|---|---|
| | | R | T | R | T | R | T | R | T |
| Minna | *Annual* | -27.88 | -0.42 | -29.58 | -0.04 | 15.80 | 0.13 | -2.37 | 0.33 |
| | *Rainy* | -34.31 | 0.14 | -29.52 | 0.40 | 35.92 | 0.56 | -93.11 | -1.10 |
| | *Dry* | 6.42 | -0.04 | 10.95 | 0.33 | -9.12 | 0.42 | -8.25 | -0.71 |
| Bida | *Annual* | -10.90 | -0.03 | 54.46 | 0.10 | -1.82 | -0.23 | -41.74 | 0.15 |
| | *Rainy* | -1.52 | -0.37 | 31.69 | -0.14 | -1.54 | 0.27 | -28.62 | 0.24 |
| | *Dry* | -9.38 | 0.46 | 22.77 | 0.45 | -0.28 | -0.92 | -13.12 | 0.03 |

*Source: Statistical Analysis. Note: R – Rainfall; T – Temperature.*

There are both similarities and differences across the two stations observation datasets (Table 4.1). The long-term annual mean rainfall for Minna and Bida stations are 1204.90 mm and 1092.18 mm. From Figure 4.7, it is observed that on both annual and seasonal basis; a wet period (1995–2004) is observed over the area which has a mean annual rainfall of 15.80 mm higher than the long-term average. Dry periods (1975–1984, 2005 - 2014) with mean annual rainfall of 29.58 and 2.37 lower than the long-term averages were also observed. The mean annual runoff of 477.95 lower than the long-term average as seen in Figure 4.9 was observed also for the dry period.

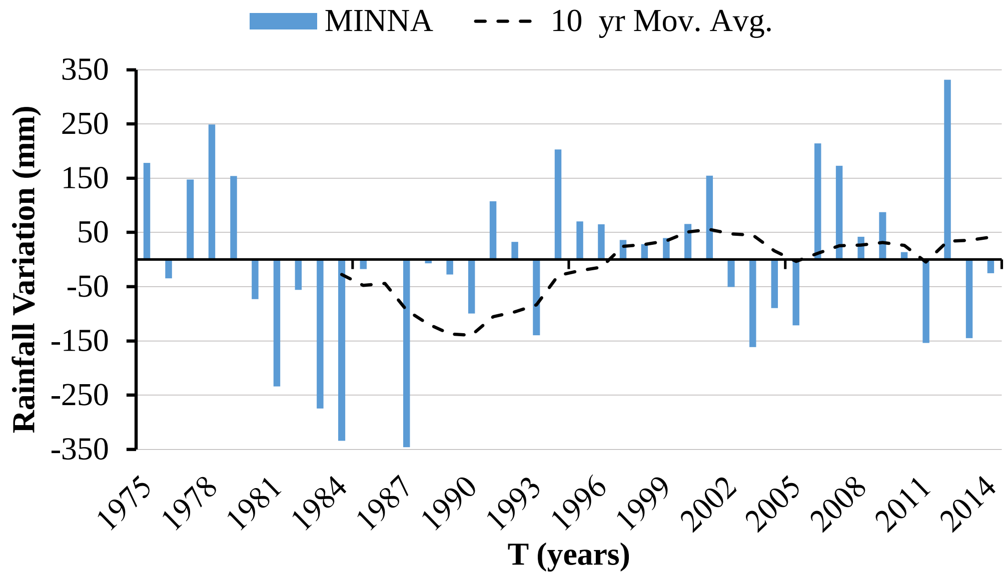


Figure 4.7: The annual rainfall variations and their decadal mean variances compared to the long-term mean (LM) at Minna station.

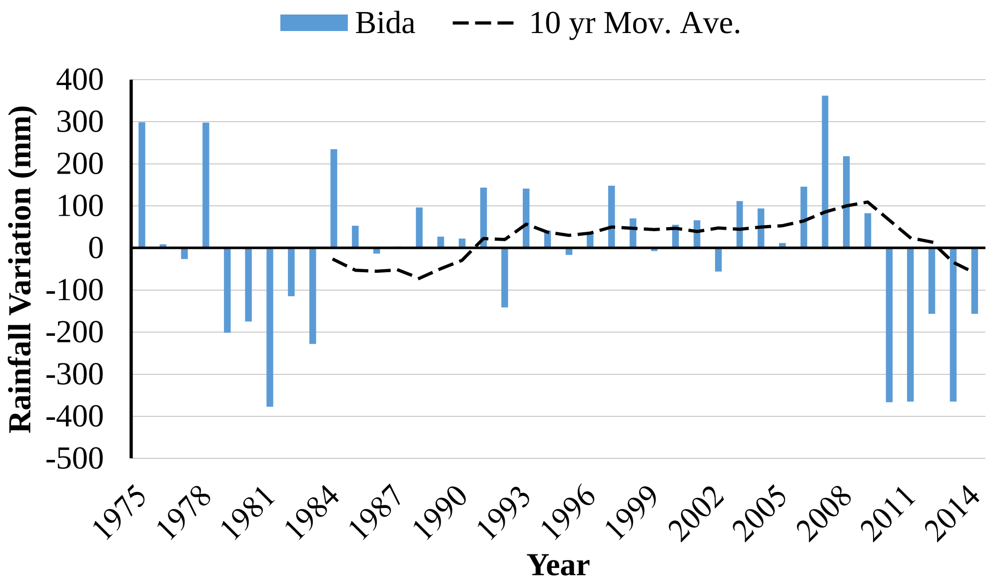


Figure 4.8: The annual rainfall variations and their decadal mean variances compared to the long-term mean (LM) at Bida station.

For seasonal variations, the results reveals that rainfall in rainy season are decreasing in almost all the decades with a higher variance than rainfall differences in dry seasons (Table 4.2). Recently (2005 – 2014), rainfall in the area and mean rainy season runoff (126.72 $m^3$) shown in Table 4.3 are less than their long-term mean (LM), correspondingly.

**Table 4.3: Mean runoff ($m^3$) decadal variations of Shiroro reservoir as compared to the long-term mean (LM)**

| Period | 1990 – 1995 | 1995 – 2004 | 2005 – 2014 |
|---|---|---|---|
| *Annual* | -477.95 | 186.11 | 52.87 |
| *Rainy* | -202.08 | 227.76 | -126.72 |
| *Dry* | -421.90 | -55.44 | 266.38 |

The decadal mean variations for runoff are not significant, the major variation in runoff was found in the (1990–1995) period with a mean of 477.95 $m^3$ lesser than the long-term mean (LM). For (2005–2014) decade, rainfall is decreasing and temperature is warmer than the long-term average (Table 4.1) while runoff is found to be 52.87 $m^3$ higher than the LM. Figure 4.9 illustrates the annual runoff variations in decades.

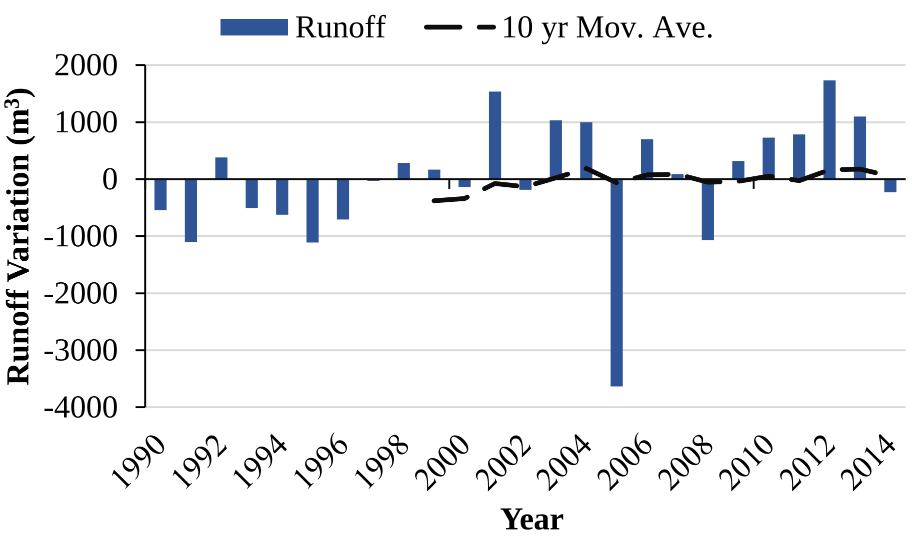


Figure 4.9: The annual runoff differences with their decadal mean variances compared to the long-term mean (LM) at Shiroro reservoir.

From the results, it can be deduced that dry period was experienced at the study area over the 1975- 1984 decade which corroborates the study conducted by Ayinde *et al*., (2013) for Niger state. Relatively modest changes in rainfall can have proportional large impacts on runoff (Gleick, 2000). There are large intra-decadal variations of the rainfall and runoff for 10-year intervals between 1975 and 2014. Consequently, low runoff observed in 1990 - 1995 period is as a result of decreasing rainfall in the 1985 – 1994 decade.

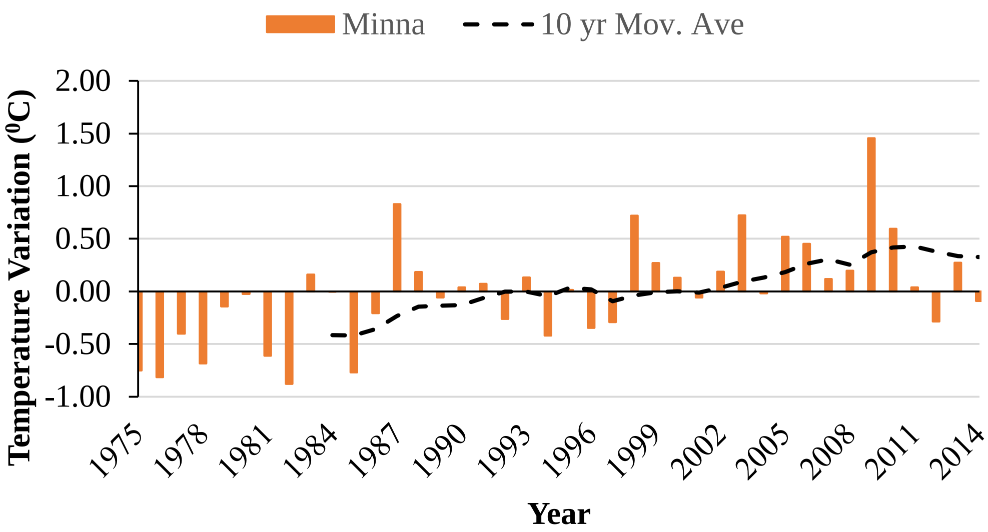


Figure 4.10: The annual temperature differences and their decadal mean variances compared to the long-term mean at Minna station.

Before the early 90s the decadal differences in temperature are less than the long-term mean (LM). The (1995 –2004) decade over Minna was warmer than the LM, while the (1975 - 1984) decade was cooler than the LM (Table 4.2 and Figure 4.10). The recent decade (2005 – 2014) was warmer, while the period (1995 – 2004) at Bida station was cooler than the LM (Figure 4.11).

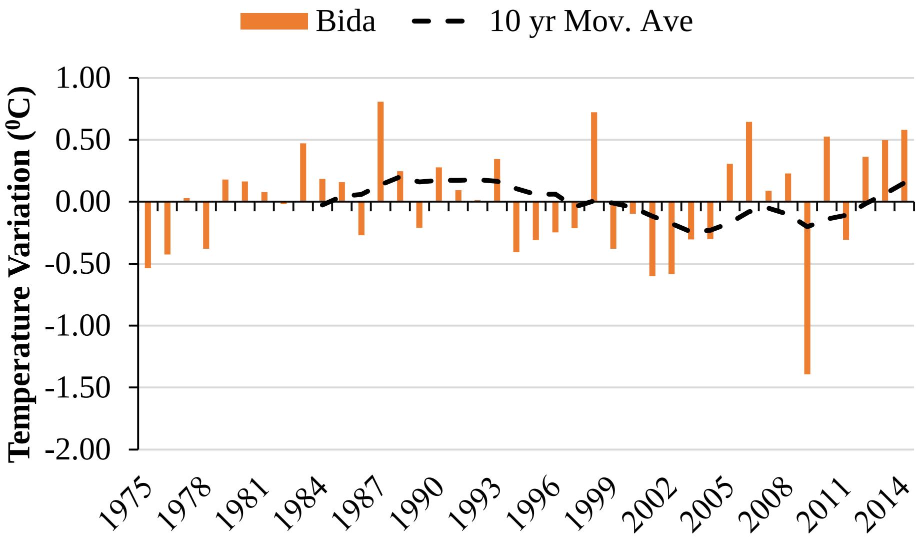


Figure 4.11: The annual temperature differences and their decadal mean variances to the long-term mean (LM) at Bida station.

The results reveal a variable rainfall and runoff pattern with alternately decreasing and increasing trends. The seasonal decadal differences are much greater than those of annual differences, mainly for rainfall. These have serious effects for water supply at Shiroro reservoir watershed that is mainly challenged by water availability. Result indicates that in the early 90s, a very dry period occurred in the Kaduna basin while decreasing rainfall and a warmer temperature have been observed over the last decade (2005 - 2014). The dry period in early nineties was also reported by Suleiman and Ifabiyi (2014). Cooler temperatures observed in the first decade (1975 - 1994) were reported by Akinsanola and Ogunjobi in Nigeria from 1971-2000. Nenwiini and Kabanda (2013) reported downward significant rainfall trend across the semi-arid zone. Therefore, recent decrease in annual rainfall over Niger State following an increase in runoff can be explained by high surface runoff from intense rainfall over the area. If this situation does continue, there will be serious imp1ications for agricu1ture, drinking and domestic water supply purposes in the State. More important1y, these variations in runoff pattern has a direct influence on the very possibility of water resource availability in the basin.

### 4.3 Temporal trends in annual and seasonal Rainfall, Runoff and Temperature as detected by the Mann–Kendall and Sen's Slope statistics

On running the MK statistic to test for the presence of trends, on rainfall and temperature data during 1974 –2014 in the Kaduna River basin, the following results as shown in Table 4.4 and 4.5 were obtained for annual, rainy and dry seasonal of rainfall and temperature for Minna and Bida stations in downstream Kaduna basin at Shiroro reservoir. The values of the Mann–Kendall statistics $Z_s$, Sens slope $Q_{med}$, and the p-value statistics are given in Table 4.5 to show time-based trends (annual and seasonal) runoff tested at 5% significance level (two-tailed). The test statistic $Z_s$ is used as measure of significance in the trend. A positive $Z_s$ specifies an increasing trend, while decreasing trends are denoted by negative values. The null hypothesis is rejected when $/Z_s/ > 1.96$ and the result is held to be statistically significant. If the p value is less than the significance level α = 0.05, $H_o$ is rejected. Rejecting $H_0$ shows that a trend exists in the time series, whi1e accepting $H_o$ indicates no trend was identified.

**Table 4.4: Statistical trend test results for the rainfall series (1975 – 2014)**

| | Rainfall | | | | | |
|---|---|---|---|---|---|---|
| | Minna | | | Bida | | |
| Statistical test | Annual | Rainy | Dry | Annual | Rainy | Dry |
| $Z_S$ | 0.41 | 0.69 | -2.71* | 0.10 | 0.41 | -0.64 |
| p | 0.68 | 0.49 | 0.01 | 0.92 | 0.68 | 0.52 |
| $Q_{med}$ | 0.95 | 2.15 | -0.41 | 0.34 | 1.01 | - |

$Z_S$: MK test, p-value, $Q_{med}$: Sen's Slope estimator. * Significant trends (α = 0.05 Sig. level)

On the annual basis, it is seen from the results of the MK - statistics and P- value that no trend was detected in rainfall data in the catchment at α = 0.05 significance level. On the seasonal scale, no significant trend (positive nor negative) was spotted by the trend tests except for dry seasonal values at Minna station, which showed statistically significant decreasing trend with the MK statistic (Z = -2.71) and p-value = 0.01 (less than 0.05). Figure 4.12 and Appendix A illustrates the trend magnitude for the two stations.

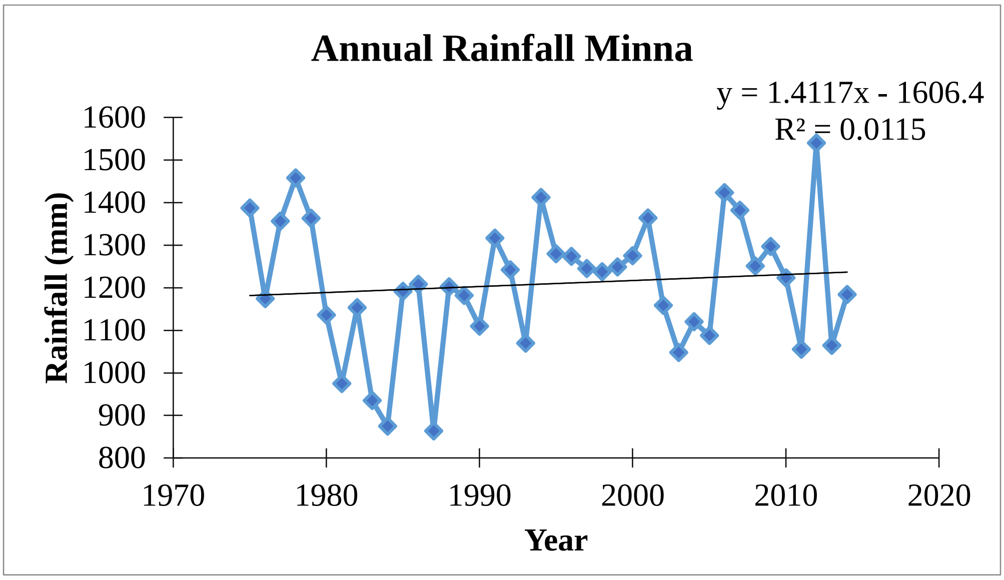


Figure 4.12: Annual rainfall trend for Minna station

Generally, there are no significant trends in rainfall at the two stations at annual and seasonal scale but significant decreasing trend was observed in dry season at Minna station. The results of trend analysis in rainfall on this research are in agreement with past work by Obasi, and Ikubuwaje (2012). They observed that the annual and seasonal rainfall showed no evidence of statistical distinctive significant trend at the Benin-Owena River Basin from 1971 - 2005 and Cervani, *et al*. (2013) predicted no trend in rainfall time series from 2001 – 2065.

**Table 4.5: Statistical trend test results for the series of temperature (1975 – 2014)**

| | Temperature | | | | | |
|---|---|---|---|---|---|---|
| | Minna | | | Bida | | |
| Statistical Test | Annual | Rainy | Dry | Annual | Rainy | Dry |
| $Z_S$ | 3.53* | 2.04* | 4.24* | 0.90 | 2.83* | -1.41 |
| p | 0.00* | 0.04* | < 0.0001 | 0.37 | 0.00 | 0.16 |
| $Q_{med}$ | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | -0.02 |

Temperature data from two stations were examined at Shiroro reservoir over same time period. Results in Table 4.4 indicated statistically increasing trends in both annua1 and seasona1 temperature series for Minna station. However, non-statistical declining trend was observed at Bida station in dry season for period of study while annual and rainy season values show increasing trends. Figure 4.13 and 4.14 demonstrates the annual and seasonal temperature trends magnitudes for the study period.

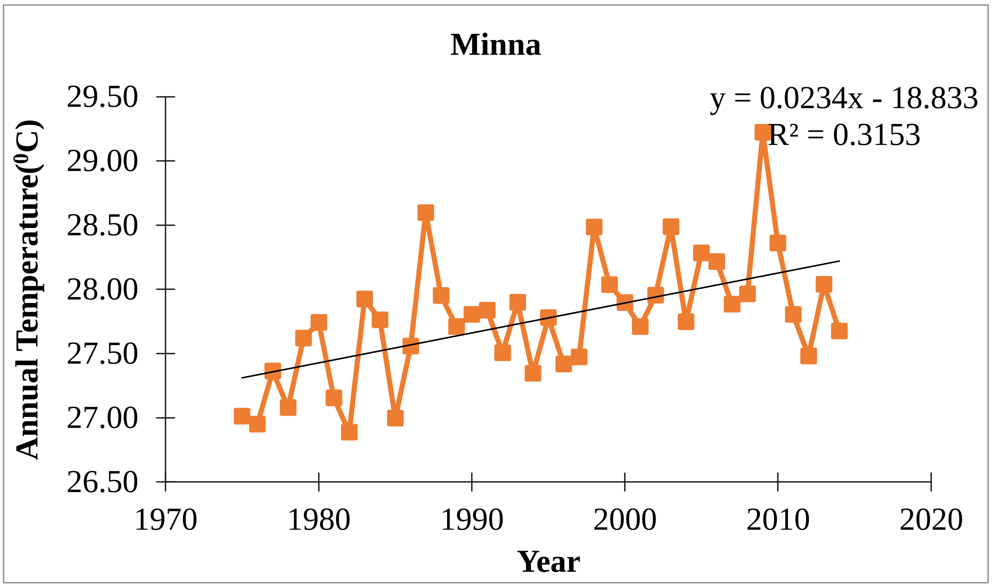


Figure 4.13: Annual Temperature trend for Minna station

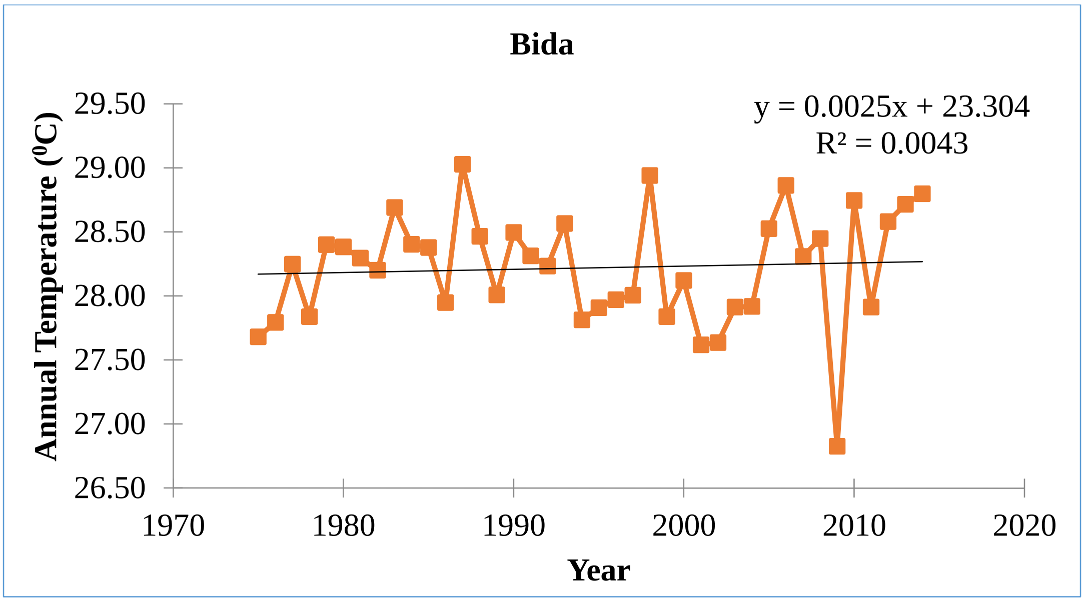


Figure 4.14: Time series plot of Annual Temperature trend for Bida station

Temperature records show apparent strong increasing trends in the study period for the two stations examined. The increase in temperature contributes to frequent dry spells which might strengthen droughts in the basin. Hence, temperature rise particularly in the growing season has substantial effect on the early crop growing stage owing to evaporation. A trend analysis for the whole Nigeria over the period 1976 - 2065 done by Cervigni *et al*., (2013) using observation and RCM data also indicated definite increasing temperature trend over the entire country in the period 1976–2065.

The results obtained for the runoff time series was summarized in Tab1e 4.6. At 5% significance level, the prevalent increasing trend in runoff for Shiroro is observed in the Kaduna River for the period 1990 - 2014 as seen by app1ying the Mann–Kenda1l statistics.

**Table 4.6: Annual runoff trend test statistic results**

| Statistical test | Runoff Variables | | |
|---|---|---|---|
| | Annual | Rainy | Dry |
| Mk statistics ($Z_s$) | 2.31* | 1.75 | 1.80 |
| p - value | 0.02 | 0.08 | 0.07 |
| Sens' slope ($Q_{med}$) | 2.14 | 2.06 | 1.68 |
| Kendell tau (τ) | 0.33 | 0.25 | 0.26 |

*Source: Statistical Test*

On seasonal basis, increasing trends that are non-statistically significant were identified for the average runoff series. However, the statistical tests showed an increasing significant trend in annual mean runoff with the Z-value = 2.31 > $Z_{\alpha/2}$ = $Z_{0.05/2}$ = 1.96, and by the p-value 0.02 < 0.05. Figure 4.12 and Appendix B illustrate the mean annual and seasonal runoff trends magnitude at Shiroro reservoir station respectively.

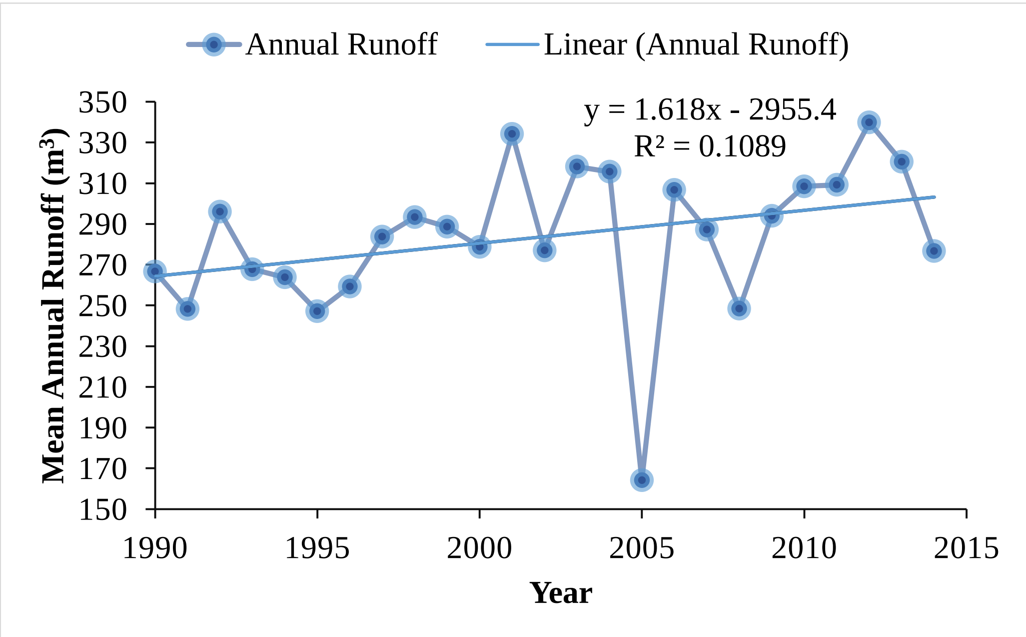


Figure 4.15: Mean annual runoff data at Shiroro

### 4.3.1 Mann-Kendall Test in Comparison with the Sen's Slope Estimator for detecting Trends in hydro-climatic variables

The Sen's estimator (Q mm/year) summarises change per unit time results of the trends identified. The Sen's slope estimator results obtained for annual and seasonal hydro-climatic series during the period 1975–2014 were shown in Tables 4.4, 4.5 and 4.6. Sen's estimator values ranges from -0.41 mm/year at Minna station to -0.02 mm/year at Bida. Variables having a negative trend (-0.41 and -0.02 mm/year) were identified as dry season rainfall for Minna station and dry season temperature for the Bida stations.

In general, there is pronounced similarity between the Mann-Kendall and Sen's statistical results shown in this study at the 5% significance level. Gocic and Trajkovic (2013) have arrived at similar conclusion.

## 4.4 Linkages between runoff and rainfall trends - Kendell Tau

The interest of the relationship analysis is to determine if the trends in runoff are attributable to climate change and variability. Similar studies applied in other basins for linking runoff trends to climatic changes were reported by Hu, (2014), Abdul Aziz and Burn (2006) and Chen *et al*., (2006). The potential causes of the significant trends in hydrological variables were investigated through a correlation analysis with climatic variables. The Kendall $\tau$ for these series are calculated and runoff is more significantly correlated with rainfall ($\tau$ = 0.280) than with temperature ($\tau$ = 0.047) at 95% confidence level. The positive relationship between these variables are apparent from both the data points and the trend series as shown in Figures 4.12 and 4.15. Over the period 1990-2014 (25 years), the strong positive correlation between pattern of annual rainfall and surface runoff was also observed at Shiroro dam by Suleiman and Ifabiyi (2014). Therefore, increasing (positive values) rainfall could be associated with increasing annual flow. The study findings however, coincide with the study conducted by Eze (2006). He noted that a slight increase in rainfall increases the amount of river runoff and runoff of flood into the Shiroro reservoir over the period 1981 - 2003.

In conclusion, the analysis of the MK test revealed that the series of temperature and runoff exhibited positive trends which are statistically significant at $\alpha = 0.05$. This implies that both variables have tendency to increase. The warming in the area mainly resulted from significant increase in rainy season temperature. However, there is no significant trend observed for rainfall at the investigated climate stations except for decreasing dry season rainfall at Bida. In general, the changes in the three indices of rainfall, temperature and runoff showed the possibility of the occurrence of drier climate and flood events. These runoff changes are resulting from collective effects of temperature and rainfall variations. As expected, significant increasing runoff trends especially during dry season may be attributed to inflows from tributaries such as rivers Dinya, Sarkin Pawa, Erena and Muyi into Shiroro reservoir and release from the dam.

Based on the results obtained, it can be concluded that there is existence of climate variability due to variations in rainfall, temperature and runoff data downstream Kaduna basin which may have impacted negatively on the water resources and livelihoods of inhabitants in the area. Hence, it is of immense importance to investigate the environmental, economic, and social impacts that may well emanate from variable hydro-climatic trends in the area.

Rainfall has impacts on river levels and river runoffs, while increases in temperature have been found to affect the rates of evaporation and evapotranspiration, reducing the amount of surface water, thus influencing water balance of a basin. Increase in temperature can resu1t in intense heat waves that could be cha1lenging for water resources management and agricultural dependent vulnerab1e populations. Also, temperature increases shortens the crop-growing period and reduces the amount of biomass that accumulates (Cerverni *et al*., 2013). This suppresses crop yields even if crops are not stressed by water conditions. If the observed decreasing rainfall trend continues in the future (as also predicted by models), this could affect the sustainabi1ity of surface water resources and groundwater recharge. The changes in water flows described are likely to have significant effects on the reliability of hydropower and irrigation systems, which are a function of both average magnitude of inflow to a dam and inflow variability (Suleiman and Ifabiyi, 2014). It is therefore of interest to study how the variations have negatively impacted on water resources and livelihoods of households as perceived by those living downstream of Shiroro reservoir in the Kaduna river basin.

### 4.5 Vulnerability to Climate Variability Impacts and Water stress

Consequences of climate variability manifest itself at any time in effects of changes in climatic elements such as temperature and rainfall, all of which have sensitive interactions that ultimately affect the availability of water. Having examined the climate and hydrological variability for the Kaduna River, focus now is on how these impacts livelihood downstream Kaduna river of Shiroro reservoir as perceived by the locals. This section reports insights gained through transect walk, focus group meetings, household and individual interviews of six communities selected from the three study local government areas – Shiroro, Gbako and Lavun.

### 4.5.1 Site Characteristics

The transect walk through the communities was embarked upon to capture the water sources, livelihood activities, diversity of ecosystem, land-use and other socio-economic activities (See Appendix C). In terms of social characteristics, the six villages selected from the three local government area in study site: Shiroro, Gbako and Lavun, are rural villages situated within a customary land tenure system, all located in river Kaduna basin.

Galadima Kogo and Mutumdaya are part of a cluster of villages in Shiroro local government. Galadima Kogo is made up of moderately built up area with large farmlands around homes and settlements located on the floodplain. Mutumdaya community lacks basic facilities such as electricity, public water supply, health centres, road networks, markets and schools. Students from Mutumdaya have to walk approximately 2 – 4km in order to attend school in Galadima Kogo. Dadi and Tsoegi Tako villages in Lavun local government area selected for the study are found along Kaduna River. Dadi village is located approximately 20km to Tsoegi Tako and they are mainly rural traditional villages that are more than 40km distance from urban cities. The nearest primary health care centre and primary school happens to be in the next village which is about 3km. The communities lack network of roads linking them to major towns. More than half of the households built their houses with mud-blocks or stone, with wood and thatches, as materials for the roofing. There are no electricity in the villages, however, Tsoegi Tako community usually make use of generators. In Gbako local government, Wuya and Gbadafu villages were surveyed. Houses here are made of mud or cemented-walls with aluminium roofs. No market or health centre is found in Gbadafu.

These six communities have traditionally had a polygamous patriarchal and nuclear family system. Shiroro is most the populated area in the study site while livelihood strategies of Gbako and Lavun were less diversified than Shiroro. Important sources of income include farming, petty trading, fishing and labourer. The Gbako households had better ease of access to facilities and livelihood options. However, there is homogeneity in the house type status in the communities.

### 4.5.2 Composition of Households and Socioeconomic Findings

They are considered useful as a means of identifying opportunities and constraints relating to adaptation strategies. Grothmann and Patt (2003) have argued the importance of socio-cognitive factors in adaptation and adaptive capacity. The socio-economic characteristics of the household sample for the surveyed villages are presented in Table 4.7.

From the survey, the percentage of household head is shown to be 70.6%, 70.8% and 59.3% of the respondents. The distribution of respondents' gender showed that 85.3%, 79.6%, 95.8 were males and 14.7%, 20.4%, and 4.2% were female interviewed in the catchment. Effort was made to get a representative female household head. The dominant age group interviewed were middle aged between 21 and 40 years showing young head of households. This also indicates that family dependency is higher in Lavun and Gbako probably due to larger family size, higher education status and better facilities than Shiroro. As illustrated in table 4.5, significant no of the respondents had no formal education. This scenario indicates that illiteracy level is minimal. Literacy level is one of the factors affecting food security and apparently determines the main economic activity of households and their coping capacity.

**Table 4.7 Socioeconomic characteristics of respondents in the study site**

| Characteristics (n=200) | Shiroro (%) | Gbako (%) | Lavun (%) |
|---|---|---|---|
| Household Head | 70.6 | 59.3 | 70.8 |
| Gender | | | |
| Male | 85.3 | 79.6 | 95.8 |
| Female | 14.7 | 20.4 | 4.2 |
| Age Category | | | |
| <20 | 5.9 | 18.5 | 6.3 |
| 21-40 | 61.8 | 57.4 | 45.8 |
| 41-60 | 20.6 | 18.5 | 33.3 |
| 61+ | 11.8 | 5.6 | 14.6 |
| Education | | | |
| No Formal | 39.7 | 22.2 | 22.9 |
| Primary | 17 | 6 | 28 |
| Secondary | 36 | 47 | 30 |
| Years lived in the area | 66.2 | 72.2 | 81.3 |
| Household Size | | | |
| 1 - 5 | 23 | 52 | 26 |
| 6 - 10 | 41 | 34 | 40 |
| 10+ | 36 | 14 | 34 |
| Social Group Membership | | | |
| Farmers' Cooperative Society | 47.4 | 70.2 | 67.1 |
| No Membership | 52.6 | 29.8 | 32.9 |

*Source: Household Survey, 2015.*

Many households interviewed in Shiroro, Lavun and Gbako had majority of the respondents who had attained primary education. Relatively more comfortable economic status and higher education levels are found in Gbako communities. Statistics of the socio economics characteristics of the respondents show that they have lived more than 15 years in the area which indicates better knowledge of the subject matter and livelihood in their communities.

The socio-demographic profile shows that the average household size was found to be between 6 - 10 members while 30.6%, 38.2%, 28.8% corresponds to 1-5, 6–10, and above 10 household size surveyed in the catchment. Approximately 87.50%, 96.30%, and 92.65% in Lavun, Gbako and Shiroro households interviewed own a farmland respectively with an average size of l – 3 hectares per household as shown in Table 4.7. Majority of respondents in Gbako belong to collective or cooperative societies in the villages. The cooperatives societies could help reduce vulnerability, for example by enabling farmers to effectively market their produce or women to engage in off-farm income earning activities, or make critical decisions as well as access agricultural credit. The social network status was similar in the area, most likely as a result of the downstream and rural specificities. Households were interdependent and seek co-operations amongst themselves, as observed during survey. Social capital networks support adaptation to livelihood constraints. Regarding land ownership, larger no of households questioned got their land through inheritance.

### 4.5.3 Climate Variability and Water Stress: Community Perceptions

Greater number of households interviewed from the six communities felt that there is increased temperature, and that rainfall has declined in quantity and they can't any longer base on the timely arrival of the rain as illustrated in the Figure 4.16.

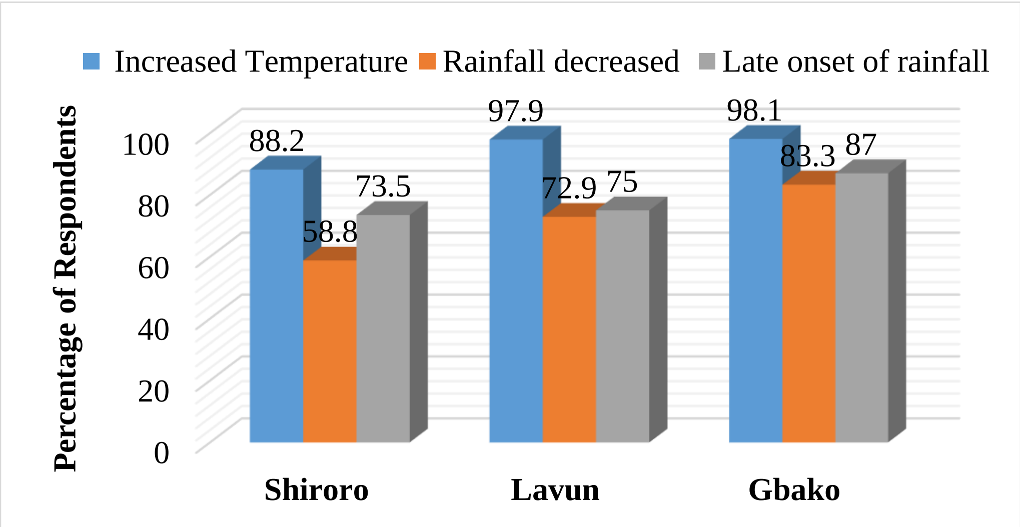


Figure 4.16: Community Perception on Climate Variability

Analysis was made to inquire households' awareness of climate change and variability. The result reveals that 62.50 %, 75.93 %, 85.29 % are aware of climate change and variability in Lavun, Gbako and Shiroro respectively. The sources of awareness on climatic changes are from the media (radio, television, newspaper), village head, personal observations, extension agents and friends but majority became aware via own radio and personal observation.

Group participants noted that heat rashes have become a problem in the last 5 years due to temperature rise, "sunshine is very scorching and has more heat" they said (Plate I). They also noted a decline in rainfall duration suitable for percolation, prolonged dry spells, and an increase in rainfall amount and flood events which destroys crops and runs-off. "The rains have been coming late of recent preventing crops to be planted by the middle of April", they said.

**Plate I**: Men participate in a focus group gathering at Shiroro to discuss main impacts and water stressors affecting the village in the last 5 – 10 years.

### 4.6 Sensitivity to water stress induced by changing climatic conditions and its contribution to people's livelihood

Water is an essential instrument of livelihood support. The major sources of water for the communities are rainwater, small streams of the River Kaduna and public water supply that dry up during the dry season which last for five to seven months. The only public water supply comes from solar powered borehole installed by MDGs in 2009. Three hand pumps are found in Galadimma Kogo which do fail sometimes. In times of pump failure, the residents contribute between 200-500 Naira per household to buy materials and repair the pump. There are no boreholes or public water supply sources in Dadi and Mutumdaya villages. Households in Tsoegi Tako main source of water is river Kaduna close to them (Plate II). In Wuya and Gbadafu villages, despite the installation of one solar system public tap and three non-functional hand pumps been installed, there still exist water scarcity due to increasing population.

**Plate II**: Kaduna River near Tsoegi Tako Village

**Table 4.8: Available household public water sources in the study area**

| LGA | No of House holds | Household size | | | Villages | Solar powered boreholes | Hand pumps |
|---|---|---|---|---|---|---|---|
| | | 5 | 10 | >10 | | | |
| Shiroro | 75 | 18 | 30 | 27 | Mutumdaya | | |
| | | | | | G. kogo | 1 | 3 |
| Gbako | 70 | 33 | 23 | 14 | Wuya | 1 | 3 |
| | | | | | Gbadafu | | 3 |
| Lavun | 55 | 14 | 22 | 19 | T. Tako | | 2 |
| | | | | | Dadi | | |

*Source: Field Survey*

The available public water sources in the study site are shown in Table 4.9. Apart from rainwater, the river sources are a bit far from their houses in the study location. It takes them about 20 minutes on the minimum to get to these sources.

Plate III: Residents at Mutumdaya dug the ground to obtain water.

According to the respondents, households consume on average, about 3 drums or 50 litres of water per day. Various uses of water by households in the study area include crop farming, livestock farming, irrigation, fishing and domestic uses such as drinking, cooking, and bathing. Water collection is done mainly by women and the girl child in these communities.

Water availability at most of these earlier mentioned sources are seasonal. The increasingly irregular availability of water threatens the livelihoods of households and smallholder farmers. Figure 4.17 illustrates percentage of households exposed to water stress in the study area.

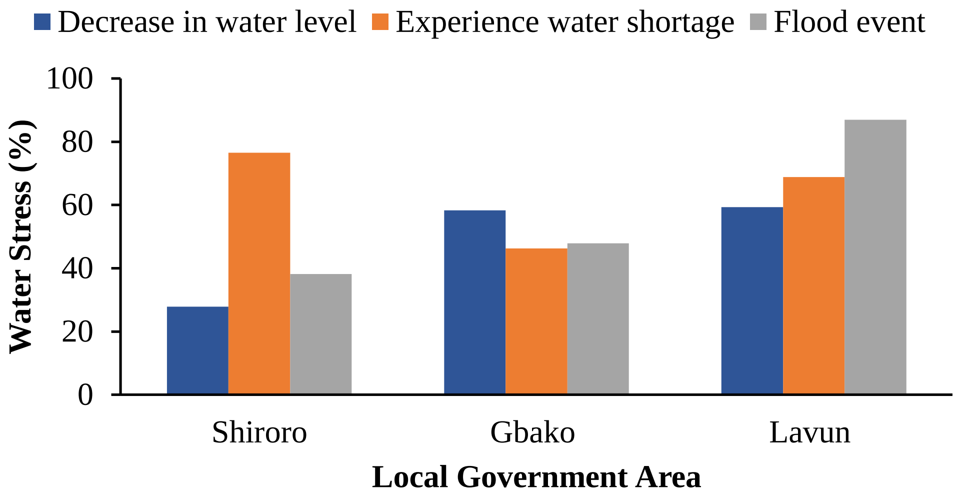


Figure 4.17: Proportions of households (%) sensitive to water stress

The assessment indicated that 76.5%, 46.3% and 68.8% of the households in Shiroro, Gbako and Lavun have experienced water shortage respectively. Gbako household has reported extreme decrease in surface water level (58.3%) over time. These are owing to population pressure, failure and drying up of boreholes, they noted. Shortage of water shortage seemingly have the maximum effects on the economy, human welfare and agricultural development (Zhou, 2013). Water scarcity is a problem especially in the dry season, and people and agriculture suffer more due to increasing dry spells. Households are increasing in size, thus the pressure on the availability and access to safe water as well as increasing reliance on groundwater. Households in Lavun are the most exposed to water stress and experience incidents of flood events (87%). This is because the Kaduna

River is the only source of water for the community, and houses are built mainly on flood plains.

Furthermore, community perceived effects of climate variability induced water stress were also assessed. This gave insight to household sensitivity to water stress and climate variability. These events lead to negative impacts felt in different forms. The detail of the effects and percentage level for households in the three study local government area is presented in Figure 4.18.

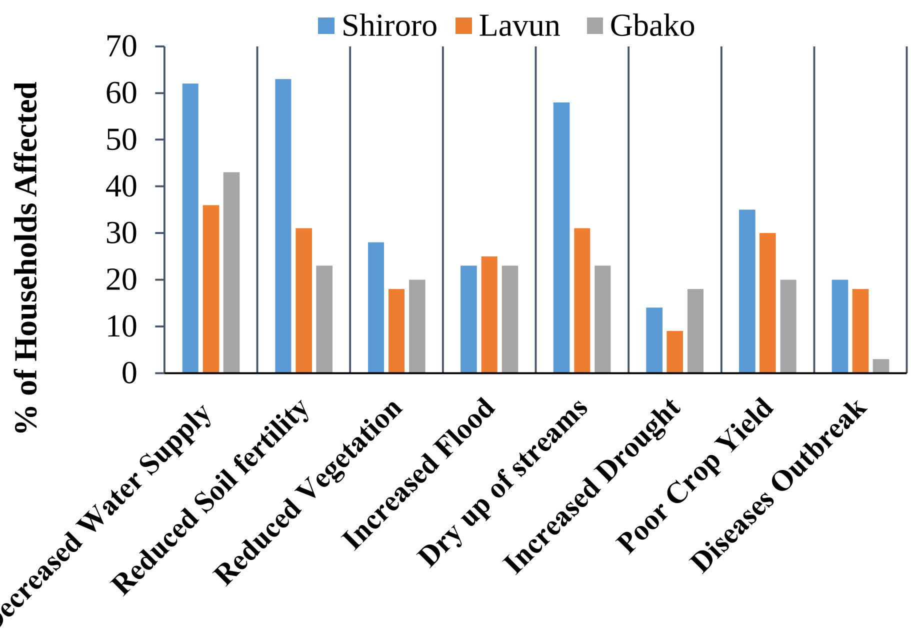


Figure 4.18: Perceived effect of climate variability on households

Decrease in domestic water supply has been observed by 62%, 36%, and 43% of the respondents and there is lack of water in streams in the dry season due to drying up of rivers, streams and ponds. This reduces water available for domestic activities such as cooking, bathing and drinking water for both human and livestock. More insect plagues (example mosquitoes) and occurrences of contagious water-related diseases such as cholera, malaria, and diarrhoea were reported by participants. They also pointed that decreased rainfall and soil moisture has contributed to reduced soil fertility, vegetation and poor crop yield. In the local people's experiences, cases of droughts are in increasing trend as crops like millet, yam, maize and guinea corn have all been damaged and dried up in the last 5 – 10 years because of poor rain. Most of the water scarcity and drought cases are reported where there is a need of rainwater for irrigating rice and millet. Equally, there were concerns that increasing flood events leads to soil erosion and wash away their farmlands especially those that planted around the river bodies (see Appendix C). From the results, households in Shiroro local government area can be identified as the most sensitive to water stress followed by Lavun.

Households in the six communities; Tsoegi, Dadi, Wuya, Gbadafu, Galadima kogo, and Metudaya are experiencing a variety of climatic changes, including rising temperatures and changes in rainfall (including increasingly unpredictable and long duration rain) and runoff. The analysis showed that most of the households are exposed to water stress related threats and climatic variations largely Lavun local government. Meteorological data shows that the rainfall and runoff are in alternating increasing and decreasing trends; major indicators of water stress and flooding in the study areas which supports the locals expressed perceived effects of climate variability. These vagaries are distressing their ability to produce food for consumption and sale. Water stress contributes to low crop yields and many people linked these climatic changes to low soil fertility.

Examining the indicators, it was found that there is decrease in domestic water supply which is worse in the dry season. Also, results suggest that households have not reached a comfortable level of water consumption and there exists differential water shortage in the communities.  Households' experiences drought, but occasional flood, due to intense rainfall. Each year floods and droughts result in crop damage worth billions of dollars and loss of livestock and human lives. Inadequate education and resources, lack of access to health facilities, road network and electricity adds to increase their vulnerability. These facts lead to the important conclusion that households living downstream Kaduna river basin are highly vulnerable to variations in climate and consequent water stress.

Finding ways to equip communities to better manage extreme variability, while also taking advantage of it, could help increase agricultural productivity. Scientific literatures suggests that water scarcity, dependence on agriculture, income levels, access to land, labour supply, access to credit and information, and gender are some of the factors that create vulnerability. These factors characterise the situation of most people in downstream area of Shiroro reservoir and demonstrates their vulnerability to current climate variability as well as to future climate change.

**4.7 Household Adaptation Responses to Climate Variability and Water Stress**

Due to the severity of water-related impacts and their socio-economic implications from the changing climate, it demands the highest attention for adaptation. Adaptation strategies are essential to reducing households' vulnerability. In adapting to climate variations and impacts to water resources, households in the research area have employed several strategies and practices in response to water scarcity and flood events. Figure 4.19 shows major water supply measures reported by household in downstream Shiroro reservoir. To improve their access to available water, they largely store water in drums, pots or basins, conserve water used for different activities and buy ground water.

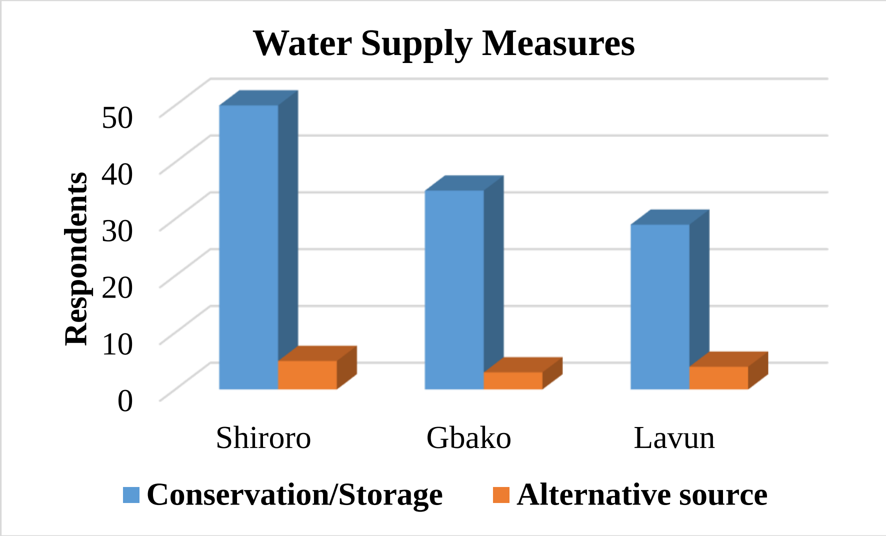


Figure 4.19: Water supply measures reported in downstream Shiroro reservoir

In the group, participants recounted that community meetings and discussion among households from Mutumdaya is done to solve water issues and provide water by going to the nearest villages to buy water. Water quality is also essential in determining water security, health and agricultural productivity of households. According to the respondents in Shiroro and Lavun, outbreaks of cholera, diarrhoea and other waterborne diseases have been reported. Household water treatment is one of the means of preventing diarrheal diseases and other water related diseases. This is likely because water often becomes contaminated before it is consumed even if it was collected from a protected source. 7 households in Lavun reported treating their water by boiling and adding Alum. Also, the use of net for water treatment was reported in Wuya.

Households are largely dependent on rain-fed agriculture. In the group discussions, there were concerns about poor rainfall which lead them to reducing their demand for water by changing cropping patterns and switching to less water intensive crops (for example pepper, vegetables), short duration crops such as  maize and cash crops like sugar cane and groundnut, that are less susceptible to water stress, adopting more efficient irrigation practices like planting near the streams, and altering dates for agricultural operations were adopted based on their experiences. Due to low rainfall all, farming activities in Tsoegi Tako and Galadima Kogo are a little distant away from their houses but near the rivers known as Fadama. Households in Shiroro and Lavun reported rainfall loss to surface runoff contributing to high levels of soil erosion. Figure 4.20 shows some of the agricultural practices adopted in the six villages.

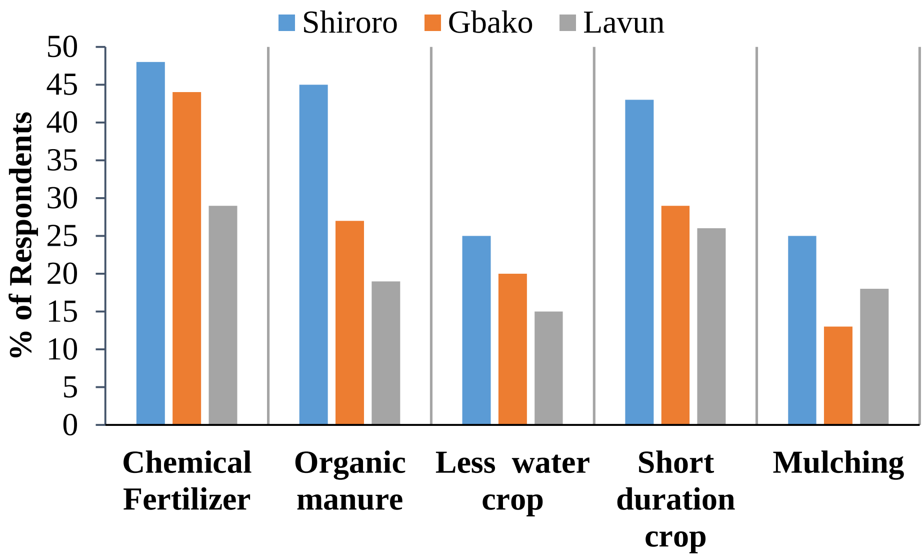


Figure 4.20: Adaptation practices in Agriculture adopted by households

Consequently, in Wuya and Gbadafu villages for example, in order to reduce continuous crop failure, household adopt soil and water conservation practices such as mulching, organic manuring and chemical fertilizers are applied to boost soil fertility and optimize productivity. The use of urea for farming, irrigation pumps was stated by respondents in Galadima Kogo village. Greater crop production can improve household food security and meet diverse household needs. Similarly, households in Lavun and Shiroro practice crop rotation and bush fallowing and recounted change in planting season due to extreme event were more pronounced. To cope with effect of increase in temperature and water scarcity in agriculture, households in Gbako also reduce the number of livestock they keep.

Lavun is highly vulnerable to flood due to proximity to Kaduna River. In Dadi village, participants complained that most rice farms were destroyed during the rainy season due to intense rain. To deal with the problem they have put measures to adapt to flood events by building embankments to check erosion, avoid building on flood plains and diversifying their sources of livelihood such as seeking for an alternative employment opportunities, migration to neighbouring towns (Figure 4.21).

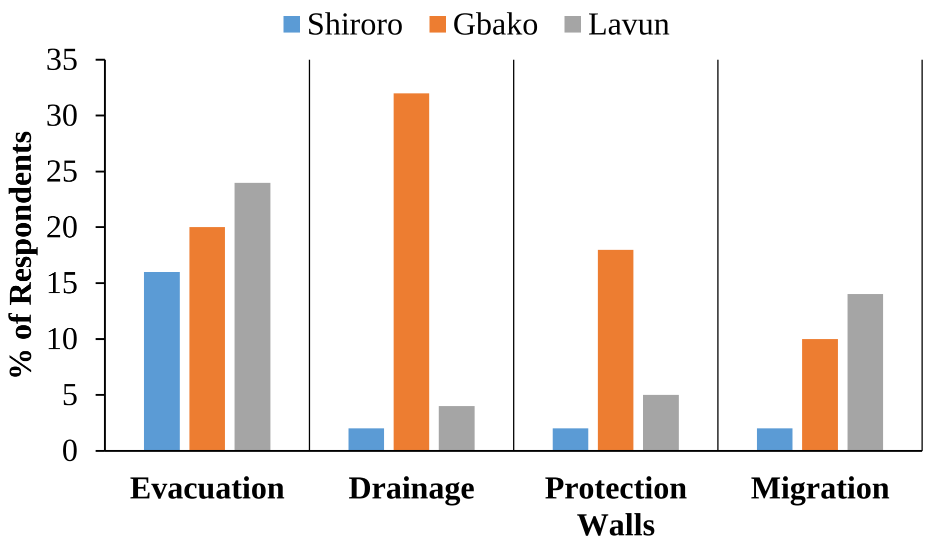


Figure 4.21: Flood control measures employed by households in the study area

Adaptations are signs of a system's adaptive capacity. Household diversify to survive in the event of crop damages by flood. It was observed that they appear to be making a more long-term adaptation to climate stresses when moving towards non- agricultural jobs in the city, but in so doing, many are becoming more vulnerable due to dislocation and disruption of their familiar way of life. As well, most of the households interviewed in

Gbako had members working outside the community and urban areas. This indicates their contribution to support household livelihood, although no quantitative assessment of how much they contribute was done. As a source of income, large proportion (90%) of all households reported engaging in rain-fed agriculture with 6, 30, 26 households practicing irrigation farming in Lavun, Gbako and Shiroro respectively (Table 4.10).

**Table 4.9: Adaptive capacities of households**

| LGA | | **Lavun** | **Gbako** | **Shiroro** |
|---|---|---|---|---|
| Awareness of climate change/variability (%) | | 62.5 | 75.93 | 85.29 |
| HH member working outside the community | | 22 | 40 | 15 |
| Access to land (%) | | 87.50 | 96.30 | 92.65 |
| Assistance | Relatives | 5 | 8 | 14 |
| | NGO | 0 | 5 | 4 |
| | Government | 22 | 11 | 12 |
| Irrigation | | 6 | 30 | 26 |
| Plant twice per year | | 25 | 39 | 40 |

*Source: Field Survey, 2015.*

In general, reports emerging from the interviews in the three study local government areas reveals that households in the six villages are exposed to climate variability, induced water stress in terms of small drought and flood. The analysis indicates that villages in Shiroro LGA are highly sensitive to water shortage while villages in Lavun are more vulnerable to flood events. The adaptive capacity of the study area includes site characteristics, socioeconomic profile, Livelihood strategies (diversification, irrigation and planting twice per year), Social group, house types and access to information and/or resources (awareness of climate change, farmland and assistance). Given the situational analysis of exposure and sensitivity, the survey in Shiroro, Gbako and Lavun villages revealed that present capacity to cope in Lavun with climate variability and water stress impacts are quite low. The communities have employed coping strategies such as water storage and conservation to improve water availability, water treatment, fertilizer application and short duration crops in order to increase food production, livelihood diversification and migration in the case of flood events.

### 4.8 Constraints and Implications Associated with Adaptation to Water Stress

Response to climate variability and water stress are determined by household adaptive capacity which includes dependency on natural resources, access to information, provision of infrastructural services and support from external sources. Therefore, inadequate provisions of all these, limits households adaptive capacity.

Access to critical infrastructure and services, such as roads, electricity and telecommunication, plays a role in people's adaptive capacity. Similarly, challenges in accessing markets, information and many services are presented by the remote and often scattered nature of rural communities. With poor road network and frequent flooding during the wet season, the lack of transportation and marketing facilities in the study area is obviously a prohibitive barrier. For instance, roads, can facilitate access to markets and to financial services which can lead to income security, in turn leading to greater resilience. Similarly, other services such as health, education, financial services, and agricultural extension of which are lacking in some of the villages surveyed; support people in meeting their essentials and reduce vulnerability to negative impacts and stresses. Thus, improved infrastructure (including basic services, communication, and transportation) may facilitate adaptation to the communities.

Strategies to adjust to the constantly changing environmental conditions necessitate one to be well-informed and knowledgeable. Households in the study location are lacking human resources in terms of; formal education or being well informed, technology which indirectly limits their choices in pursuing off-farm employment prospects particularly in Lavun and adequate resources that will enable them to tap available groundwater. Households in the study sites rely largely on agriculture. Limited job opportunities lead to negative diversification and further depletion of capital assets, increasing household vulnerability. Also reported is insufficient fund to afford chemical fertilizer. Agricultural land is left barren due to shortage of manpower as younger ones migrate to cities in aspirations for city living standards.

The Local institutional capacity to support adaptation to livelihood constraints in the area is limited. Few number of households reported receiving external assistance either from government, NGO or relatives/friends in the form of money, food items, mosquito nets, cement and roofing materials. Institutional capacity is poor, particularly in terms of reaching out to farmers, the provision of formal credit and support from external sources (e.g. professionals to share information on how they can adapt), which constrains their ability to use their agricultural skills and assets more effectively.

### 4.8 Women's Role in Adaptation

Clear gender roles were observed within households in the six villages surveyed. Women and girl child mainly carry out agricultural tasks and gathering supplies needed by household such as fetching water, gathering fodder and firewood, and preparing manure. While men engage in labour demanding or intensive activities such as felling of trees for firewood, (Kalaba *et al*., 2013). Women and girl child in the six villages are found to be the main collectors and suppliers of water for all domestic purposes. They are forced to walk long distances to fetch water, even when the water is scarce owing to drought.

However, the present study points no significant difference among different head of household genders in the use and consumption of water resources.

Women are also effective agents of change in relation to adaptation. Their responsibilities in households and communities (concerning production, collection and storage of food) have equipped them for livelihood strategies adapted to changing environmental realities. Women at the villages are responsible for making, cooking and storing grains, vegetables and fruits using stylos during the growing season for use in the dry period when food are not available. In Mutumdaya and Wuya village, women sold firewood, sugarcane to earn income, while in Dadi community, women farmers formed a cooperative society known as 'AIEDABA Women Society' to enable them access agricultural credit.

Plate IV: Women in Wuya sell sugarcane to earn income b) women processing food for storage.

In summary, changes in climate is exacerbating the prob1ems and inequities that women are a1ready facing. At the same time, Women are engaged in more c1imate change re1ated activities than what is reported, documented or recognized by the public. We see that at the study area, women in most households were at the frontline of adaptation to water stress induced by climatic variations, having the major responsibility for gathering and preserving food, fuel for cooking, and water for all domestic uses. When weather patterns are erratic, women spend more time on each of these tasks, which allows them less time to spend on education, development work and health. Therefore, it is necessary to strengthen women's ability to contribute and exercise their unique skills and valuable perspectives on adaptation to the changing climate.

# CHAPTER FIVE

## 5.0 CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

The key concern of this study was to evaluate vulnerability of households' downstream Kaduna River to water stress induced by climate variability, identify existing adaption options and highlight other possible areas of intervention. The study focused, not only much on the existing impact from climate variability which can be attributed to changes in water availability and but also on social, environmental and economic stressors emanating from household livelihood strategies.

In this study, historical trends of precipitation, runoff and temperature were examined using statistical analysis. In addition to that, vulnerability-based framework using stakeholders' participatory survey was employed to gain insights on how household might be impacted. The statistical analysis of hydro-climatic data and reported respondents experiences has demonstrated that Kaduna River over the past 40 years have been affected by changes in climate. The downstream sector has become hotter and experienced some periodic varying changes in rainfall, which also supports an emerging global picture of warming and the observed positive trends in rainfall extremes, declining rainfall over the tropical land areas of the Northern Hemisphere during the 20th century.

Consequently, the survey in six communities suggests that overall, households in the area have been exposed to climate variability and sensitive to water stress impacts. It is concluded that there is a change in availability of water which have impacted on food production and livelihoods of local communities. Households in these communities depend mostly on agriculture for their food security and income. Their livelihood conditions, together with reliance on local rainfall for food production, creates their vulnerable to climatic variability, such as the poor and erratic rainfall, and climatic threats such as droughts and increased incidence of floods. The adaptive capability and sensitivity of Gbako and Shiroro households was apparently higher than Lavun, however, the exposure recognition was more pronounced in Lavun households probably due to relatively high understanding of climatic responses. The differential vulnerability suggests the need to have robust coping and adaptation measures to deal with the variations in climate system. Nonetheless, there is similarity among households in the area due to similar traditions, physical settings of households and collaboration among community members.

Households have acted in response and proved to be vulnerable to water stress and climate variability impacts. To reduce vulnerability, the types of responses reported by households includes both short-term coping measures and adaptation strategies such as soil and water conservation practices, diversification and migration usually adopted during periods of stress. It was found that recent increase in drought and flood incidences destroys and erodes farmlands, social assets, which are their very means of adapting. Adaptations are signs of a system's adaptive capacity. The study indicates that access to resources such as land, labour supply, and credit, traditional knowledge/information, and gender, were the key determinants of a household's adaptation. Women in the study area are at the forefront of adaptation to water stress induced by climatic variations due to the roles they play in the homes. Water scarcity and local institutional capacity clearly emerged during the research as a key restraining factor in people's ability to adapt to the climatic changes they are experiencing.

Overtime, household vulnerability might increase since important components of current livelihood activities to survive such as deforestation are still sensitive to conditions of the biophysical environment (models predicted future climatic variations) and will adversely increase impacts of climate change on water security, and thus undermine sustainable adaptation. The decreasing trend of water availability from limited sources for farming and domestic purposes especially during crop production time have increased their vulnerability

**5.2 Recommendation**

This thesis investigated the vulnerability of households in Kaduna river basin to climate variability induced water stress. Thus the study provided the historical trends of hydro-climatic variables at temporal scale and the consequent households' vulnerability status and adaptive capacities in the basin. Based on the findings from this study, the following recommendations are made:

1. The use of historical records of hydro-climatic variable proves valuable in understanding the potential hydrological consequences of the changing climate and the natural variability within the climate system. Overall, data scarcity problem can be mitigated by increased efforts in the establishment and maintenance of data networks and the development of reliable historical data.
2. The study revealed water scarcity and flood incidents as major water-stresses induced by climate variability. Therefore, increased effort should be made to building community/household based rainwater harvesting units and storage systems such as farm ponds and reservoirs, investment in appropriate irrigation systems to use especially during the dry season. Moreover, digging deep wells,

subject to availability of groundwater sources should be properly developed to consider as adaptation measures.

3. Issuance of early warning, external support and disaster risk management can tremendously improve communities' efforts to cope with floods.
4. In short term, the need to increase socio-ecological resilience and better livelihoods may well be necessary through improved agricultural techniques such as crop diversification and agricultural extension services, conservation and sustainable use of natural resources, and creation of more diverse livelihood options. At the level of households, there is a need for improved agricultural practices to maintain and improve soil fertility in order to increase food production and reduce risks to food security.
5. Likewise, in the long run, policies to promote alternatives for fuel wood and use (plus maintenance mechanisms) owned by vulnerable communities, and due emphasis given to development initiatives to avoid increasing vulnerability.
6. Among illiterate and poor people, increased climate change awareness needs to be promulgated to combat heat-stress and water related diseases by ensuring training, education, information and awareness raising programs that addresses vulnerability.
7. More context-specific studies on vulnerability, such as that of the present paper, should be conducted across various watersheds to understand how climate and hydrological events impacts livelihoods for providing appropriate solutions.

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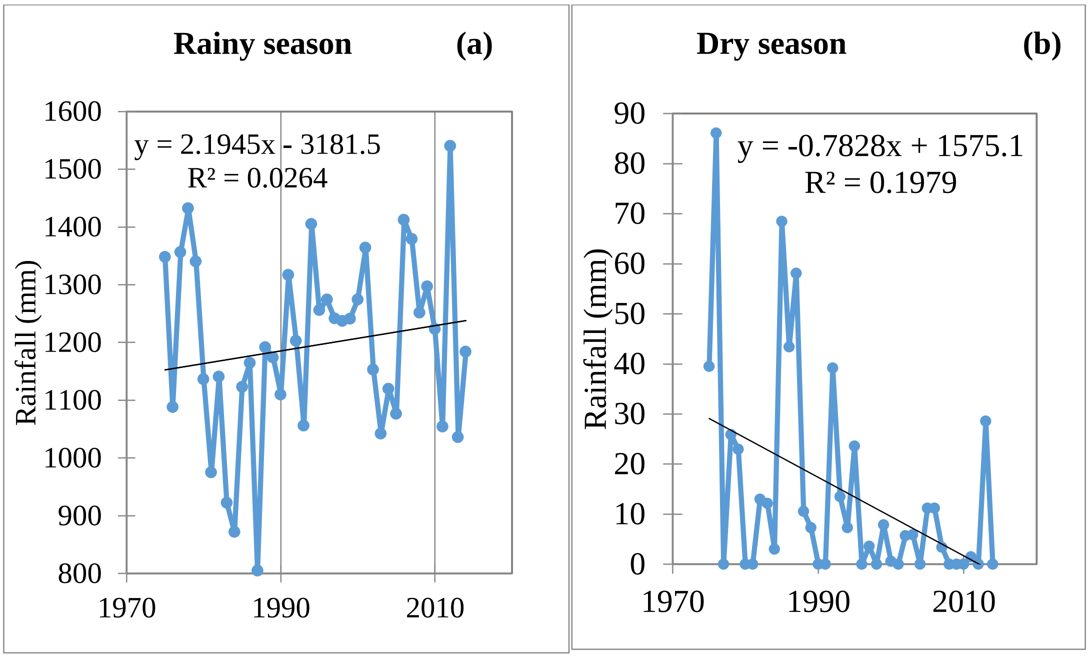
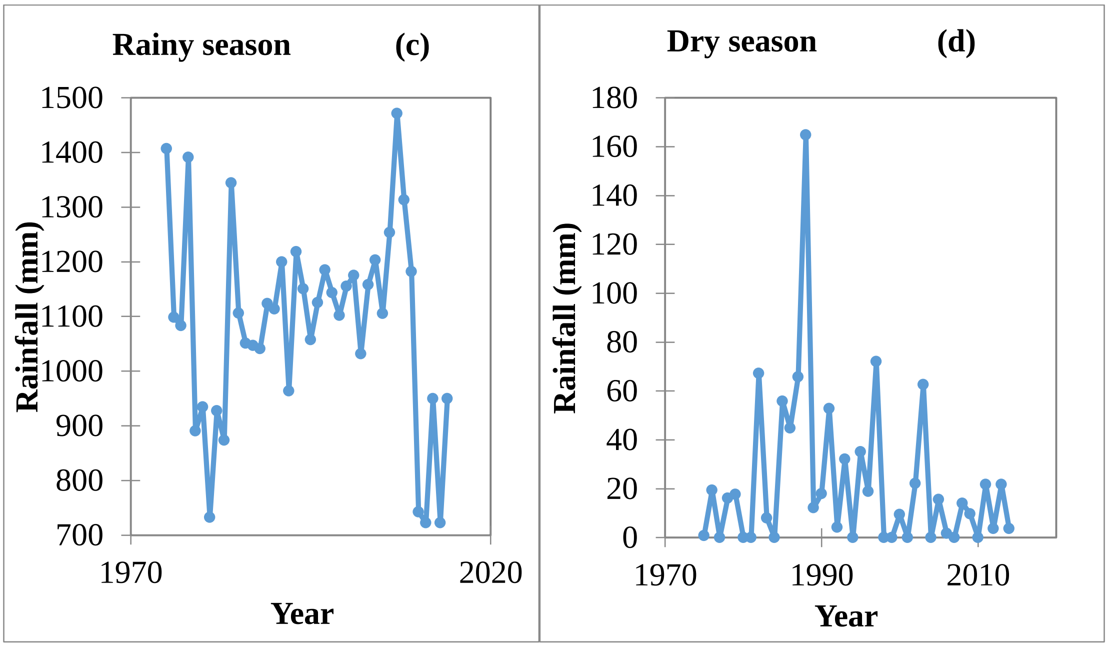
**APPENDICES**

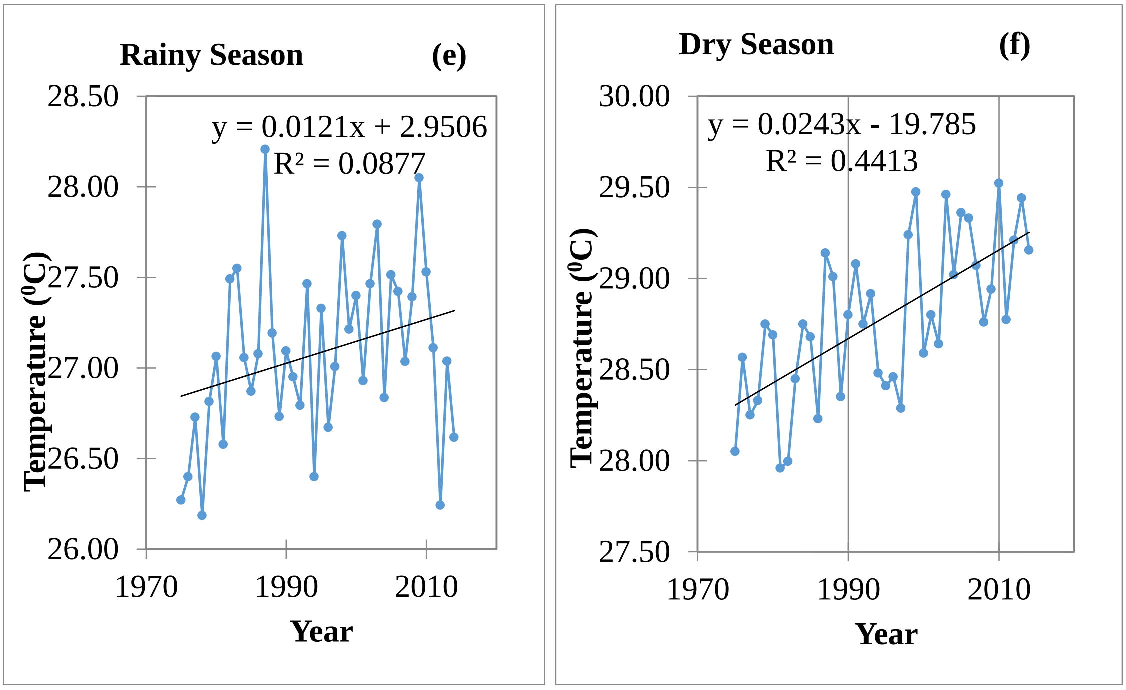
**Appendix A**: Time Series Plots Showing Linear Trend Lines



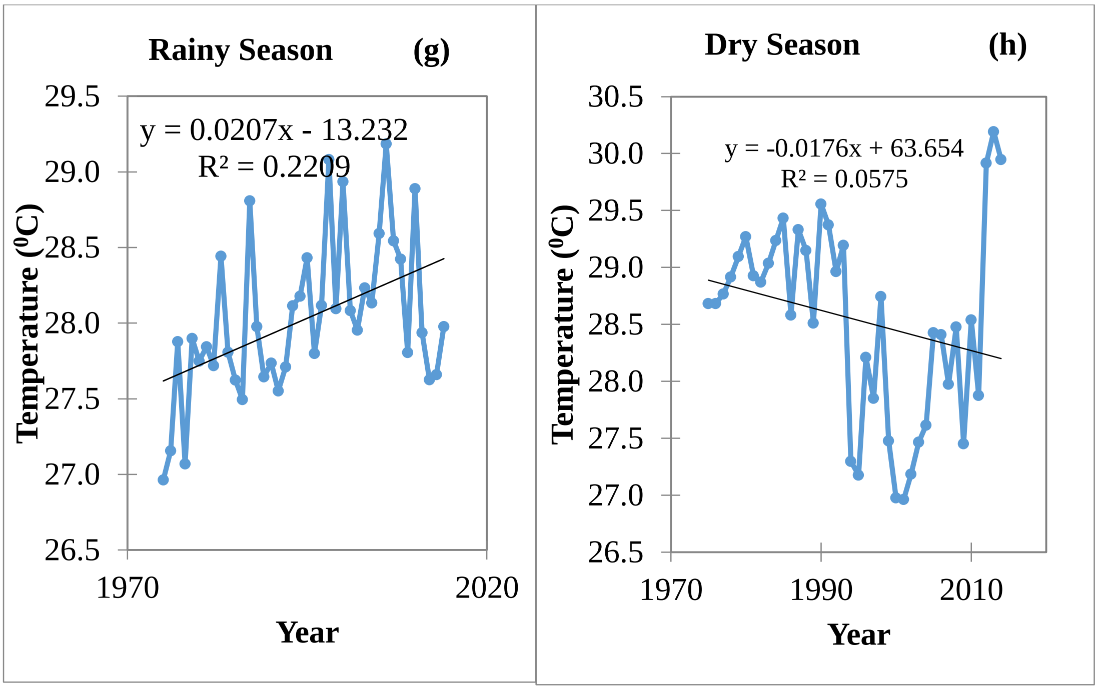

Time series plots for (a) Rainy b) Dry season Rainfall for Minna station




Time series plots for (c) Rainy d) Dry season Rainfall for Bida station




Time series plots for (c) Rainy d) Dry season Temperature for Minna station




Time series plots for (c) Rainy d) Dry season Temperature for Bida station

**Appendix B:** Household Questionnaire to Assess indigenous knowledge on Climate Variability impacts and Adaptation to water stress in Kaduna River Basin of Niger State.

| | | |
|---|---|---|
| *LGA:* | *Questionnaire ID* | *Interview Date:__/__/15* |
| *Community* | *GPS Coordinate* | |

**Section A: Respondent Details and Household Characteristics**

1. Sex: Male☐ Female ☐
2. Age in years: <20 years☐ 21– 40 years☐ 40 - 60 year☐ Above 60 years ☐
3. Are you the HH head? a) Yes☐ b) No☐
4. Highest level of education: a) Primary☐ b) Secondary ☐c) Tertiary☐ c) Islam☐ d) None☐
5. What is the size of your household? a) 1-5 ☐ b) 6 – 10☐ c) 10+☐
6. How many household members are educated: Male …….. Female ……..
7. What is the major source income of the household head? A) crop farming☐ b) livestock farming c) fishing☐ d) civil worker☐ e) petty trading☐ e) other …………
8. How many household members have other source of income? ……..……..
9. How many of the household members are working outside the community? ……..…….
10. House type a) mud ☐ b) concrete ☐ c) aluminium☐ d) thatch☐
11. How long have you lived in this area? a) <1 year☐ b) 1-5 years☐ c) 6-1☐ years ☐ d) > 15 years☐
12. Does your household own a farmland? a) Yes☐ b) No☐
13. If yes, what is the size of your farm (Plots/Ha)? a) 1-3☐ b) 4-7 ☐c) 8-10 ☐ d) 10+☐
14. What type of agriculture do you practice? a) Rain-fed ☐b) irrigation ☐
15. Do you plant twice in a year? a) Yes☐ b) No☐
16. What are the major food crops you grow? ……..……..……..………………………………
17. What are the major cash crops you grow? ……..……..……..………………..…………….
18. What are the major livestock(s) grown? ……..……..……..……..……..……………………

**Section C: Climate Trend and Variability – perception, awareness and effect**

19. Which of these changes in climate did you observe over the last 3 - 5 years?

| **Climatic Events** | **Increased** | **Decreased** |
|---|---|---|
| Hotness/heat | | |
| Rainfall (amount, intensity and duration) | | |
| River runoff/streamflow | | |
| | **Early** | **Late** |
| onset of rain | | |

| | | |
|---|---|---|
| cessation of rain | | |

20. Have you heard of climate variability? Yes ☐No ☐
21. If yes, what source(s) did you hear it from? a) Media ☐ b) Village Head ☐ c) Neighbours☐ d) Weather station ☐ e) Extension Agents ☐ f) Other …………….
22. How have you been affected by climate variability?

| Perceived Effects Of Climate Variability | Tick as appropriate |
|---|---|
| Decreased water supply | |
| Reduced soil fertility | |
| Reduced vegetation/pastures | |
| Increased flood occurrence | |
| Drying up of rivers/ponds/streams | |
| Increased drought occurrence | |
| Poor crop/livestock/fish yield in recent times | |
| Outbreak of waterborne disease | |
| Others (specify) | |

**Section B: Assessment of Water Stress in Terms of Availability**

23. Where do you get water for various uses?

| Sources Of Water | Indicate Uses (farming, livestock, fishing, irrigation and Domestic uses) | Distance (In Time) From Your House | (depth)/ quantity |
|---|---|---|---|
| Rainwater | | | |
| Rivers | | | |
| Ponds | | | |
| Shallow-wells | | | |
| Public water supply | | | |
| Boreholes | | | |
| Other (specify) | | | |

24. How is water availability from these sources? a) all year round ☐ b) seasonal ☐
25. Over the last 3years, have you experienced water shortage in this area? a) Yes☐ b) No ☐
26. If yes, for how long? a) Days☐ b) week☐ c) Months ☐ d) Years☐
27. Which months did you experienced water shortage? ……..……..……..…………………………..
28. What do you think is the cause of the experienced water shortage? ……………………..………………………………………………
29. Do you buy water when there is shortage? a) Yes ☐ b) No ☐

30. Which of these areas have you been affected by the shortage? a) farming ☐ b) Domestic uses ☐ c) livestock ☐ d) fishing ☐ e) Other ………………………
31. For the past 3 years, have you experienced crop failure (low fish/livestock production) due to water shortage? a)Yes ☐ b) No ☐
32. Over the last 3years, have you experienced flood event in this area? a) Yes ☐ b) No ☐
33. If yes, for how long? a) Days ☐ b) weeks ☐ c) Months ☐ d) Years ☐
34. Which months did you experienced flood? ………………………………………………………………..
35. What do you think is the cause of the flood event? a) Increased rainfall ☐ b) dam release ☐ c) don't know ☐ d) other ………….
36. Who collects water in your household? a) Man ☐ b) Women ☐ c) Girl child ☐ d) Boy child ☐ e) Household ☐ f) Other (specify)…………
37. How many gallons/buckets of water does your household use in a day? ------------
38. What do you store water in? a) Pots ☐ b) drums ☐ c) underground reservoir ☐ d) other ………..
39. Do you treat your water before use? a)Yes ☐ b) No ☐
40. If yes, what type of treatment do you use? a) Boiling ☐ b) adding alum/ashes ☐ c) none ☐ e) other ………..
41. Have anyone in your household experienced from any of these water and heat related disease? a) Cholera ☐ b) Diarrhoea ☐ c) Malaria ☐ d) typhoid ☐ e) pneumonia ☐ f) rashes ☐ g) hypertension ☐ I) other ………..

**Section D: Adaptation to Climate Variability and Water Stress**

42. Did you receive a warning about the climate variability in terms of?

| **Climate events** | **Yes** | **No** |
|---|---|---|
| Flood | | |
| Late rain | | |
| When to plant | | |
| Others (specify) | | |

43. Who among those listed here were more affected by climate events? a) Men ☐ b) Women ☐ c) children ☐ d) all ☐
44. Did you take measures to cope with these events? a) Yes ☐ b) No ☐
45. If yes, which of these immediate measures have you taken to cope with climate variability?

| **Measures in agriculture** | **Tick** | **Water supply measures** | **Tick** | **Flood control measures** | **Tick** |
|---|---|---|---|---|---|
| Use of chemical fertilizer | | Conservation | | Evacuation | |
| Organic manuring | | Alternative sources | | Building houses above floodplain | |

| | | | | | |
|---|---|---|---|---|---|
| Less water consumptive crop | | Tube wells | | Drainage | |
| Short duration variety crop | | storages | | Protection walls | |
| Reduce farm size/livestock | | | | Migration | |
| Agroforestry | | | | | |
| Mulching | | | | | |
| None | | None | | None | |

46. During these periods, has any member of your household received assistance from any of these? a) Relatives☐ b) friends ☐ c) NGO☐ d) government ☐ e) other ………..
47. If yes, list type of assistance received? -----------------------------------------------
48. Do you belong to any of these social group? a) Cooperative society ☐ b) water users associ☐on c) others (specify) …………….
49. Who needs to be part of improving water shortage/flood in this community? a) community members ☐ b)Village head ☐ c) Extension agents☐ d) NGOs☐
50. Do you have access to these facilities in your community? a) Electricity☐ b) Health centre ☐ c) schools☐ d) market ☐ e) tarred road ☐ f) None

**Appendix C**: Water Sources, Land-Use and Livelihood Activities


a) Girl children fetching water from public hand pump at Galadima Kogo b) farmland situated near the streams


a) Land degradation from flood and deforestation b) block making near the streams used for building houses


a) Household Survey b) Selling of wood by women to earn income