COMPARATIVE ANALYSIS OF THE SPATIAL AND TEMPORAL VARIATIONS IN HYDROLOGICAL PARAMETERS AT KAINJI AND SHIRORO DAMS, NIGER STATE, NIGERIA

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ABSTRACT

Climate variability has been one of the major issues of the 21st century. The idea is to understand the differences in the climatic conditions and long-term catchment regimes using mean monthly seasonality indices and to explore the differences in the hydrological parameters at the long-term event scale. This comparatively analyze of spatial temporal variations in hydrological parameters at Kainji and Shiroro Dams in Niger State towards achieving a better future plan in the area. Quantitative and qualitative research approach was used, geospatial techniques were used to analysis the landuse pattern of the dams areas. Landsat satellite imagery was also acquired for 1997 to 2017. The imagery was subjected to digital process and five landuse classes were generated. Mann-Kendall test and Sen's slope test on the monthly coefficient of variation for rainfall, reservoir inflow, reservoir elevation. The results show rainfall deviations increased between 1998 and 1999. On decadal basis, the years 1998, 1999, 2004, and 2006 have positive rainfall deviations while the remaining years have negative and least rainfall deviations. It was also revealing that evaporation deviation was increased in the years 1995 but it reduced drastically between 1993 and 1994. The analyses revealed a negative trend, and a slight decrease in rainfall and it can be brought to conclusion that since evaporation and reservoir inflow has the greatest impact because increase evaporation will increase and there will be shortage of water in the dam. It recommended that operators optimize the release of water from Kainji dam and ensure continuous monitoring of changes in hydro metrological variables to provide early warning for effective performance of the dam and to protect the environment.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Hydrology is the science of water which deals with the water of earth and its atmosphere. It is the study of occurrence, circulation, distribution, chemical and physical properties of all forms of water and also their reaction with the nature including human (Apalando, 2012). It is an important aspect for the living being including both human and the environment. It concerns with the water in streams, lakes, rainfall, snowfall, snow, ice on the land and even water occurring below the earth’s surface in the pores of the soil and rocks. Hydrological parameters such as precipitation, surface runoff, evapotranspiration, interception, infiltration, change in soil moisture, river flow, and change in groundwater storage are part of Earth's dynamic ecosystem.

Climate and human induced changes on catchment hydrological processes are major concerns for scientists, water decision-makers, and politicians. Different scenarios of climate change and its impact on water balance directly and on ecological, chemical, and geomorphological processes indirectly are the main issues of many studies in the last ten years all over the world. Most of them were dealing with different climate scenarios and their impact on global ecosystem, water management, or economy. Global modelling with simulating global water cycle and in that context analysing hydrological extremes and water balance components is the most common approach, as Corzo Perez *et al*. (2011) stated (Corzo-Perez *et al.*, 2011). Droughts are global hydrological phenomena found to increase in duration, area, and severity, according to Lloyd-Hughes *et al*. (2013). But validation of global models had to be done by observations on smaller scale, on the number of catchment areas of different characteristics, as it was studied by Stahl *et al*. (2010).

Climate change is the alteration in the temperature, rainfall, humidity, wind and seasons. It is the seasonal alteration of weather over an extended period due to global warming (Apalando, 2012). These alterations have an impact on surface water like a dam, rivers, agriculture production, and causes either flood or drought in the area. Globally, the effect of climate change has led to numerous issues in water resources like flooding and drought (Shen and Qiang, 2014). Rainfall is the only parameter that changes the reservoir inflow, reservoir elevation and turbine discharge in the dam (Shen and Qiang, 2014). These changes occur in space and time. Rainfall inconsistency in different locations over time causes counterpart runoff generation which affects water availability positively or negatively in the area (Warwade *et al*., 2018). The rate of change of runoff has a critical effect on hydrological cycles and its variables. Runoff influenced by human activities such as land use and housing development at the upstream and climate change. Identification of the spatial and temporal variations caused by rainfall and runoff is essential for water resources planning and management (Lee and Kim, 2017).

Climate variability has been one of the major issues of the 21st century. In fact, its importance keeps on increasing with the realization that its impacts cut across all sectors of a country's economy. Hence it should not only be looked at just as an environmental issue but also a developmental issue. Presently the scientific consensus on climate change is that human activity is very likely the cause for the increase in global average temperatures over the past several decades (IPCC, 2001). The increase in the world's population over the last century, complemented by the rise in the standards of living, has resulted in a rise in the demand for energy. According to John and James (2011); Adegbehin, *et al.,* (2016) Scientists predict that the global population will swell to over 10 billion by 2050. The impacts of climate variability and change are real and would continue to affect sensitive sectors of the global economy. Productive sectors such as agriculture, water, health, energy, and transport among others bear the brunt of these variability and change in the world's climate. Even though the entire globe will experience the impacts of these changes, the more severe impacts will be felt in low latitude developing countries where several non-climatic stressors are already at play (IPCC, 2007a). Sub-Saharan Africa continues to exhibit vulnerability to variability and change in climatic parameters such as temperature, rainfall and extreme events resulting from both anthropogenic climate change and natural variability. The principal known source of tropical climate variability is the El Niño-Southern Oscillation [ENSO] (Collins *et al.,* 2010; Camberlin *et al*., 2001).

The Intergovernmental Panel on Climate Change (2007) reported that rainfall variability on spatial and temporal had increased globally. These variations affect dam variables such as reservoir elevation, reservoir inflow, and turbine discharge. Furthermore, the disposition of spatial and temporal rainfall variability and others hydrological variables such as reservoir inflow, reservoir elevation, and turbine discharge were poorly understood (Cristiano *et al,* 2017).

The spatial temporal variations of hydrological characteristics are one of the key factors controlling the development and stability of natural ecosystems. From a hydrological perspective, spatial temporal analysis of runoff and precipitation is an appealing method for inferring flood generation mechanisms, which, in turn, supports other hydrological applications, such as hydrological regionalisation. Recently, the assessment of hydrological seasonality and regime stability has attracted a renewed interest, especially in connection with water resources management, engineering design and land cover and climate change assessment studies (Krasovskaia and Gottschalk, 2002; Krasovskaia *et al*., 2003; Bower *et al*., 2004; García and Mechoso, 2005).

Although, previous studies use weather radar to analyse the spatial and temporal variation and the outcome was poorly understood. Presently, numerous studies use multivariate statistics such as cluster, discriminant and Principal component analysis and Mann Kendall test to analyse the spatial and temporal variation of hydrological variables. Shen and Qiang (2014) examined the spatial and temporal variation of annual precipitation in a river of the loess plateau in China and multivariate statistical methods, and Mann Kendall were used. Their results showed that there was two spatial pattern that increases in the northwest, a decrease in the southeast and an increase in the west and the decrease in the east. Javari (2016) examined the spatial-temporal variability of seasonal precipitation in Iran. This study used an annual time series procedure and spatial (GIS) method, and their results showed that the rainfall had two spatial patterns in the area.

Hence, this study will comparatively analysis the spatial temporal of hydrological parameters of both Kainji and Shiroro dam within the context of ecosystem sustainability. The main idea is to understand the differences in the climatic conditions and long-term catchment regimes using mean monthly seasonality indices, and to explore the differences in the hydrological parameters at the long-term event scale. It is anticipated that the combination of both concepts within the framework of comparative hydrology may give an insight into the main hydrological processes in Kainji and Shiroro dams. The two hydrological dams have many common features with respect to runoff forcing and generation. Similar precipitation regimes exist in both areas (Tolulope, 2011).

1.2 Statement of the Research Problem

The overdependence on hydropower has exposed the country to the impacts of climate variability. One of the potential effects of variability in climate, especially reduction in the amount and deviation in the distribution of rainfall, is the possibility of changes to river flow and runoff which will affect energy supply from hydropower sources (Energy Commission & United Nations, 2012) Harrison *et al*., (2014). The existing hydropower capacity in Nigeria was built long before engineering and general public were aware of the impact of climate change on large infrastructure. Sudden climate variability has posed a dangerous threat in our poorly managed hydropower dam. Rising global temperatures will lead to an intensification of the hydrological cycle, resulting in drier dry seasons and wetter rainy seasons, and subsequently height and risks of more extreme and frequent floods. It will equally have significant impact on the availability and accessibility of water as well as the quantity of water that is available and accessible. All these factors highlighted will have an adverse impact on our hydropower dams. Therefore, periodic check on hydro climatic condition of our various dams is of serious concern, because failure of it will result to economic loss, and its attendant problems.

This study is purposely undertaken due to the frequent destruction of vegetation, farmlands and residential area downstream of Kainji and Shiroro dam. Biophysical impact analysis is necessary in order to reduce the impact of subsequent flooding event in the community. Government, although had already conducted many surveys to measure and assess flood damage, but the impact assessment at the micro-level based on community data, including the effect on the community hasn’t been done yet. No such studies attempted to link these destructions to emission of greenhouse gases whose increase in the negative environmental consequences of dam construction on inundation of terrestrial habitats, modification of hydrological regimes, and modification of aquatic habitats is thus, emphasized lead to climate change. Therefore, this study will be carried out to comparatively analysis the spatial and temporal variations in hydrological parameters of Kainji and Shiroro Dams in Niger State for effective sustainability of ecosystem.

1.3 Aim and Objectives of the Study

The aim of the study is to comparatively analyze the spatial and temporal variations in hydrological parameters at Kainji and Shiroro Dams in Niger State towards achieving a better future plan in the area. The specific objectives are to:

i. examine the spatial-temporal characteristics of Kainji and Shiroro Dam;
ii. examine the spatial variations of rainfall, reservoir inflow, reservoir elevation, evaporation and turbine discharge in Shiroro and Kainji dam.
iii. compare the spatial variations on discharge as a function of human activities, climate change and land use patterns in the upstream areas of the selected dams

1.4 Research Questions

i. What is the spatial-temporal characteristics of Kainji and Shiroro Dam;
ii. What are the spatial variations of rainfall, reservoir inflow, reservoir elevation, evaporation and turbine discharge in Shiroro and Kainji dam?
iii. Are there difference in spatial variations on discharge as a function of human activities, climate change and land use patterns in the upstream areas of the selected dams

1.5 Justification of the Study

The spatial and temporal distribution of hydrological variables such as rainfall, reservoir inflow, reservoir elevation and discharge are crucial in hydrology, water resource management, agriculture and irrigation under climate change. The noesis of the spatial and temporal variation of the reservoir inflow, reservoir elevation, and turbine discharge is essential for water resources planning and management. The knowledge of spatial and temporal changes of reservoir inflow, reservoir elevation, and turbine discharge will be used as an essential tool for quantifying the variations (Saraiva *et al*., 2015) and predicting future hydrological variables like reservoir inflow, reservoir elevation and turbine discharge under rainfall variability and climate change.

The significance of this research cannot be over emphasized, especially for the optimum result in saving lives and protection of properties in the long run. In the past, the spatial temporal of hydrological characteristics was analysed mainly in the context of flooding (Falkenmark & Chapman, 1989). The main idea was to study the character of hydrological processes and to identify regions with similar hydrological responses. There are numerous studies on the spatial temporal variations of the long-term mean monthly runoff regime (e.g. Lvovich, 1938; Pardé, 1947; Gottschalk, 1985; Haines *et al.*, 1988; Arnell *et al*., 1993; Krasovskaia *et al.*, 1994; Dettinger & Diaz, 2000; Bower *et al*., 2004; Johnston & Shmagin, 2008). In many studies the hydrological regime is analysed over a single region (Pfaundler, 2001; Archer, 2003; Birsan *et al*., 2005; Assani *et al*., 2006; Molnar & Burlando, 2008; Petrow *et al*., 2007; Sauquet *et al.*, 2008; Solin, 2008), but only a few studies compare two dams with large data sets to evaluate the seasonality across the boundaries of administrative units (Krasovskaia, 1995, 1996; Dettinger & Diaz, 2000; Krasovskaia & Gottschalk, 2002). Therefore, this study will fill the gap by comparatively analysis two big dam (Kainji and Shiroro) in the context of their spatial temporal characteristics in hydrological parameters.

This study requires an understanding of the hydrological characteristics and its interaction with the spatial temporal variations of the catchment. Hence, for effective planning and application of water resources management, there should be a basis or a study that must expose the areas that need attention. In this regard, this study will provide the opportunity for well-structured spatial and temporal variation of hydrological parameters and offer a sound scientific analysis for a coordinated management and planning. This in turn will facilitates reasonable and equitable use of scarce and vulnerable water resources by all stakeholders. It is hoped that the results from this study will have significant implications on the current and future land and water resources management in Nigeria.

1.6 Scope of the Study

The focal point of this study covers Kainji and Shiroro dams, the study deal with the hydrological parameters such as rainfall, reservoir inflow, reservoir elevation, evaporation and turban discharge, it will cover a duration of 30 years (1987-2017). It examine and compare the spatial variations of the hydrological characteristics of the area and also use geospatial techniques to analysis the landuse pattern of the dam's areas.

1.7 The Study Area

1.7.1 Location of the study

Geographically, Shiroro dam is located on 6° 51' 00" E and 6° 75' 10'' E longitude and latitude 9° 58' 00" N and 9° 65' 25'' N at 550 meters elevations downstream of the confluence of Kaduna River with river Dinya as its tributary in Shiroro Local Government Area of Niger State (Usman and Ifabiyi, 2012). Also, Kainji dam is located on Longitudes 04°36′ 48″E, 4° 34'3 .8 "E and latitudes 10° 11'45.71"N, 09° 5 ′ 45″N in Borgu Local Government Area of Niger State (Ehigiator *et al.*, 2017) as shown in Figure 1.1 and 1.2 respectively.

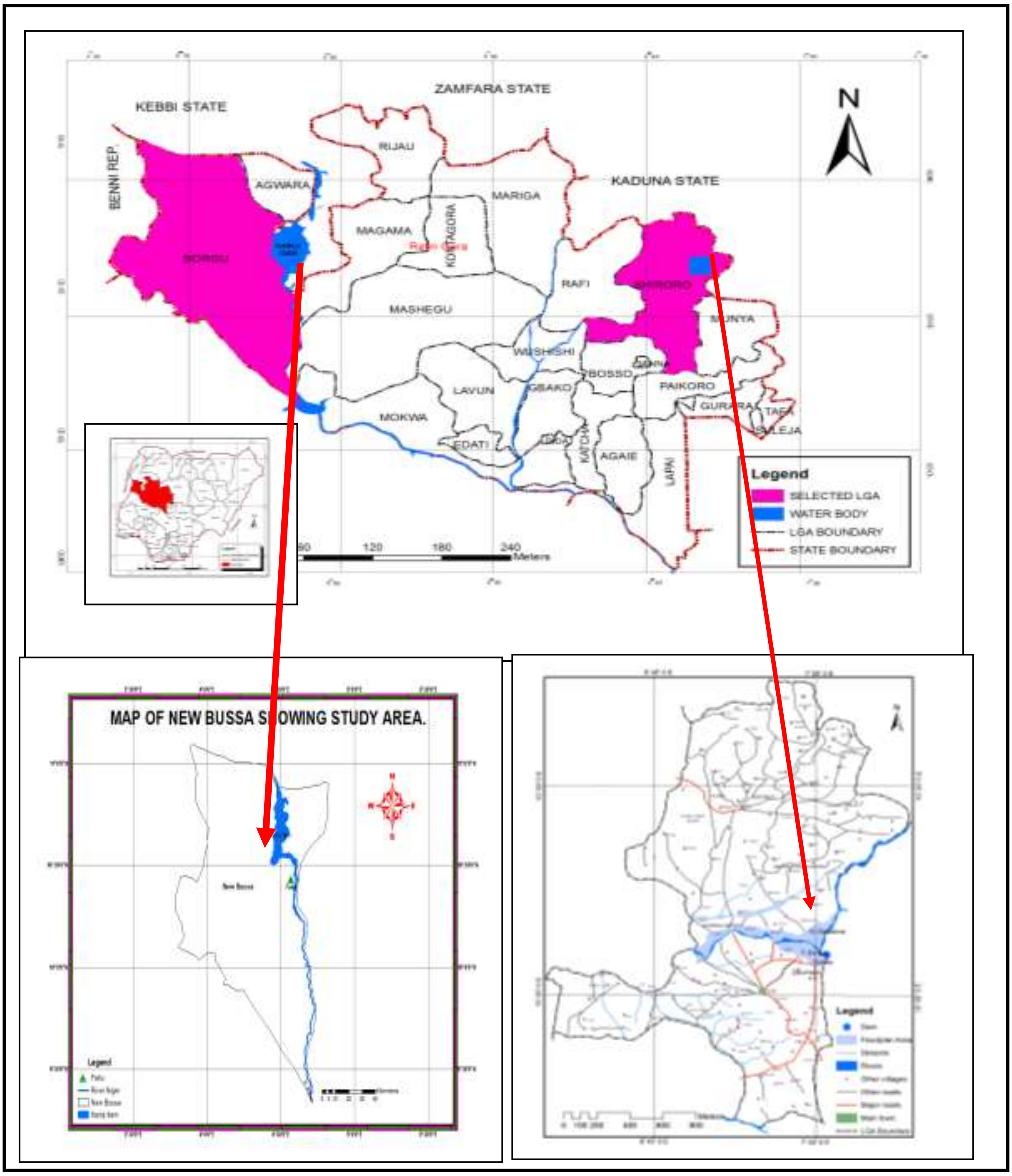


Figure 1.1: Niger State showing Kainji and Shiroro Dams

Source: Modified by Ministry of Land and Housing, Minna (2019)

1.7.2 Vegetation and soil of the study area

Shiroro watershed is a guinea savanna which consists of coarse grasses, shrubs and woodland (Ovie and Adeniji, 1994). The watercourse, in most areas, is characterised by evergreen short-bowled, broad-leaved trees (Ovie and Adeniji, 1994). Adegbehin *et al.*, (2016) reported that vegetation in the areas consists of a mixture of grass, woodlands in Kainji. These are in the group of Northern Guinea savanna type. The soils in the area are sandy loam, loamy sand, and clay-loam to clay in the land bordering the river throughout the lake area. The river bedrock covered by a layer of coarse to the medium sand of variable thickness, fine sand and clay (Adegbehin *et al.,* 2016).

The soil parent material is derived from a number of geological formations. The precambricum crystalline and metamorphosed sedimentary rocks of the basement complexes, the upper cretaceous conglomerates, sandstones and silt-stones of the Nupe formation. The alluvium varying in texture from sandy to clayed odpleistocene to recent age. The various rock types may play a decisive role in the soil derived from them and determine to a large extent their physical and chemical properties. The soil type is alluvial. Soil types within the study area are well drained shallow to moderately deep. The color varies from very dark gravity brown to dark or strong brown or yellow red the name of the soil of the Shiroro catchment area are derived from pre-existing rock i.e. Precambrian basement (complex rocks) consisting of gross, granite amphibolies schist. The soil type is also further grouped from association which are named after important features such as towns and rocks which have been used after some scientist (Raltche 1973).

1.7.3 Climate of the study area

The raining season occurred between the month April and October while the dry season came between November and March in both study area (Adegbehin *et al*., 2016). Kanji area has a daily maximum of 33.5^{o}C in the warmest month while the mean annual temperature is about 30^{o}C. The mean temperature in both seasons is 35^{o}C (dry season) and 270C (raining season) in Shiroro area. The months of April and May are the hottest month while December and January are the coldest. (Kuti *et al,* 2015).

1.7.4 Hydrology of the area

The variation in the reservoir water level is controlled by inflow into the lake (a) from the area surrounding the reservoir basin (white flood-August to November); (b)from the upper catchment of the Niger (black flood- December to march)(2) rainfall at the lake about 1071mm,(3) evaporation losses of the water surface estimated at 1500-2000 mm (4)seepage (5)out flood through turbines for power generating purposes (6) spilling (manly to satisfy commitments downstream) (7)domestic water use and (8)irrigation water supply (Kuti, 2015). Figure 2.1 is the hydrological map of Kainji area.

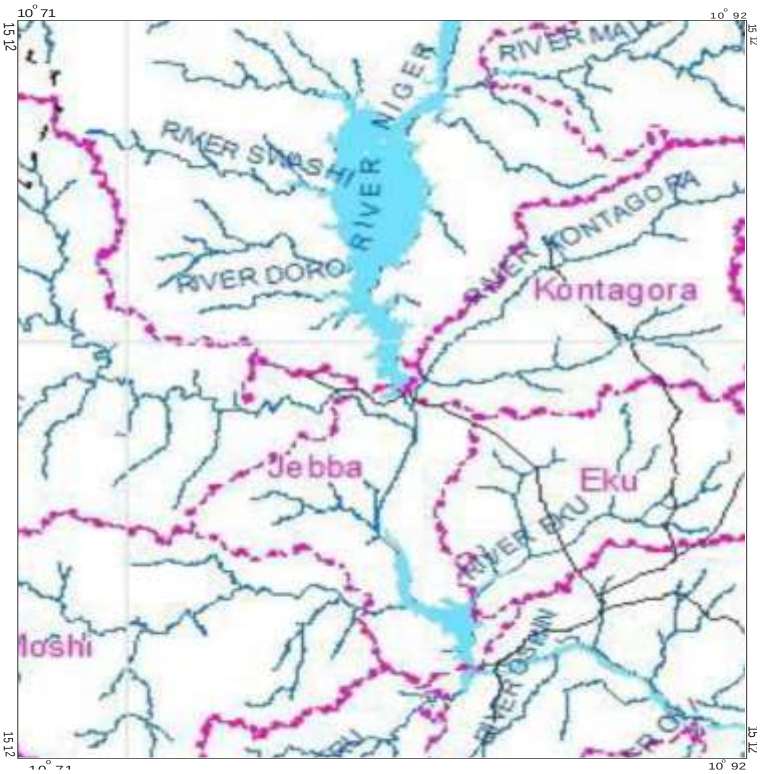


Figure 1.2: Hydrological map of Kainji

Source: Niger State Geographical Information System, 2019

Shiroro Lake was built on river kaduna, one of the principal tributaries of river Niger, its source is from plateau mountains and travels a distance of about 356km before emptying into reservoir. Unlike the most rivers in the Northern Nigeria, river Kaduna a perennial river. The river flow in a fairly straight course in the upper and middle stage within same meaned at the lower course. Long profiles consist of a number of steep gradient valley steps which is separated by parches of others sit low gradient. Its course is interrupted where it cross hard rocks, deep gorges have been cut across the area of more pronounced steeps in the valley (Figure 1.3 Hydrological map of Shiroro). This includes the 5.0km ravine in the granite of Shiroro and the 9.5km gorge through schist of guria. Rainy season between April and October peak falls between August and September. Dry season spell usually between November and March. River Munya, SarkinPawa, Gum and Dinya are the major tributaries in the vicinity of the study area that feed the main Kaduna River (Kuti, 2015).

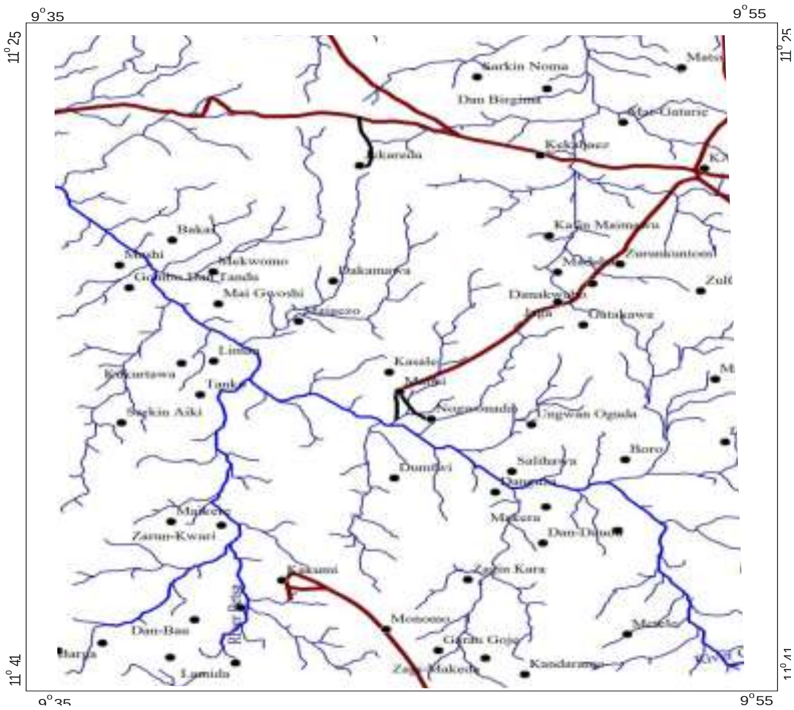


Figure 1.3: Hydrological Map of Shiroro

Source: Niger State Geographical Information System, 2019

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework on Hydrological Parameters in Dam

2.1.1 Concept of climate change

Climate change refers to a change in climate that is attributed directly or indirectly to human activity that alter the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. The intergovernmental panel on climate change has evolved its own usage of the term climate change as any change in climate over time whether due to natural variability or as a result of human activity. Attribution of climate change to natural forcing and human activities has been addressed by Working Group I of the IPCC in climate change 2001 which is the most recent assessment of research on the topic of climate change, (IPCC, 2001). The Working Group I report concludes that globally average surface air temperature is projected to warm 1.4 to 5.8^0C by the year 2100 relative to 1990, and globally averaged sea level is projected to rise 0.09 to 0.88m by the year 2100.

Climate change is a long-term change in the statistical distribution of weather patterns over periods of time that range from decades to millions of years. It may be a change in the average weather conditions or a change in the distribution of weather events with respect to an average, for example, greater or fewer extreme weather events. Climate change may be limited to a specific region, or may occur across the whole Earth. According to the National Oceanic and Atmospheric Administration (NOAA), there are 7 indicators that would be expected to increase in a warming world, and 3 indicators would be expected to decrease. In recent usage, especially in the context of environmental policy, climate change usually refers to changes in modern climate. It may be qualified as anthropogenic climate change or anthropogenic global warming (AGW). Figure 2.1 shows 10 indicators of a human fingerprint on climate change.

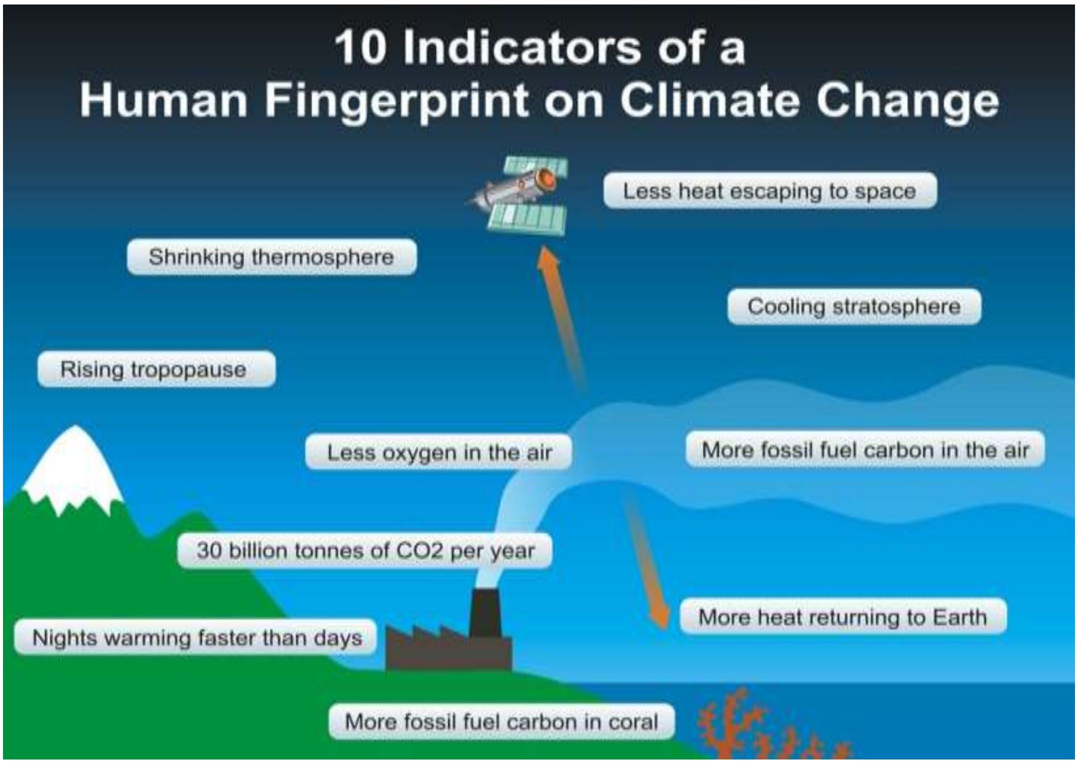


Figure 2.1: Climate change defining
Source: Modified from John 2011

Climate change within Nigeria during the next 100 years will depend primarily on the global change in climate. In turn, expected global change in climate will depend on increase in the concentrations of the greenhouse gases including carbon dioxide, methane and, nitrous oxide. Increasing concentration of greenhouse gases in the atmosphere enhances the potential of the atmosphere to conserve heat and therefore bring about global warming.

2.1.2 Impact of climate change on hydrology

Evaluating regional impacts from possible climate change in the future requires a methodology to estimate certain meteorological variables for the time period and the geographical region of interest. In general, two physical systems are involved: the climate system and the hydrological system (Figure 2.2). The effect of greenhouse gases emissions forcing on the climate system can be simulated by GCMs. Many impact analysis studies in the past were based merely on the results of such simulations. The results available at the time from GCM simulations were limited, and the impact analysis based on such data are the first attempts to evaluate impacts from climate change, as predicted by physical models of the atmospheric dynamics.

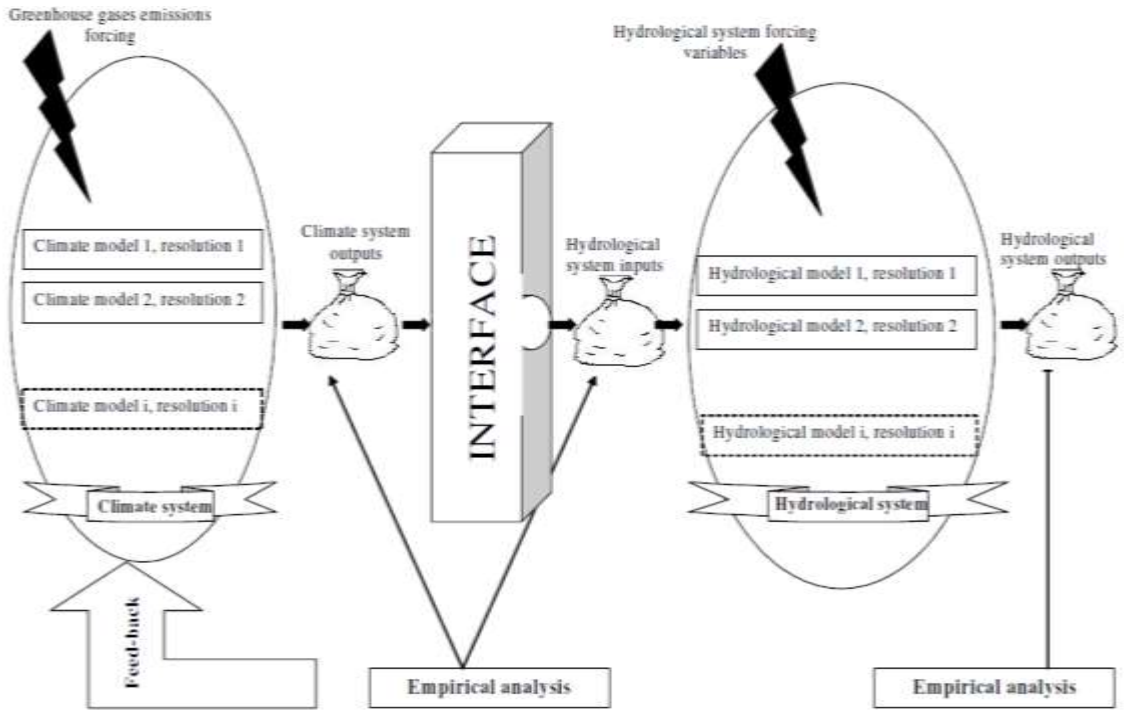


Figure 2.2: Different aspects involved in hydrological impact analysis of climate change

Source: Modified from GCM, 1997

2.1.3 Uncertainty in climate change predictions

There is wide acceptance that anthropogenic activity is leading to global changes in climate through increased concentrations of greenhouse gas (IPPC, 2001). Although there is general consensus that the climate in the UK is changing and that the rate of change is likely to be influenced by ongoing anthropogenic activity, it is not possible to predict with any certainty the likely future climate in the next 50-100 years. There remains substantial and possibly growing uncertainty of the most likely climate change outcome over the medium to long term (Jenkins and Lowe, 2003; Murphy *et al*., 2004). In particular, the uncertainties will preclude firm predictions. They stem from uncertainties over trends in emissions, uncertainties over the scientific understanding of the climatic processes involved, uncertainties about how these will disaggregate regionally and uncertainties generated by natural variability. Moreover, projected outcomes from equally probable futures diverge substantially in the longer term. Exemplifying these uncertainties, future model projections for the 2080s include: Global temperature over the next 100 years increasing by between 1.5 and 5.5°C; Summer mean temperatures for the UK increasing by 3°C to >8°C depending on location; Global mean precipitation increasing by between 2 and 7 per cent; • Winter precipitation for the UK increasing by 1-60 per cent and summer precipitation changing from less than –30 per cent to more than +4 per cent, depending on the models used;

2.1.4 Regional and seasonal variability in predicted climate

Accepting the limitations to the predictive outcomes stated above, work to date in the UK indicates that there will be both regional and seasonal variability in the rate and influence of climate change. Having considered the caveats on the confidence that can be ascribed to using single CGM outputs to simulate potential future climate (Jenkins and Lowe, 2003), it is illuminating to consider the future climate outcomes that may be produced.

To frame a relatively severe potential outcome, the UKCIP02 medium–high emissions scenario has been used, projected to the 2050s, to provide an indication of the sensitivity of freshwater ecosystems vulnerable to climate change in this study. Relevant abiotic factors associated with climate are introduced are changes in rainfall, air temperature (as mean and diurnal range), humidity, wind speed and solar radiation (as cloud cover). These factors are all addressed by UKCIP (Hulme *et al.*, 2002), including regional and seasonal perspectives.

These modelling outputs provide a general indication of the potential regional and seasonal changes. This is reasonable for general shifts in ecological function, but the extremes may be more significant for habitat change and species distributions. The UKCIP02 scenarios provide a considerable amount of new information on future changes in daily climate, which is important for analysing possible changes in extreme events. These include the number of ‘extremely’ warm days, changes in number of ‘intense’ rainfall days, changes in precipitation for a range of return periods (2-20 years) and changes in daily mean wind speeds for a range of return periods (2-20 years).

2.1.5. Global hydrological cycle

The hydrological cycle refers to the repeating effect of different forms of water movement and changes of its physical state in nature on a given area of the Earth (Kuchment, 2004). Water movement in the hydrological cycle covers atmosphere, hydrosphere, lithosphere, and biosphere and strongly depends on the local peculiarities of these systems (Kuchment, 2004). The function of the phenomenon in hydrological and their description depend on the chosen spatial-temporal scales and the significant parts of the terrestrial hydrological cycle (Kuchment, 2004), and the global hydrological cycle as shown in Figure 2.3 and 2.4.

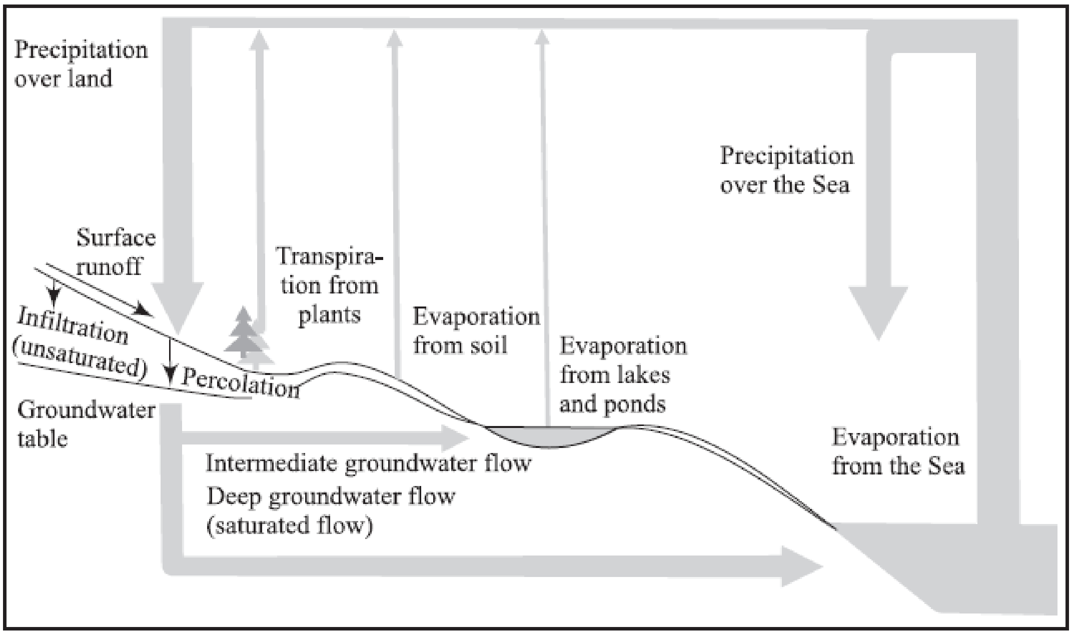


Figure 2.3: Global hydrological cycle
Source: Modified from Kuchment, 2004

The mean rainfall on the earth's surface equals total global evaporation. Nevertheless, the complete annual evaporation from the ocean surface is higher than the rain. The excess evaporated water (about 47 000 cubic kilometres) is transported by air currents from the oceans to the continents (Kuchment, 2007). Forty (40) percent of the rainfall goes back to the oceans as river runoff or as direct groundwater discharge to the beaches while the other part re-evaporates and falls back to the land (Kuchment, 2007).

Water moves through physical processes like evapotranspiration, precipitation, infiltration and river runoff (Stagl *et al*., 2014). These cycles require energy such as heat transfer, solar radiation and gravitational potential energy to transfer water from one reservoir to another. During this phenomenon water changes either in liquid or vapour/ice (Stagl *et al*., 2014).

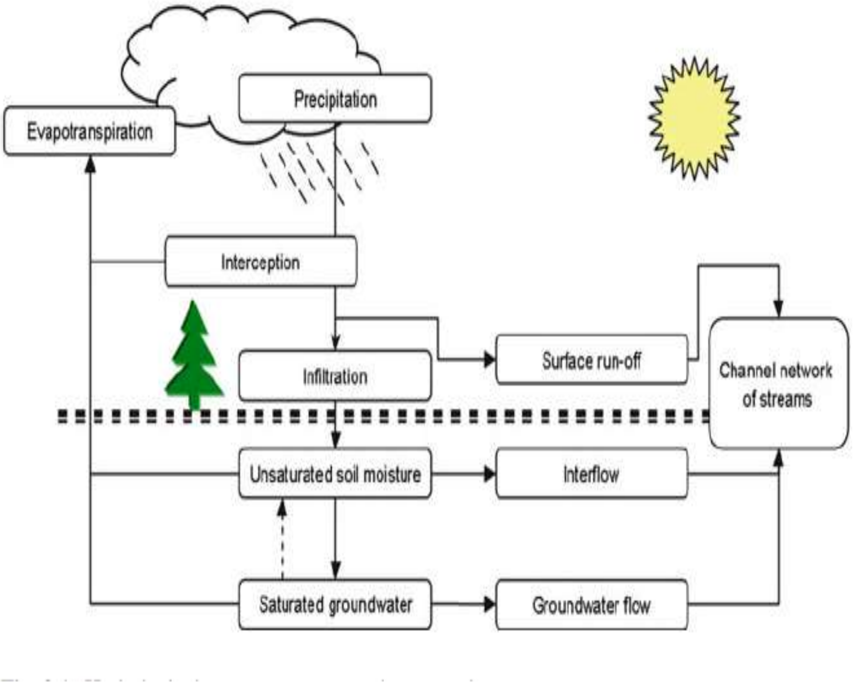


Figure 2.4: Hydrological components on a catchment scale
Source: Modified from Kuchment, 2004

Hydrological processes involve different spatial and temporal scales. Runoff generation in the river networks are the key parts of the terrestrial hydrological cycle. In other to assess the terrestrial hydrological cycle, it is useful to know the important factor like topographic, vegetation, geological and soil parameters which determine the generation of runoff. These conditions give an opportunity to represent the land surface heterogeneity. The following hydrological parameters may be temporal and spatial variations in hydrological cycle:

(i) **Rainfall:** the source of water in the earth surface is the rainfall. It drives the hydrological cycle over the land surface and changes surface salinity (and temperature) over the ocean and affects its thermohaline circulation (Oki, 2006). Highly variable, and rainfall behaviour in time and space domain compared to other major hydrological fluxes mentioned below makes the observation of this quantity and the aggregation of the process complex and difficult (Oki, 2006).

(ii) **Evaporation:** it brings back water flow from the surface to the atmosphere which produces latent heat flux from the surface (Oki, 2006). Atmospheric and hydrological conditions estimate the quantity of evaporation. Oki (2006) reported that the evaporation condition separated as driven hydrology.

(iii) **Transpiration:** it is the evaporation of water through the stomata of leaves. It consists of two different features from evaporation from soil surfaces. The stomata resistance is associated with dryness of soil moisture and physiological conditions of the vegetation via stomata opening and closing. The root of each plant transfers water from the soil than evaporation from bare soil. Vegetation's modify the surface energy and water balance by changing the surface albedo and by intercepting rainfall and evaporating this rainwater (Oki, 2006).

(iv) **Runoff:** it is a nonlinear and complex process. It brings backwater to the ocean that is transported in the vapour phase by atmospheric advection for inland. This runoff that moves into the ocean is relevant for the freshwater balance and the ocean salinity. Rivers transported sediment, chemicals, and soil nutrients from continents to seas. Without rivers, global hydrologic cycles on the earth will never close. Surface runoff could generate higher rainfall intensity which is greater than the infiltration rate of the soil over the wetland surface. Saturation at land surface can be formed mostly by topographic concentration mechanism along hill-slopes (Oki, 2006).

2.2 Theoretical Framework of Climate Change on Hydrological Parameters

Elevated greenhouse concentration drives to increased atmospheric moisture variability due to increased surface warming. This, in turn, leads to an accelerated hydrological cycle and increased regional precipitation variability. Climatic moisture content dramatically increases because of the exponential relationship between temperature and moisture overload (Goswami and Himesh, 2002). Because temperature becomes an essential application on sensitive hydrological parameters such as evaporation and potential evapotranspiration (Goswami and Himesh, 2002) and relative humidity (Goswami and Himesh, 2002). Global warming has serious impact on global and regional hydrological cycles, which in shift become critical indications for water resources, agriculture, economy and environment. Production of spatiotemporal variability of water resource on a long-term basis equal varying anthropogenic and environmental pressure need complex. Modelling tools, wherein, GCM models (deal with climate change and rainfall prediction) are linked with hydrological models (Goswami and Himesh, 2002).

2.2.1 Global climate scenarios

Global climate models are numerical models that are fundamentally very similar to the atmospheric models used for everyday weather forecasting. These models assume a given initial state of the atmosphere and predict the future developments with the help of hydrodynamic and thermodynamic relationships (so-called primitive equations). While weather forecasts are typically made for the next 1–2 weeks in a limited region, climate models are run for hundreds of years and cover the whole Earth. To make these calculations within a reasonable time, both the temporal and spatial resolution of the calculations are considerably lower than in the forecast models, typically about 10 min and 3°. One effect of this is that some small-scale processes, such as local convection, cannot be simulated directly but only estimated through simplified relationships.

A fundamental difference between forecasting models and climate models is that while the former predict the weather at a specific time (e.g. Wednesday at. 18:00), the latter instead predict statistical properties (e.g. the average rainfall in August). This is possible because of the limitations of climate, which are governed by regional characteristics in for example solar radiation, atmospheric composition and land surface. These restrictions allow a basically forecasting model to not derail when run in a continuous “climate mode” but continue to generate statistically realistic weather sequences. In a climate model, certain large-scale interactions are considered, e.g. those that occur between the atmosphere and oceans. These play little role in the short term perspective but an important role on seasonal scales and therefore the atmospheric model is usually combined with an ocean model.

Future climate scenarios are typically generated by starting the climate model in pre-industrial times (typically 1850), with a generalized initial state, and driving it to the present day with observed greenhouse gas concentrations. The model is then run into the future (typically until 2100), with certain assumptions about how the concentrations of greenhouse gases will change in the future. This change is linked to six major so-called emission scenarios, which in turn are based on different assumptions regarding the speed and scale of different aspects of global development (socio-economic, demographic, technological, ecological, etc.).

A number of global models (around 10–20) are being developed at the main international meteorological/climatological institutes. While all models are based on the same fundamental physical relations, there are differences in the precise description of the many climatic processes and relationships that must be included. This means that the models give different results, even for the same emission scenario. If one also takes into account the results of different emission scenarios there is a large spread in the results, which increases the further into the future we look. At the end of this century, the increase in global average temperatures in the results vary between about 1°C and 5ºC, compared to today’s temperature. (By comparison, the observed warming over the past century is about 0.8ºC).

2.2.2 Scientific theoretical aspects

Hydrological impact studies are basically highly applied research that is not explicitly aimed at increasing the understanding of natural processes. Well-established models are used to generate results that make it possible for society to prepare for future hydrologic conditions. But there are also elements that touch upon basic research. As mentioned in previous chapters, climate model results must be adjusted before being applied in the hydrological model. This adjustment is based on a detailed analysis and quantification of the systematic errors in the climate model's temperature and precipitation. These errors are fed back to the climate modellers who in turn interpret them in terms of process descriptions and deficiencies in these. The deviations form the basis for new hypotheses about how the physical processes work and can best be described. The exact mechanisms of the formation of clouds and precipitation, for example, are not completely known and they are difficult to study empirically in full scale. To compare the model results with observations, based on progressively refined hypotheses about the mechanisms, is therefore a useful and widespread hypothetical-deductive method in this context (Thurén, 2007).

2.2.3 The hydrological concept

Hydrological science is a clear example of empirically-based logical positivism (Hacking, 1983). Hydrology is basically about how water flows through the natural land and this process cannot be observed in detail (at least not with today's measuring instruments). You can pour water on the ground, then dig a cut surface and see how far the water moved and what routes it took. But this provides only a snapshot. You can bring your soil back to the lab, put it in a Plexiglas cylinder, pour on water and see what happens. But these are not natural conditions. These empirical difficulties, combined with the inherent and equally hard-to-observe irregularities of natural soil (stratification, rocks, roots, holes from worms and moles, treasure chests, etc.), mean that we cannot accurately describe the pathways of water in natural soil on the small scale.

To make the process manageable, we broaden the perspective to a larger scale, the catchment scale. This is inherently a defined system that follows certain physical laws, especially that of mass balance. The basic empirical material consists of observations of both the water coming into the system, rainfall (and possibly inflow from the upstream catchment area, but we ignore that here) and the water disappearing from the system, i.e. the discharge in the outlet and evaporation from the catchment area. Now we can through a chain of hypotheses use these data to obtain an understanding of the total water flow through the soil in the catchment.

2.2.4 The hydrological model

A hydrological model calibrated for the current climate conditions also works in a future climate.

That the hydrological concept itself would not apply in the future seems unlikely. However, there are uncertainties regarding the validity of the related process descriptions. One example is evaporation, which is central to describing water balances over time. In one type of description, they increased more than proportionally with temperature. This description works well for today’s conditions, but when applied to future climate scenarios the effect was that large lakes in a relatively short period of time evaporated away, which is unrealistic. Figure 2.5 is an hydrological model.

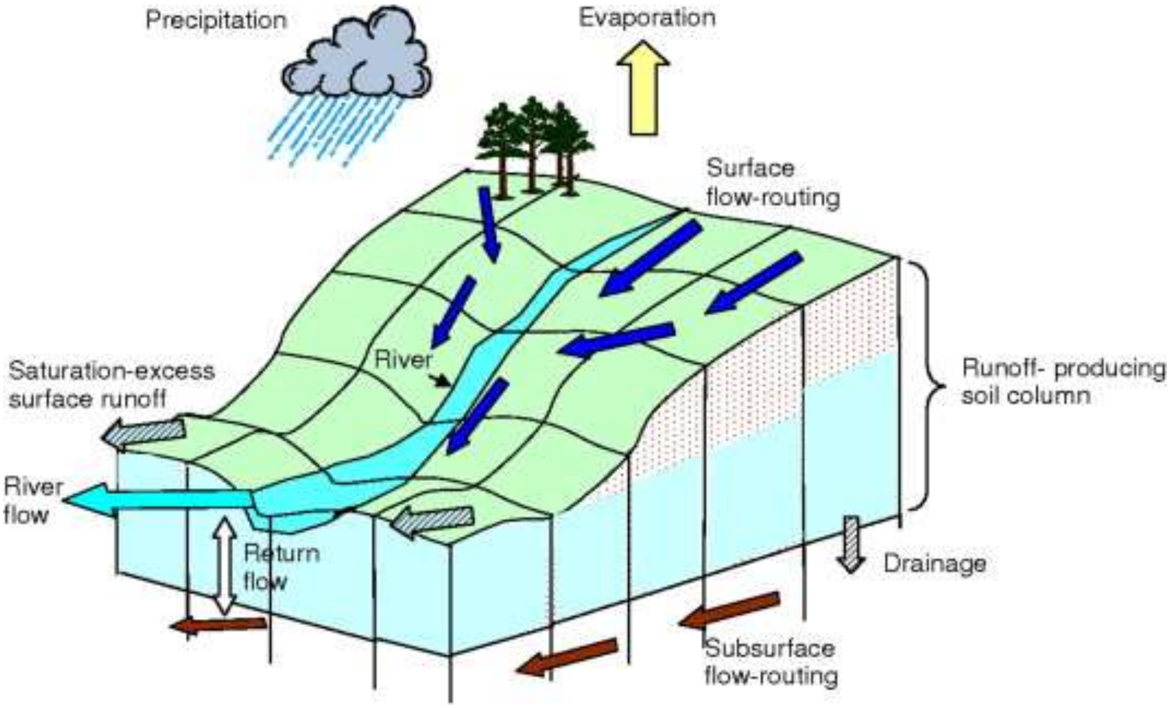


Figure 2.5: Hydrological Model
Source: Modified from Thurén, 2007

2.2.5 The future change

Climate change is the most significant future change for hydrological processes. Besides the climate, hydrological processes depend on catchment characteristics. In rural areas, changes in these characteristics are generally unlikely to have a substantial impact. It is mostly about local shifts between different types of agricultural land, limited felling of trees, etc., which rarely affect the hydrological processes in a dramatic way. Noticeable effects would require large-scale and systematic changes in the countryside, such as extensive deforestation or shifts from cultivation of traditional crops to new types (for example energy crops). In urban areas, however, it may well be assumed that changes in the urban environment have a stronger impact than the climate change. This is due to the large hydrological difference between natural soil (slow infiltration) and impervious surface (rapid runoff) and the resulting differences in flow dynamics. For urban or peri-urban areas becoming condensed or further exploited, the changes in land use are likely to impact the hydrology more than climate change. The opposite could also happen, with less dense cities with more green space.

Another aspect concerns the regulation of rivers, for hydropower production or general levelling. Regulation has a strong impact on the hydrology, and future changes can for various reasons be significant. Perhaps many more rivers than today will to be regulated, or perhaps a perfect energy source will be invented so that we no longer need to produce hydropower.

2.2.6 Global impact of climate change on the hydrologic cycle

2.2.6.1 Impact on rainfall

Sohoulande *et al.,* (2016) reported that increasing heat is the primary physical expression of climate change on the terrestrial system. Numerous studies agreed that increased atmospheric moisture is a consequence of more oceanic evaporation due to the increase of sea surface temperature. Nevertheless, the effect of a change in climate on rainfall is experienced in different ways worldwide. Modification in the term of frequencies of rainfall events, prolonged dryness, decreases in the number of rainfall events, and an increase of extreme rainfall events. At the annual level, profound diversions of season onsets and demises experienced (Sohoulande *et al.,* 2016). The impacts of these disturbances (i.e., drifts in season onset and demise, alteration of precipitation patterns) are significant for the society. For instance, the change in rainfall pattern often causes an important agricultural loss regarding yield. Also, the persistence of low rainfall jeopardises the sustainability of groundwater resources, since it often utilised as an option to overcome the deficit of water supply (Sohoulande *et al.,* 2016). However, this option of using groundwater has resulted in depletion issues. Subsequently, more policies are aiming to regulate the pressure on groundwater across the globe (Sohoulande *et al.,* 2016).

2.2.6.2 Impact of groundwater

Water quality, quantity, and functionality are the parameters used to assess the impact on groundwater system (Sohoulande *et al.,* 2016). Naturally, streamflow sustained by groundwater, and it plays a critical role in hydrology. During the dry season, groundwater is the major water supplier of streamflow and river. Apart from raining season, the balance of the streamflow/river and base-flow controls the streamflow behaviour (Sohoulande *et al.,* 2016). An unbalanced situation often results in low-flow regime and impairments. Besides, groundwater recharge is controlled itself by soil infiltration, land-cover, and amount of rainfall. Under climate change, the disturbances in the rainfall regime coupled with land-cover degradation significantly change groundwater recharge (Sohoulande *et al.,* 2016). Water supply becomes problematic for streams if groundwater could not recharge adequately, and this scenario is more drastic when groundwater directly pumped for irrigation, domestic and industrial use. The use of groundwater has become an option for compensating for water deficit. However, this alternative raises important environmental and social concerns.

2.2.6.3 Impact of evapotranspiration

Evaporation and transpiration are the important part of the water cycle. It depends on the magnitude of the terrestrial biophysical functionality (Sohoulande *et al.,* 2016). The amount of water involved in this phenomenon is a determinant of the local climate. Indeed, the long-term balance between evapotranspiration and rainfall controls the gradient of aridity and land-cover features (Sohoulande *et al.,* 2015). The rise of global temperature affects the atmospheric water demand under climate change directly. Finally, the actual moisture release in the atmosphere is higher than normal. The water vapour in the atmosphere results from the pressure exerted on soil moisture, water bodies, and plant transpiration. Sohoulande *et al.*, (2016) reported that the trend of dryness is remarkable across the globe.

2.2.7 Global temporal and spatial variations in water Storage

Guntner *et al*. (2007) reported that water storage acts important function in the water Earth's, energy, and biogeochemical cycles. Water storage appends evaporative demand of plants. It serves for human consumption, including various types of agricultural and industrial use (Guntner *et al*., 2007). Water storage includes water on groundwater, vegetation surfaces, unsaturated soil or rock zone, surface water in rivers, wetlands, natural lakes, and human-made reservoirs. It estimated as the sum of soil moisture, groundwater, and surface water storage. Temporal storage variations were analysed at monthly, seasonal, and interannual timescales (Guntner *et al.,* 2007). An Empirical Orthogonal Function (EOF) is normally used to analyse the spatial variation in water storage. This multivariate technique is employed to identify the dominant simultaneous patterns of space-time variability (Guntner *et al*., 2007). A spectral analysis of the amplitude (principal component) of the EOFs was carried out to derive the preferred frequencies of storage variations (Guntner *et al*., 2007). Furthermore, the spatial continuity of water storage patterns depicted and spatial autocorrelograms estimated on a monthly basis. The gap in this work is that the temporal and spatial variations of water storage are presently not known with sufficient accuracy for large areas.

2.2.8 Temporal and spatial variations of river discharge

Warwade *et al*. (2018) reported that the uneven distribution of rainfall leads to counterpart between water availability and demand so as irrigation structures be needed to redistribute water in line with the requirements of a specific region. The incidence of extreme rainfall events is relevant for the design of dams, spillways, flood protection structures, and drainage networks. The intensity of spatial, interseasonal, and inter-annual variability of rainfall events have heightened risen in Asia over the past few decades (IPCC, 2014). Global, a rise in temperature of about 0.74℃ between 1906 and 2005 led to more considerable rainfall variability (Warwade *et al*., 2018). This phenomenon has a negative impact on crop water requirements, evapotranspiration, groundwater level depletion, environmental flows, trans-boundary issues, and interstate disputes, among others. Numerous works show that rainfall variability is increasing on both a spatial and a temporal basis. Various studies showed that the trend of India is strongly affected by atmospheric factors viz. regional pressure anomalies, sea surface temperature variations (Goswami *et al.* 2006), thereby making rainfall less predictable (Shiklomanov, 2007). Mann–Kendall (MK) test, Sen's slope estimator, percentage change and breakpoint analysis are the methods for determination of the spatial and temporal variation of river discharge. Furthermore, identification of the downstream discharge trend is still a challenge for a large basin with sizeable spatial variation across the catchment, and a human factor which is affecting the hydrological cycle of the watershed.

2.2.9 Spatial and temporal variability of rainfall

Globally, climate change is inducing severe issues. The difference in rainfall associated with runoff changes. This process has a negative impact on ecosystems and socioeconomic development (Shen and Qiang, 2014). There is an incessant natural disaster in Weihe basin. Hence, assessment of the spatial and temporal variation in rainfall in the pool is crucial for understanding changes in runoff, and a negative impact on the socioeconomic and ecological aspect of the region for developing robust, cost-effective strategies to adapt and mitigate the effects of climate change on hydrological variables (Shen and Qiang, 2014).

Rainfall is one of the prominent variables for qualifying water resources and understanding the climatic change impacts on the local hydrologic system in Haihe River

Basin (HRB) of China (Luo *et al.*, 2014). Inadequate knowledge of the variations of rainfall on time and space, systematical management of the reservoirs is not available, resulting in inefficient utilisation of water resources in the basin (Luo *et al.*, 2014). Therefore, the negative impact of the change in climate on the hydrologic cycle and water resources associated with considerable uncertainty (Luo *et al*., 2014).

The variability of the climatic variable is useful for identifying changes in variability patterns of the environment over time (Javari, 2016). Locally, in the recent periods, rainfall spatial-seasonal variability, temporal trends' variability, and extreme consequences have caused massive damages to the environment (Javari, 2016). Therefore, numerous studies placed special emphasis on rainfall spatial-seasonal variability, temporal trends variability, and their impact on the environment. Globally, numerous analyses have examined spatial-seasonal variability and temporal trends' variability at various temporal periods. The spatial and seasonal variability analysis method concentrated not only on estimating climatic variations but also demonstrating variations in a series of rainfall and other climatic elements (Javari, 2016). According to Cristiano (2017), inadequate information on spatial distribution of rain is a source of error in urban runoff estimation. Understanding of hydrological processes in urban areas is still poor especially in the interaction between rainfall and runoff (Cristiano, 2017). Rainfall event is classified and identified by looking at their variability in space and time. Spatial variability is defined as variability derived in multiple spatially distributed rainfall fields for a given point in time (Peleg *et al*., 2017). Peleg *et al*. (2017) also introduced the definition of climatologically variability as the variability obtained from multiple climate trajectories that produce different storm distributions and rainfall intensities in time.

2.2.10 Impact of climate change on water resources in Nigerian perspective

Climate change is the variability in climate even if average weather conditions remain unchanged (Odjugo, 2010). Natural and artificial events cause changes in the environment. The primary physical factors that enhance climate change include volcanic eruptions and changes in the intensity of sunlight reaching the earth are the main factors of natural phenomena of climate (Odjugo, 2010). Figure 2.6 shows the detail causes of climate change.

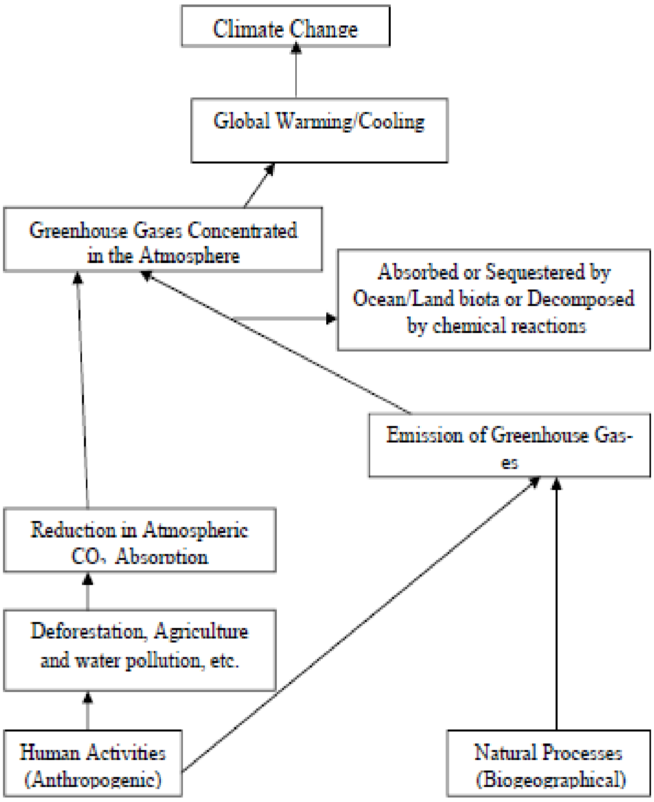


Figure 2.6: Causes of climate change
Source: Modified from Odjugo, 2010

Nan *et al*. (2011) reported the relationship between water resources and the hydrologic cycle and linked to a change in climate. Water quantity variations is an indicator that change in environments such as rainfall and temperature variations affects water resources, and achieved by the differences in hydrological cycle links (Nan *et al*., 2011). Globally, change in climate will cause the hydrologic cycle to redistribute water resources in time and space (i.e., spatial and temporal variations). This variations in water resources have a direct impact on the evaporation, runoff, soil humidity, etc. (Nan *et al*., 2011). Change in water resources and redistribution causes society and ecology to alter as well, and the water resources system variations will turn to affect the local climate (Nan *et al.*, 2011). The relationship between climate change and the hydrological cycle as shown in Figure 2.7.

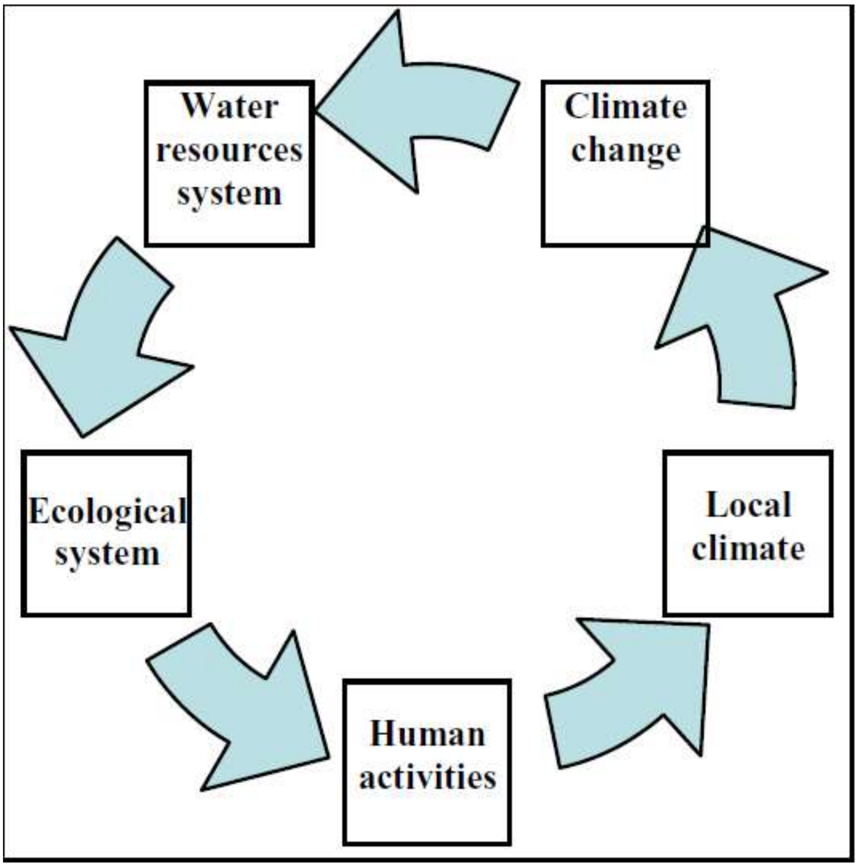


Figure 2.7: Relationship between climate change and water resources
Source: Modified from Ifeanyi, 2011

In Nigeria, rainfall becomes more intense in the past 50 years and are projected to grow more frequent and severe (Ifeanyi, 2011). Alteration in climate is expected to cause significant changes in yearly and seasonal rainfall and water flow, flooding (Ifeanyi, 2011).

2.2.11 Historical perspective of global climate variability

The high-accuracy measurements of atmospheric CO_2 concentration, initiated by Keeling in 1958, constitute the master time series documentation of the changing composition of the atmosphere (Le Treut, *et al,* 2007). These data have iconic status in climate change science as evidence of the effect of human activities on the chemical composition of the global atmosphere Keeling's measurements on Mauna Loa in Hawaii provided a true measure of the global carbon cycle, an effectively continuous record of the burning of fossil fuel. They also maintain an accuracy and precision that allowed scientists to separate fossil fuel emissions from those due to the natural annual cycle of the biosphere, demonstrating a long-term change in the seasonal exchange of CO_2 between the atmosphere, biosphere and ocean. Later observations of parallel trends in the atmospheric abundances of the CO_2 isotope and molecular oxygen (O_2) *(*Le Treut *et al, 2007)* uniquely identified this rise in CO_2 with fossil fuel burning

2.2.12 Spatial and temporal variations for dam hydrological variables

Temporal variation refers to a change of hydrological variables such as rainfall, reservoir inflow, reservoir elevation, turbine discharge with time. A spatial variation occurs when a quantity of hydrological variables such as rainfall, reservoir inflow, reservoir elevation, turbine discharge that measured at different spatial locations exhibits values that differ across the areas. Spatial variability can be assessed using descriptive spatial statistics such as the range.

Sakka (2011) reported that rainfall in the semi-arid and arid watershed qualified by a great unevenness of the small amount received in space and time. Approximately 80 per cent of the annual rain collected during raining seasons for 3 to 6 months, and each rainfall event occurs with high intensity and short duration storms. Sakka (2011) reported that the particular features of the semiarid and arid hydrological processes include the marked seasonal variation in semiarid climates may require segregation of data by season. A combination of hydrological factors common in one season of the year may be virtually non-existent during another season. Besides, the particular combination of factors may exist for only a few days in several years and may render hydrological computation based on average values grossly erroneous. Actual evaporation from semi-arid zones is a highly transient phenomenon with extreme variation within a day because of the available water but not over a season. The temporary nature of evaporation also controlled by the rapid growth of vegetation to climax followed by rapid die-off (Sakka, 2011). In a humid climate, hydrological processes in the semiarid and arid region often vary significantly over different parts of a catchment (Sakka, 2011). Besides, the sparse vegetation cover and its sharp response to the first rain have an impact on the evaporation process prevailing in such regions. The rivers in such areas are generally characterised by having long periods of low flow regime (Sakka, 2011).

Another distinct characteristic of such regions is that in some cases infiltration could be minimal because of outcropped rocks on the slopes while it could be high in areas with fractured bedrock channels (Sakka, 2011). There could also be the possibility of channel infiltration from the bed of the rivers supplying the groundwater in the river downstream (Sami, 1992). This fact implies that especially during low flow regime the stream flow that originates from upstream will be depleted by the channel bed before it reaches the outlet (Sakka, 2011).

2.2.13 Impact of climate change on dam system in Nigeria

Climate change is the variability in climate even if average weather conditions remain unchanged (Odjugo, 2010). Natural and artificial events cause changes in the environment. The primary physical factors that enhance climate change include volcanic eruptions and changes in the intensity of sunlight reaching the earth are the main factors of natural phenomena of climate (Odjugo, 2010).

2.3 Empirical studies of Spatial and Temporal Variability for Rainfall and Temperature in Nigeria

Abaje *et al*. (2018) examined the spatiotemporal Analysis of rainfall distribution in Kaduna State linear trend line equation, second order polynomial, Cramer's test, and student's t-test. Abaje *et al*. (2018) reported that the result of the student's t-test for the two nonoverlapping sub-periods (1961-1990 and 1991-2016) of each station showed that Kafanchan and Zaria were significantly wetter in the last 26 years (1991–2016) while Kaduna had a healthy condition. Ifabiyi and Ashaolu (2015) assessed the spatiotemporal pattern of rainfall distribution over Ilorin Metropolis, Nigeria trend analysis using reduction analysis, and ordinary kriging with Gaussian semivariogram model; their results show that the variability and percentage change in the amount of rainfall over thirty (30) years. Besides, a spatial distribution of annual rainfall in Ilorin varied from one part to the other.

Ezemonye and Emeribe (2015) assess the spatial and temporal patterns of climatic change in the Sokoto-Rima River Basin, Sudano-Sahel region, Nigeria using Mann-Kendel, Spearman's Rho, Linear regression, free distribution CUSUM, cumulative deviation and Worsley Likelihood tests. Their results show a decreasing trend in the time series of annual rainfall, while evidence of a rising trend detected in the time series of temperature.

Egor *et al.* (2015) examined the inter-annual variability of Rainfall in some States of Southern Nigeria using Standardized Anomaly Index, and the results showed that the variability in rainfall as Calabar, Port Harcourt, Owerri, and Enugu have 4062.70mm, 3911.70mm 3064.0mm and 2262.4mm. Besides, their least rain for these areas was 2099.4mm, 1816.4mm, 1228.4mm, and 913.10mm. Oguntunde *et al.* (2012) assessed spatial and temporal temperature trends in Nigeria, between 1901 and 2000 using Mann-Kendall test and spectral analysis, and their results showed that Annual temperature has risen by 0.03 ^{o}C/decade during the last century. Besides, alterations in minimum temperature are higher than that of maximum temperature. Their findings showed that yearly temperature showed significant negative correlation Southern Oscillation Index.

Akinsanola and Ogunjobi (2014) assessed rainfall and temperature variability over Nigeria using confidence levels, coefficients of kurtosis, skewness, and coefficient of variations, and their results showed that the longtime trends suggest a sequence of alternately decreasing and increasing trends in mean annual rainfall and air temperature in Nigeria.

Salami *et al;* (2011), worked on the assessment of climate variability on Kainji hydropower reservoir, Niger State Nigeria, they obtained the following rainfall data (2000-2009) reservoir inflow (1970-2003) and temperature data (1972-2009) from Kainji hydropower station. This study aimed to detect trends in the long-term hydro-climatic series using non-parametric methods. The annual and seasonal linear trends of rainfall, temperature, runoff, water level and evaporation were analyzed for stations in downstream Kaduna River Basin during 1975-2014. The non-parametric Mann-Kendall and Sen’s estimator of slope procedures were adopted to identify if there exists an increasing or decreasing trend with their statistical significance at 95% level of confidence. The datasets were checked to account for auto-correlation prior to determining trends using Mann-Kendall test. The existence of abrupt changes was detected by means of Cumulative Sum Charts and Bootstrapping analysis. The results of study indicated increasing trends for seasonal and annual temperature and runoff series. Water level and evaporation revealed statistically decreasing trends both on annual and seasonal periods. However, for the period 1975 to 2014 no significant distinctive trend was observed for rainfall at the investigated stations. Change-points in time series were identified in all the investigated hydro-climatic records for the sub-basin. Generally, the detection of the trend for hydro-climatic variables by Mann-Kendall test conforms to Sen's test results. It is concluded that the basin is sensitive to climate variability and water stress impacts which will affect food security. So, it would be necessary to make adjustments in the adaptive water-use strategies being adopted at present in the catchment.

Salami *et al.* (2010) worked on impacts of climate change on the water resources of Jebba hydropower reservoir. The meteorological and hydrological variables under study were subjected to statistical test. The study showed some notable changes in the climate of Jebba hydropower station, it reveals that for the past few years, rainfall and relative humidity have exhibited negative trends. This implies that both variables will decrease slightly, while for the past few years, the reservoir inflow, outflow and temperature have shown significant positive trends. This indicates that the parameters have tendency to increase and rate of their changes are significantly positive. The evaporation loss also shows negative trends and may be due to low relative humidity. The study concluded that there is positive impact of climate change on water resources of the study area due to increase in reservoir inflow and low evaporation, hence more water for hydropower generation.

Jimoh (2008) examined the operation of hydropower systems in Nigeria and observed that the combined installed capacity of power stations in Nigeria is far below the country's electricity demand, resulting in epileptic supply of electricity. He noted that the situation is compounded by the failure of the existing power stations to operate at installed capacity and attributed the inability of the hydropower stations to operate at installed capacity to the following reasons.

(a) Hydrological factors, such as seasonal deviation inflow to the reservoir, inter-annual deviation inflow to the reservoir with low and high extremes, conflict among competitive uses, and sediment trapped in the reservoir

(b) Non-hydrological factors, such as maintenance and spare part problems, inadequate fund, human resources, and policy issues. The findings also revealed that the low and high extremes inter-annual deviation inflow to Kainji reservoir is caused by two distinct peaks at Kainji on River Niger. These are called black (December or January) and white (August or September) floods.

Daniel (2013) Climate Variability Impacts on Water Resources of the Area Kaduna was investigated in this report using 47years (1960-2006) record of hydro-meteorological data. The Climate variability was evaluated using a simple approach which considered variability as the difference between the means and standard deviations of climatic elements of two equal –length time periods. Other methods used include coefficient of deviation, time series methods and anomaly approach. The impacts of climate variability on water resources of the study area were investigated using comparative and correlation analyses. From the results, the hottest year within the zone was 1993 with day time temperature increase of15.3℃and a zonal average of 0.08℃, indicating warming while within the catchment, the highest increase in maximum temperature was 2.6℃.The historical observations of temperatures, rainfall land evaporation in the study area indicated annual maximum temperature trend of0.12℃, annual minimum temperature trend of 0.88℃,annual mean temperature trend of 0.48℃, annual rainfall trend of 100mm and annual evaporation trend of 99mmwhich are all statistically significant except for the annual maximum temperature.

Jimoh and Ayodeji (2003) assessed the impact of the Gurara river inter basin water transfer scheme on the Kaduna River at the Shiroro dam, Niger state, Nigeria. The inter-basin water transfer 48 is intended to stabilize the Shiroro reservoir level. The paper examined the effect of the water transfer on the storage level of the reservoir, using fourteen years of daily inflow record to study the real time operation of the reservoir. The results indicated that with the water transfer, the reservoir attains its maximum operating level in July and maintains it until September or October, whereas the maximum operating level would have been attained in August without the transfer. Although the inter basin water transfer into the Shiroro reservoir would enhance power generation. But it will lead to increase flood frequency severity annually downstream of the dam. So, appropriate flood damage mitigation measures were recommended for the Kaduna River basin to optimize the benefit of the proposed interbasin water transfer scheme.

Garbrecht and Schneider (2008) worked on the impacts of decadal precipitation deviations on reservoir inflow, flood releases, and pool elevation in Fortcobb reservoir, at Central Oklahoma, using three dry periods and one wet period with the use of 1940-2004 precipitation record. The study reveals that the differences in mean annual precipitation between dry and wet periods was 33% of the mean, and led to a corresponding 100% change in mean reservoir inflow, 170% change in mean annual flood releases from the reservoir, and a maximum pool elevation drop of 2 meter from the top of the conservation pool. Thus, watershed runoff, reservoir inflow and flood releases were highly sensitive to decadal precipitation deviations. Yet, the only reservoir operation that appeared to be impacted by decadal precipitation deviations was the frequency of flood release activities. So it was observed that high reservoir inflows during wet periods led to an increase in flood releases. Also the increase in frequency of downstream flow was not believed to appreciably enhance stream habitat and riparian vegetation, due to the sporadic and intermittent nature of flood releases.

Keming and Bagale (2012) carried out a study on dam slope stability under the condition of rainfall. The study investigated the static and dynamic simulation analysis of the cracks using the strength reduction principle, to get the stress, strain and displacement distribution rule and the corresponding safety factor in the water level change and rainfall infiltration. It was observed that rainfall has a great influence on the slope stability of the dam. The rainfall impact causes change of the seepage and the stress field, influencing the stress and strain distribution of the dam, which will eventually change the situation of the dam skeleton and finally causing instability in the dam. The study shows that safety factor decreases along with rainfall duration increasing in the different return periods of rainfall. When the slope is reduced, slope safety factors reduce slowly in the range of allowable value.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study carry out a comparative analysis of spatial temporal variations in hydrological parameters at Kainji and Shiroro Dams in Niger State. It examine the spatial-temporal characteristics of the dams, compare the spatial-temporal characteristics of the Dams; examine the spatial variations of rainfall, reservoir inflow, reservoir elevation, evaporation and turbine discharge in Shiroro and Kainji dams and compare the spatial variations on discharge as a function of human activities, climate change and land use patterns in the upstream areas of the selected dams

3.1 Type of Data Used

Three sets of data used in this study; namely: Climate, Hydrological and Remote sensing data sets. The climate data include annual rainfall and evaporation record of 30 years (1987-2017), hydrological record includes reservoir inflow, reservoir outflow reservoir elevation, and turbine discharge for 30 years (1987-2017) was collected from NIMET stations in Kainji and Shiroro dams. Landsat satellite imagery of the study areas (Kainji and Shiroro) was acquire from Ground Cover Land Facility (GFLF) for three decades (1987-2017). The imagery was use to examine the spatial-temporal characteristics of the landuse pattern in the study areas.

3.2 Methods of Data Analysis

3.2.1 Spatial-temporal characteristics of the dams

It involve the use of satellite imagery of the study area to analysis the spatial-temporal characteristics of the dam areas in terms of landuse surrounding Kainji and Shiroro the dam site. Landsat imagery of three decade (1987, 2007 and 2017) was used, the imagery was subjected to digital image processing, which basically involve classification of landuse surrounding the study area. Field reconnaissance survey and physical observations during the pre-satellite image analysis and use of GPS to capture geographical coordinates each community and coordinates for training site for accuracy assessment. In order to obtain the required information from satellite image data, processing and interpretation were made systematically. The interpretation phase preceded by establishing preliminary legend.

Basic for any landuse mapping is an appropriate classification scheme. This is required to organize the needed information in such a way that it would satisfy the research problem, objectives, type of resource data being sought and the physical nature of the terrain. When there is no prior land variance as the case of Nigeria, an appropriate one has to be developed. For the purpose of this study, a classification scheme suited to it will be developed. In this regard, a preliminary ground truth was carried out to serve as a guide. ArcGIS 10.1 was be used for image processing and classification and MS Excel was used for tables and graphical presentation of questionnaires analysis of the study.

3.2.2 Comparative analysis of the spatial-temporal characteristics of the dams

Image thinning was carried out through contract. Contract generalized an image by reducing the number of rows and columns while simultaneously decreasing the cell resolution. The methods of analysis adopted in this are: Calculation of the area in hectares of the resulting land use types for each study year was generated. Overlay operations. – i.e. mathematical and logical operation between two raster layers on a pixel-to-pixel basis to detect change that has occur in the area, the images was overlay to detect the direction and extent of changes in the area.

The comparison of the spatial temporal characteristics use statistics assist in identifying the percentage change, trend and rate of change was determine. Percentage change to determine the trend of change can then be calculated by dividing observed change by sum of changes multiplied by 100.

$$\text{(Trend) percentage change} = \frac{\text{observed change X 100}}{\text{Sum of change}} \tag{3.1}$$

3.2.1 Spatial variations of rainfall, reservoir inflow, reservoir elevation, evaporation and turbine discharge in Shiroro and Kainji dams

After establishing that these dams' hydrological parameters are not serially autocorrelated, the study explore Mann-Kendall test and Sen's slope test on the monthly coefficient of variation for rainfall, reservoir inflow, reservoir elevation, and turbine discharge. These tests was analysed in the Statistical software and data analysis add-on For Excel environment. The seasonal Mann-Kendall test takes proper account the seasonality of the time series which means that monthly data with seasonality of 12 months examine whether there is a trend in the overall series or not. The study explored Kendall tau statistic, τ, to test for randomness against the trend in hydroclimatic time series (Cigizoglu *et al.*, 2005). In this test, the null hypothesis Ho states that the deseasonalized data ($x_1 . . . x_n$) are a sample of n independent and identically distributed random variables (Zhao *et al.*, 2017). The alternative hypothesis H_1 of a two-sided test is that the distribution of x_k and x_j is not identical for all $k, j \leq n$ with $k \neq j$ (Zhao *et al.*, 2017). The test statistic (S) was calculated with equation 3.3 and 3.4, with mean zero and variance of S, computed by:

$$Var(S) = [n(n-1)(2n+5) - \textstyle\sum_t t\,(t-1)(2t+5)]/18 \qquad (3.2)$$

$$S = \textstyle\sum_{K=1}^{n-1} \sum_{j=k+1}^{n} Sgn(\,x_j - x_k) \qquad (3.3)$$

$$Sgn(x_j - x_k) = \begin{cases} +1 \quad if\ (x_j - x_k) > 0 \\ 0 \quad if\ (x_j - x_k) = 0 \\ -1\ \ if\ (x_j - x_k) = 0 \end{cases} \qquad (3.4)$$

and is asymptotically normal, where *t* is the extent of any given tie, and *t* denotes the summation over all relationship. For the cases in which *n* is more significant than 10, the standard variate Z computed by using the following equation (Cigizoglu *et al*., 2005):

$$Z = [\begin{cases} \frac{S-1}{\sqrt{Var(S)}} \\ \frac{S+1}{\sqrt{Var(S)}} \end{cases} \begin{cases} if\ \ S > 0 \\ if\ \ S = 0] \\ if\ \ S < 0 \end{cases} \qquad (3.5)$$

The test statistic Zs was used as a measure of the significance of the trend. In fact, this test statistic was also used to test the null hypothesis, $H0$: There is no monotonic trend in the data. If Zs is greater than $Z\propto$ 2, where represents the chosen significance level (usually 5%, with $Z_{0.025}$= 1.96), then the null hypothesis is invalid, meaning that the trend is significant. Besides, the calculated slope is multiplied by the number of years to indicate the magnitude of change over the period (Oguntunde *et al.,* 2012). The objective one will achieve through the use of Mann-Kendall test to assess the trend of the temporal variations of the monthly coefficient of variation for rainfall, evaporation, reservoir inflow, reservoir elevation, and turbine discharge. These non-parametric test was used to achieve objective two.

3.2.2 Comparative analysis of the spatial variations on discharge as a function of human activities

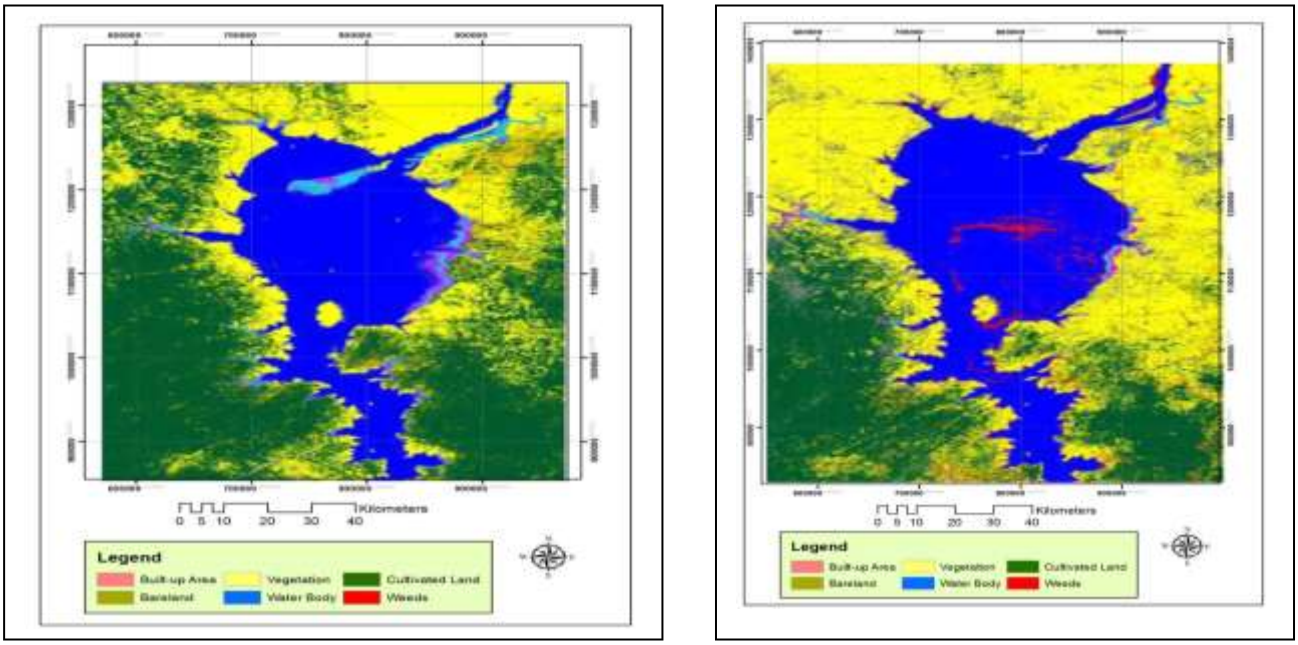
In order to achieve objective three, the monthly coefficient of variation (CV) for hydrological parameters between 1987 and 2017 at different locations was used for this study. Two-way analysis of variance with post-hoc comparison was used to compare spatial and temporal variations of the hydrological parameters of each dam. In spatial variations analysis, the variables were grouped as dependent variable (discharge) and independent variables such as monthly CV for rainfall, evaporation and locations with Shiroro dam as a control. In temporal variations analysis, the variables were grouped as dependent variable (discharge) and independent variables such as monthly CV for rainfall, evaporation and time (April to October) with months between 1980 and 2017 as control. The residual of the model was subjected to Durbin-Watson test (to determine whether the dataset is autocorrelated or not) and normality test. Also, these hydrological parameters was subjected to equality of variance (parametric test) and Kruskal-Wallis test (Non- parametric test). The outlier test was examined to check whether to reject null hypothesis or not.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

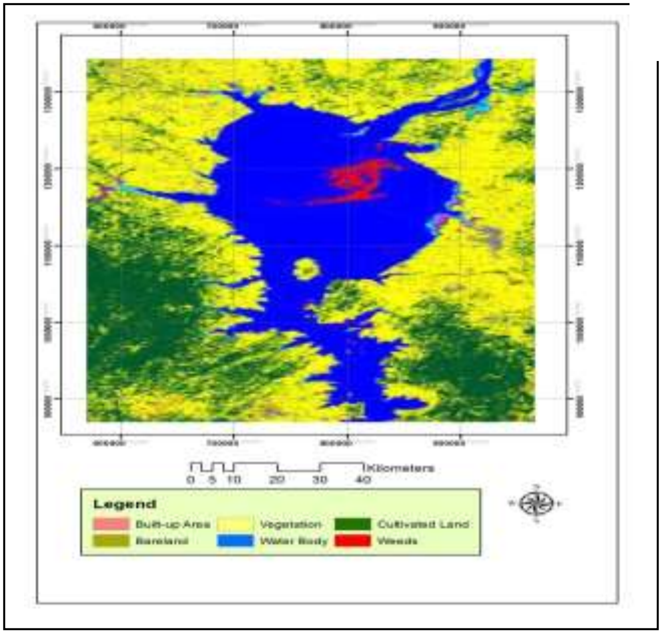
4.1 Spatial-temporal characteristics of Kainji and Shiroro Dams

The result of spatial temporal characteristics of Kainji dam is presented in Table 4.1, the spatial temporal analysis is between 1997, 2007 and 2017. Figure 4.1 shows the spatial analysis of landuses and their changes in the area within the study period. Six landcover classification were generated from the analysis, Buit up area, Vegetation, Cultivated land, Bareland, Water body and weeds. It shows that in 1997 water body cover 22.12% of the total landcover Vegetation covers 44.15%, Cultivated land covered 23.42%, Built up 9.62%, weeds 0.56% while bare land covered a total of 0.13%. it also reveal that in 2007, water body covered 23.38%, Vegetation covers 31.33%, cultivated land covered 33.21%, built up land also increase to 11.22%, weed covered 0.67% and bare land covered 0.19% and in 2017 water body has increase to 24.38%, vegetation had reduce to29.53%, cultivated land has also increase to 40.95%, built up also increase to 12.65%, weeds also increase to 0.26%.



Landuse 1997

Landuse 2007



Landuse 2017

Figure 4.1: Kainji Landuse Classification of 1997, 2007 and 2017

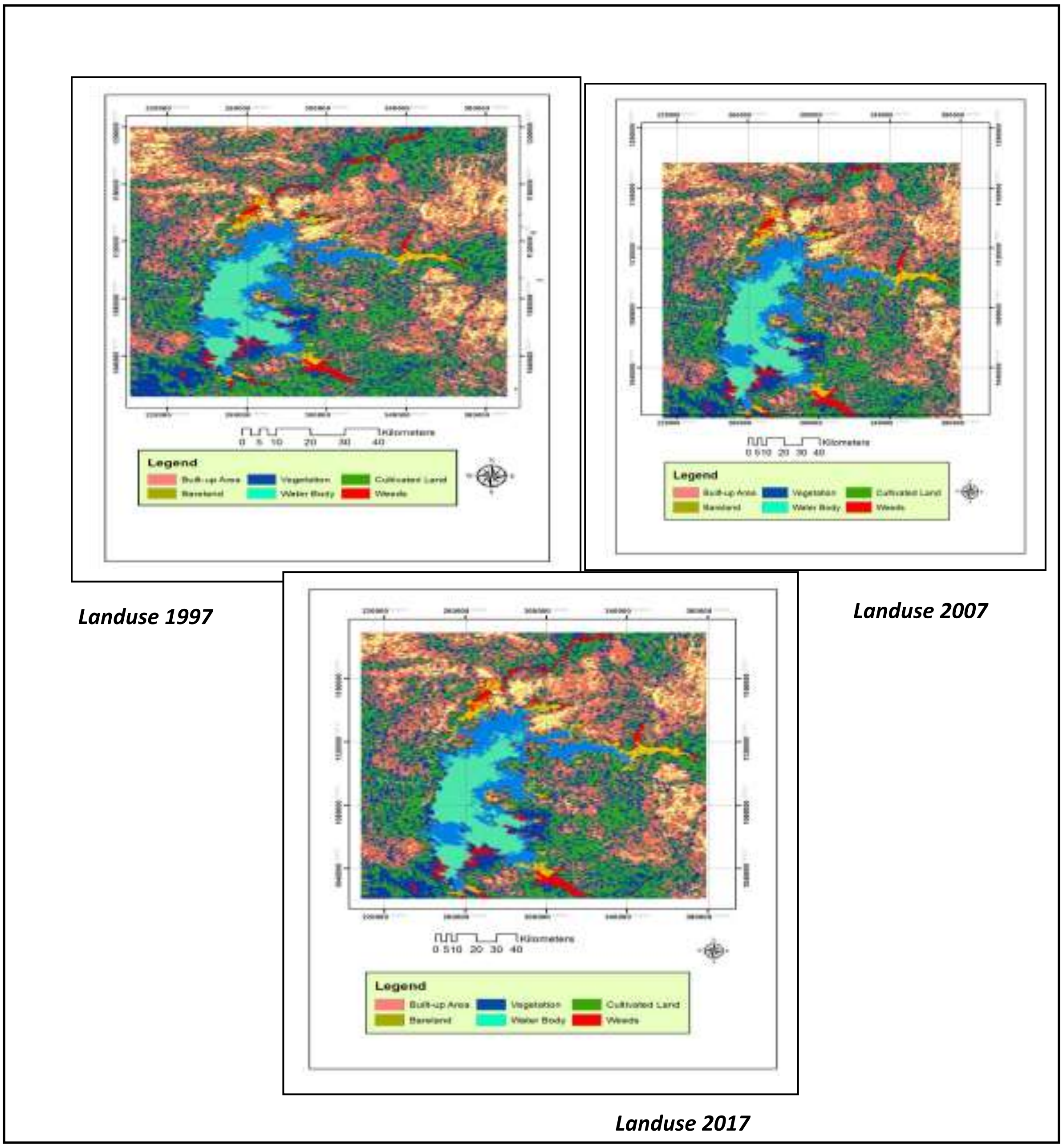
Table 4.1 shows three classified images of 1997, 2007 and 2017, respectively, it reveals that some parts of the area have not been subjected to changes (static) between 1997 and 2017. Table 4.2 shows the trend in terms of the area coverage and the percentage of each class of the area from 1997 to 2017. This means that some parts of the areas surrounding Kainji dam has been subjected to changes. This was also revealed in Figure 4.1 in 2007, settlement and human activities in around the dam were very little, Extensive agriculture/grazing land and intensive agriculture had the highest percentage changes of 41.78 and 35.45%, respectively, between 1997 and 2017, though, while extensive agriculture changes positively, intensive agriculture recorded negative changes. From 1997 through 2007 to 2017, extensive agriculture/grazing land reduced drastically which is a result of the policy of the Federal Government against grazing in the area.

Table 4.1: Summary of Kainji Landuse Classification 1997-2017

Land cover	1997 Area (Hectares)	Area (%)	2007 Area (Hectares)	Area (%)	2017 Area (Hectares)	Area (%)
Water Body	9.5	22.12	10. 10.	23.38	10.13	24.38
Vegetation	192.5	44.15	136.6	31.33	136.5	24.53
Cultivated Land	133.1	23.42	154.9	33.21	147.5	38.95
Built-up	99.9	9.62	140.7	11.22	135.5	12.06
Weeds	4.5	0.56	7.2	0.67	9.1	0.71
Bare land	1.6	0.13	2.1	0.19	2.3	0.26

Figure 4.2 shows the spatial temporal analysis of Shiroro dam and identify the changes in the area extent of the different land-use type involved evaluation of remotely sensed satellite imagery for the period of 1997, 2007 and 2017. It shows that Shiroro area covers a landmass of 72km^2. The built-up area in 1997 was low while vegetal cover was high because it has not been tempered with much. It also reveals that built-up area covered 9.7km^2 (13.4%), vegetated land covered 7.9km^2 (11%), cultivated covered 35.3km^2 (49%), bareland land covered 8.6km^2 (12%) and water body covered 10.5km^2 (14.6%) in

1997. The analysis that in 2007, Built-up area had increased from 9.7km^2 (13.4%) in 1995 to 28.5km^2 (39.6%) in 2007, vegetated land increased from 7.9km^2 (11%) in 1997 to 8.6km^2 (12%) in 2007, cultivated surface decreased from 35.3km^2 (49%) in 1997 to 23km^2 (32%) in 2007, bareland land decreased from 8.6km^2 (12%) in 1997 to 4.5km^2 (6.2%) in 2007 and water body decreased from 10.5km^2 (14.6%) in 1997 to 7.3km^2 (10.2%) in 2007.



Landuse 1997

Landuse 2007

Landuse 2017

Figure 4.2: Shiroro Landuse Classification of 1997, 2007 and 2017

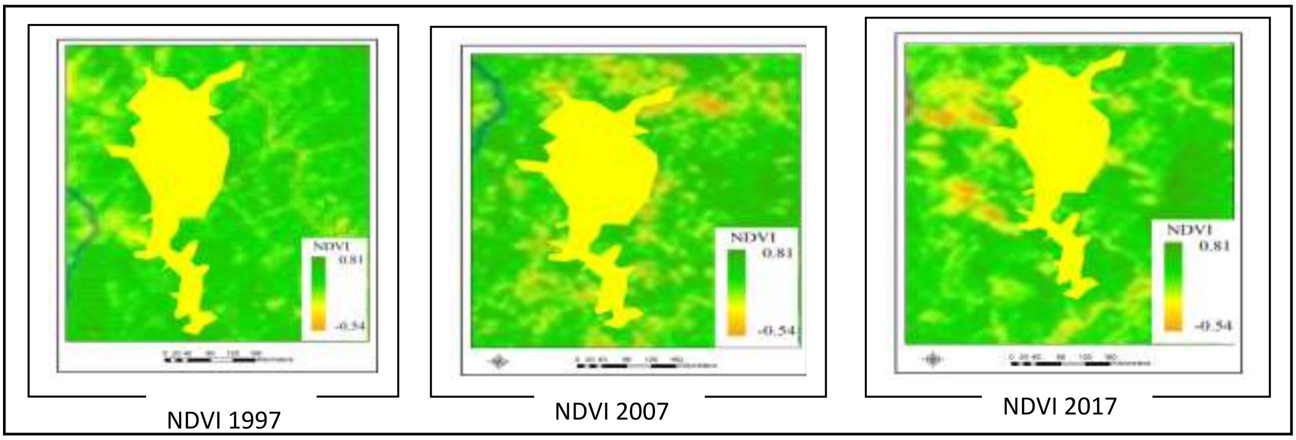
Table 4.2 Summary of Shiroro Landuse Classification 1997-2017

land cover	1996	2007	2017
Built-up area	9.7	28.5	38.9
Bare land	7.9	8.6	5.5
Vegetated land	35.3	23.0	10.6
Cultivated land	8.6	4.5	11.7
Water body	10.5	7.3	5.3
Weeds	3.7	4.1	4.5

From Table 4.2, built-up area changed from 9.7km^2 (13.4%) in 1997 to 28.5km^2 (39.6%) in 2007 and increased to 38.9km^2 (54%) in 2017; vegetated land changed from 7.9km^2 (11%) in 1997 to 8.6km^2 (12%) in 2007 and decreased to 5.5km^2 (7.7%) in 2017; vegetated changed from 35.3km^2 (49%) in 1997 to 23.0km^2 (32%) in 2007 and further decreased to 10.6km^2 (14.7%) in 2017; farm land changed from 8.6km^2 in 1995 to 4.5km^2 (6.2%) in 2007 and increased to 11.7km^2 (16.3%) in 2017 and water body reduced from 10.5km^2 (14.6%) to 7.3km^2 (10.2%) and further decreased to 5.3km^2 (7.3%) in 2017.

4.4 Comparative analysis of the Spatial-temporal characteristics of the dams

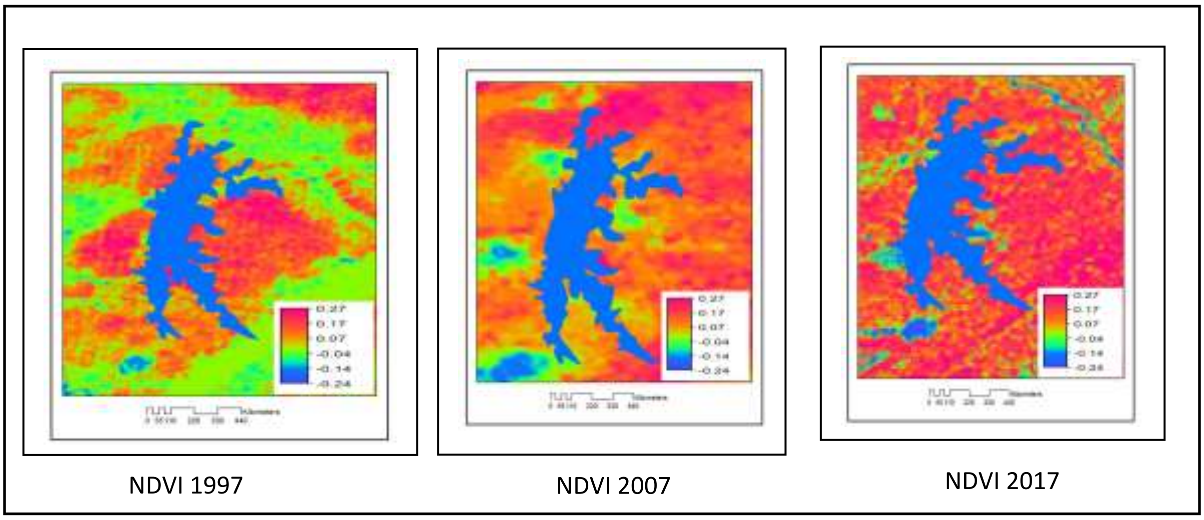
It is important to compare the extent of spatial temporal changes of Kainji and Shiroro dam so as to assess the areas in any desired unit and percentages for proper land-use planning. The image calculator of the Idrisi software was used to determine the extent of spatial temporal changes around Kainji and Shiroro dam. The image shows a typical growing season pattern covering the time-series representative the study area (Figure 4.3 and Figure 4.4).



NDVI 1997 NDVI 2007 NDVI 2017

Figure 4.3 Kainji NDVI analysis between 1997, 2007 and 2017

The NDVI shows variations on spatial temporal characteristics such as natural vegetation and agricultural land, the index ranges between 0.81 high and -0.54 low, it indicated that the southern part clearly shows a more intensive agricultural activity while the southern part show a low vegetation biomass based on the NDVI. It was revealed that in 2007 the spatial temporal characteristics has reduced compared to 1997 and this also has a negative effect on other landuse classes. In 2017 the spatial temporal characteristics as the coefficient of variation (COV) of the study area where more variation exists along the Dam.



NDVI 1997 NDVI 2007 NDVI 2017

Figure 4.4 Shiroro NDVI analysis between 1997, 2007 and 2017

Figure 4.4 shows a serious negative effect on the spatial temporal characteristics of Shiroro in 2017, a total area of 205.2558 km^2 representing 4.75% of the area has been captured by the reservoir between 1997 and 2017. This means that the area is actually expanding as has earlier been reported by Abiodun (2009) and Ikusemoran (2009a). The spatial temporal characteristics has also lost a total area of 943.2975 km2 (21.83%) between 1997 and 2017. Cultivated land is the degrading factor of the area as 1587.7759 km2 (36.75%) of the area have been lost to intensive agriculture between 1997 and 2017.

4.5 Spatial variations of rainfall, reservoir inflow, reservoir elevation, evaporation and turbine discharge in Kainji

4.3.1 Trend analysis of rainfall

The intra seasonal variation of rainfall over Kainji shows that rainfall generally begins in March / April, increase until the mount of November and decrease thereafter until cessation takes place completely in November. Figure 4.5 shows that about 50% of the annual rainfall total accumulates in three heaviest rainy months of July, August and September and lowest in the months of January, February and December. There is thus a marked dry and rainy seasons.

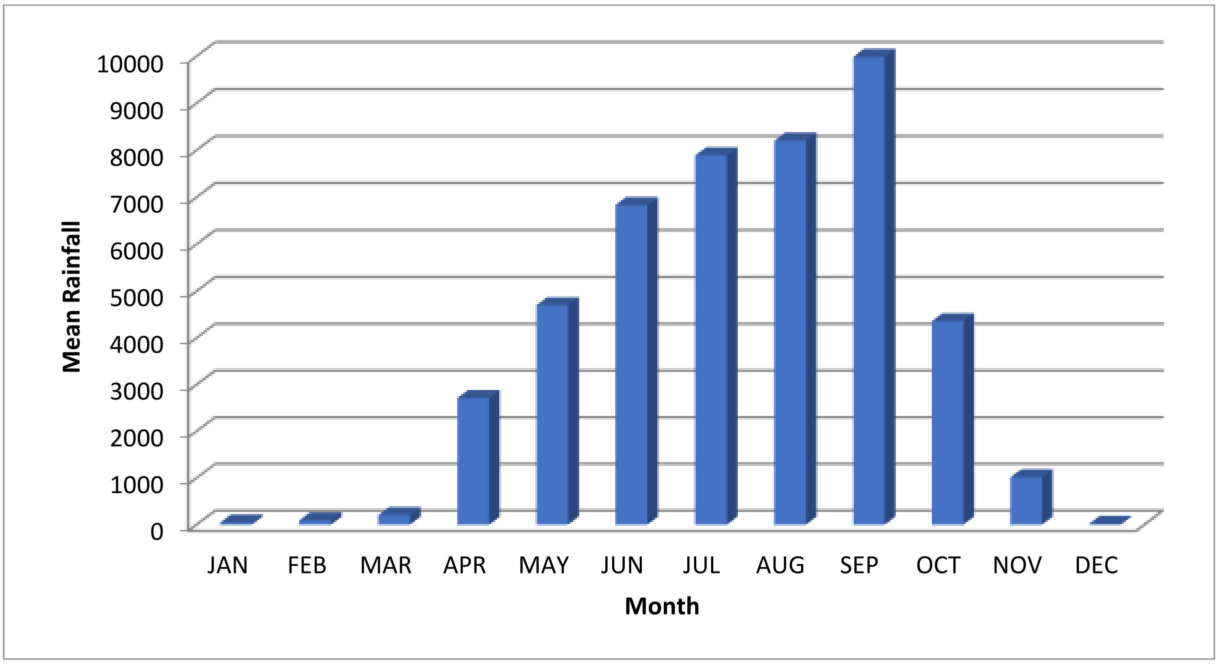


Figure 4.5: Mean Monthly Rainfall of Kainji

Figure 4.6 shows rainfall trend of Kainji between 1987 – 2017 was also analyzed; the deviation of mean annual values of rainfall over thirty (30) years was shown in Figure 4.6. The deviation of rainfall negative between 1987and 1988. Between 1989 and 1991, the deviations is positive over a period of five years. On decadal basis, the years 1991 and 1994 have the highest deviations while the remaining years have very low deviations. The rainfall deviations increased between 1998 and 1999. On decadal basis, the years 1998, 1999, 2004, and 2006 have positive rainfall deviations while the remaining years have negative and least rainfall deviations. Between the year 2008 and 2016, the rainfall deviations were positive in the year 2008, 2010 and 2011. However, the deviations were lowest in the year 2012 and 2014. The years 2009, 2013, 2015 and 2016 have a negative rainfall deviation within the area. This implies the rainfall between 1987 and 2017 have a slightly decreasing trend (graphically) in the study area. The result of the study conclude that as water is a main component for generating electricity in Kainji the slight decreasing trend in rainfall will have significant effect on energy generation.

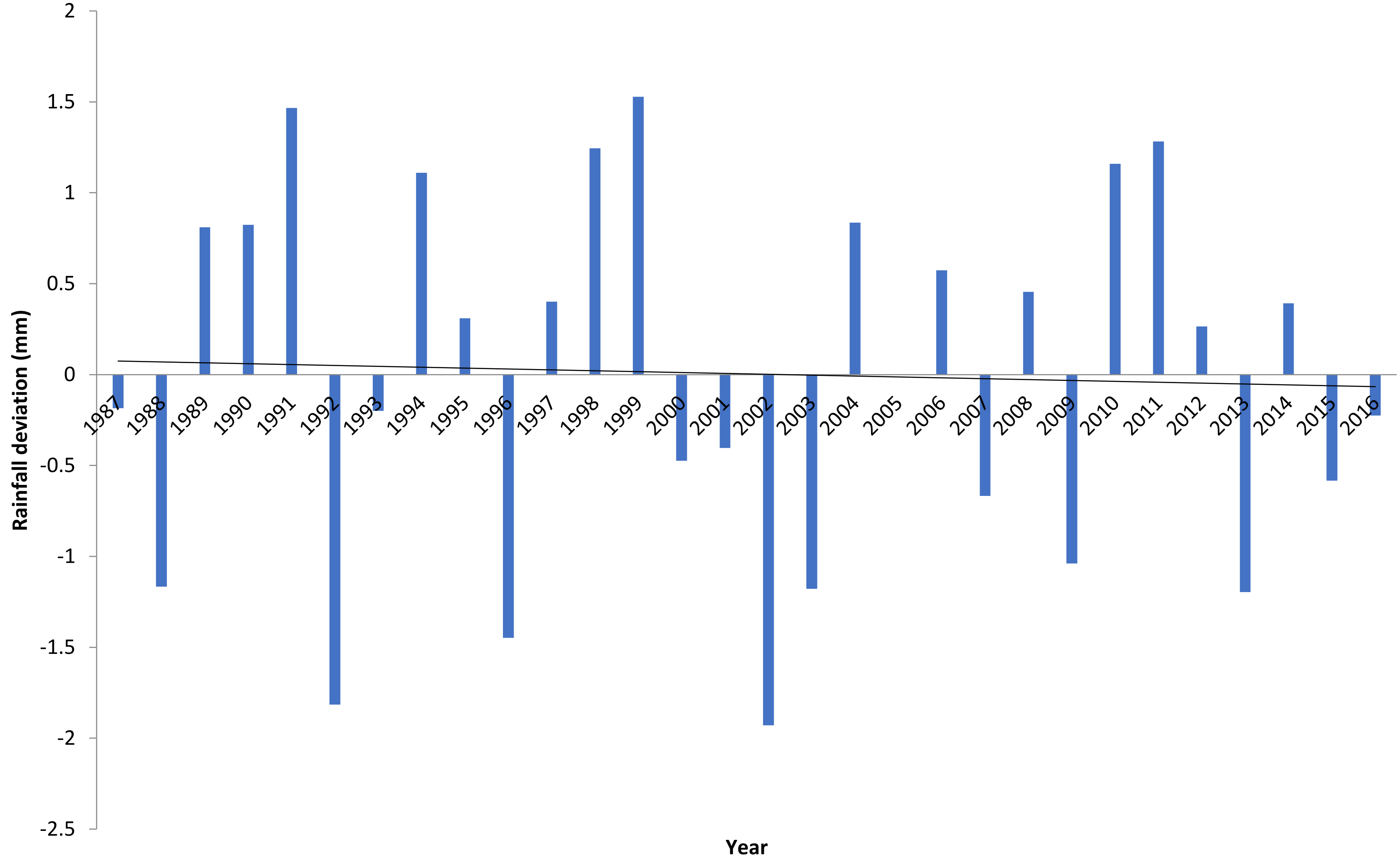


Figure 4.6 Rainfall deviation

Table 4.3 shows the trend of rainfall over thirty year. The months of January, February, March, April, May, July, August, September , November, December have Z values less than 1.96 meaning that these months have insignificant trend. The months of June and October have z values greater than 1.96. This implies that the trends were significant. The month of October has a positive trend while the month of June has a negative trend. On annual basis, the rainfall records have decreasing trend.

Table 4.3 Trend analysis of rainfall between 1987 and 2017 using Mann Kendall test

Month	tau	S value	Zvalue
Jan	0.0713	31	0.6612
Feb	0.0506	22	0.4629
March	-0.0989	-43	-0.9257
Apr	0.0667	29	0.6172
May	-0.0483	-21	-0.4408
June	-0.2552	-111	-2.4246
July	-0.0345	-15	-0.3086
August	-0.2046	-89	-1.9397
Sept	0.2046	89	1.9397
Oct	0.3195	139	3.0417
Nov	0.1563	68	1.4768
Dec	0.0667	29	0.6172

4.3.2 Trend analysis of Evaporation

Evaporation from the land surface includes evaporation from open water, soil, shallow groundwater, and water stored on vegetation, along with transpiration through plants. Figure 4.7 shows the mean monthly evaporation for Kainji, it was discovered that evaporation was high in the first three months (January, February and March), and started decreasing from April to July. It pick up again in August and September and slighting down in September and rise again in November and December. It was discovered that July has the lowest mean evaporation (3.24) while December has the highest (15).

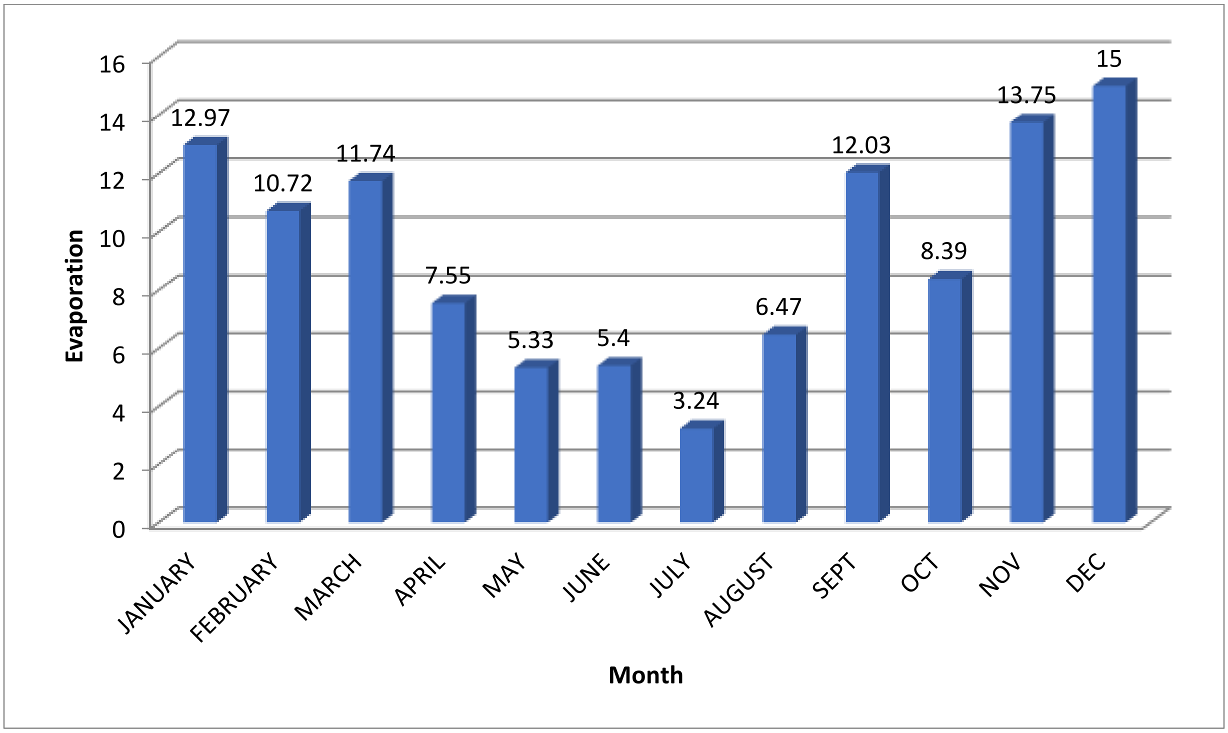


Figure 4.7: Mean Monthly Evaporation in Kainji Dam

The rate of evaporation from the land surface is driven essentially by meteorological controls, mediated by the characteristics of vegetation and soils, and constrained by the amount of water available. Climate change has the potential to affect all of these factors in a combined way that is not yet clearly understood with different components of evaporation affected differently.

Annual trend of evaporation was presented in Figure 4.8, it revealed the deviation for mean annual values of evaporation over thirty (30) year in the study area. There were stable deviations between 1987 and 1991. The evaporation deviation was increased in the years 1995 but it reduced drastically between 1993 and 1994. In the year 1995, the deviation was very high. On the decadal basis, the years 1996 and 1997 have negative and least temperature deviation. On decadal basis, the year 1998 and 2000 have the highest temperature deviations while the years 1999 and 2001 have the least deviations. Between 2012 and 2008, the study showed that the deviations have lowest values with a negative pattern. Furthermore, the year 2010 has a positive and least value while the remaining years showed negative deviations.

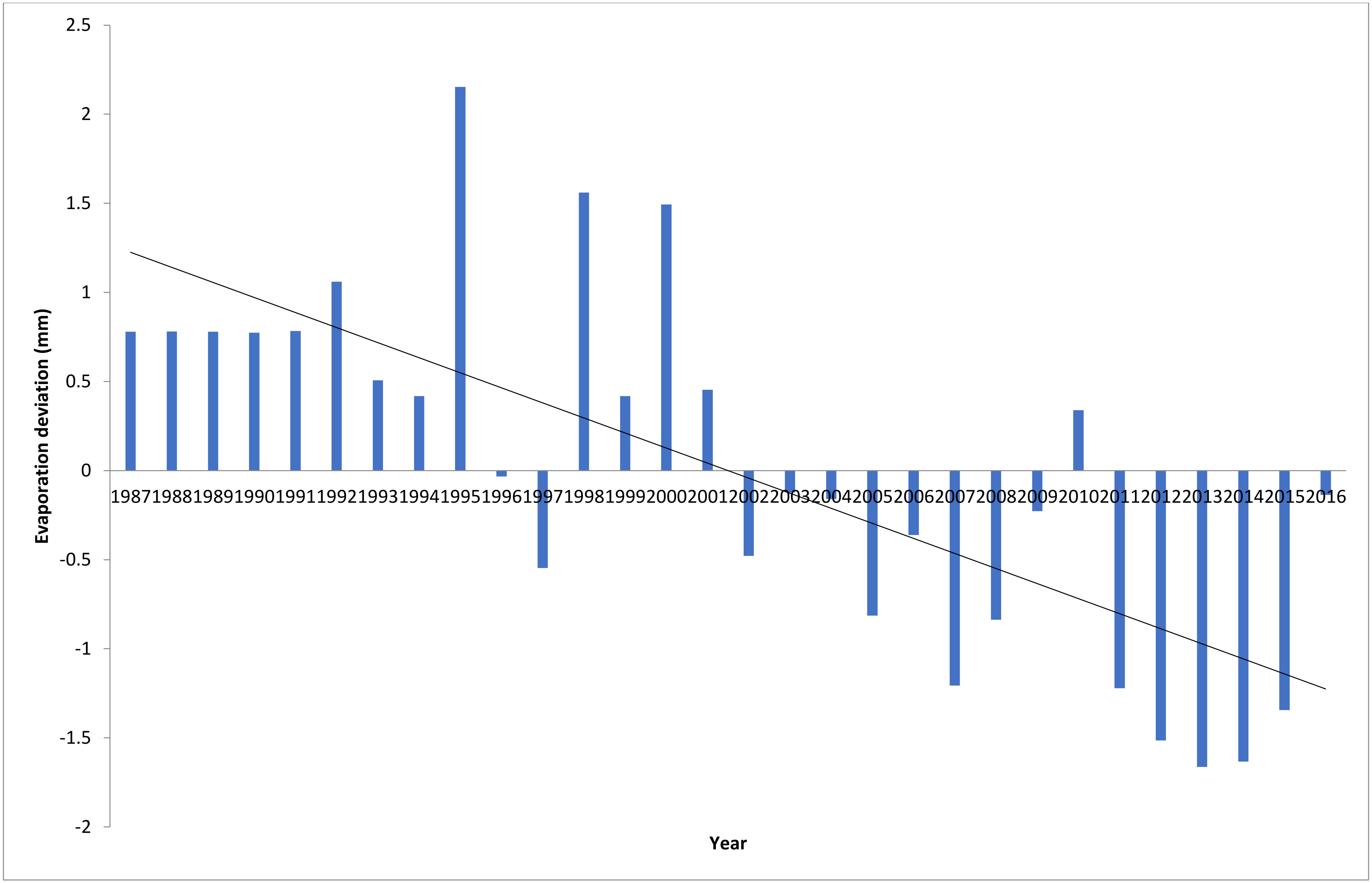


Figure 4.8 Evaporation deviation

Table 4.4 showed the trend analysis of evaporation over years. The months of April, May, June, July, September, October, January, February and March between 1987 and 2017 have Z values$greater\ than\ 1.96$. This study showed that these months have significant trend. This means that the month of September has a positive trend while the remaining months have negative trends. The month of August, November and December have $Z\ values\ less\ than\ 1.96$ meaning that there were no trends for these months.

Table 4.4 Trend analysis of evaporation between 1987 and 2017

Month	tau	S value	Z value
Jan	-3540	-154	-3.3724
Feb	-0.4368	-190	-4.1659
Mar	-0.4759	-207	-4.5406
Apr	-0.5425	-236	-5.1798
May	-0.5149	-224	-4.9153
June	-0.2506	-109	-2.3805
July	-0.4138	-180	-3.9454
Aug	0.154	67	1.4547
Sep	0.3379	147	3.2181
Oct	-0.446	-194	-4.254
Nov	-0.0874	-38	-0.8155
Dec	-0.1195	-52	-1.1241

4.3.3 Trend analysis on reservoir inflow

Outlet usually is expressed as stream flow; over durations of a month or more, it usually is expressed as runoff. Runoff tends to increase where precipitation has increased and decrease where it has fallen over the past few years. Figure 4.9 shows the reservoir inflow of Kainji Dam. It reveals that January has a mean inflow of 1145 and it was decrease to 580 in February. The decrease continue until June with mean inflow of 79, it raise in July to 390 and continue raising to 1335 in December. Flows have increased in recent years in Kainji dam, Variations in flow from year to year have been found to be much more strongly related to precipitation changes than to temperature changes. A major and unprecedented shift in streamflow from spring to winter has been associated not only with a change in precipitation totals but more particularly with a rise in temperature: Precipitation has fallen as rain, and therefore has reached rivers more rapidly than before.

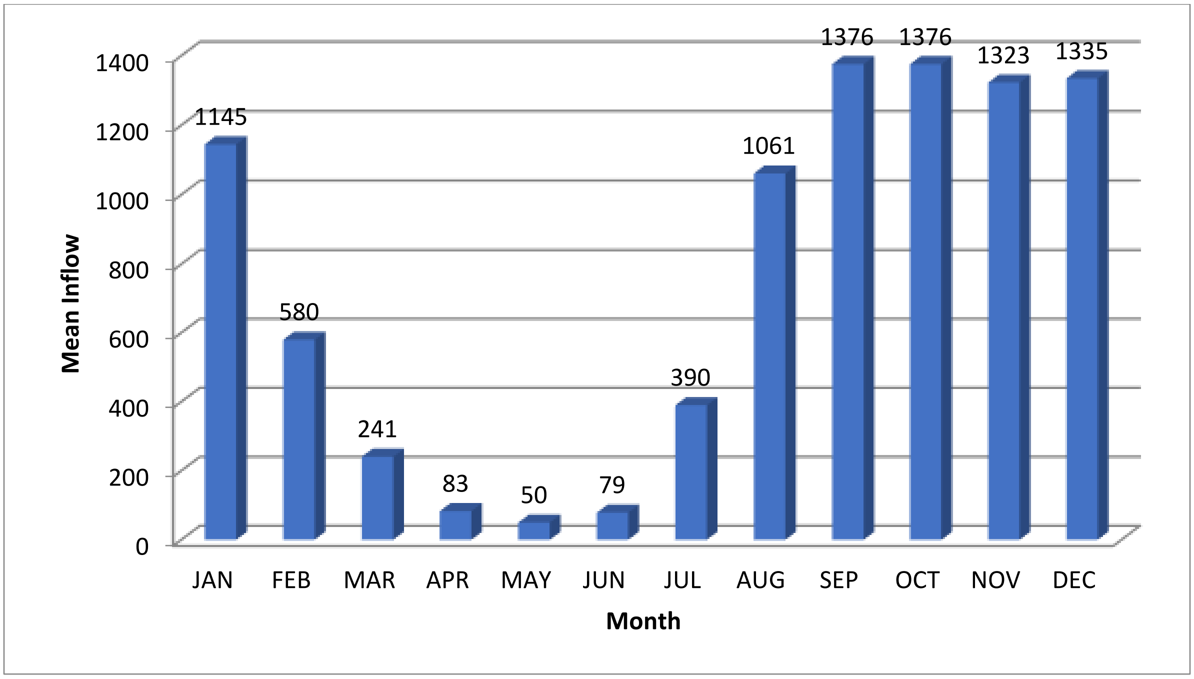


Figure 4.9: Mean Monthly Reserviour inflow in Kainji

Figure 4.10 revealed that the deviation for mean monthly reservoir inflow over thirty (30) year. Between 1987 and 1993, the reservoir inflow deviations decreased with negative values. In addition, the years 1994, 1995 and 1996 have positive deviations. Furthermore, the deviation reduced in the year 1997. Between 1998 and 2008, the reservoir inflow deviations were high in the year 1998, 1999 but reduced in the year 2000 with a little increase in the year 2001 but drastically reduced in the year 2002. The deviations increased in the year 2003 but reduced in 2004 with a negative deviation values in the year 2005 and 2006. The deviation increased from 2007 to 2008 but reduced in 2009 and later increased in the year 2010. The year 2011 and 2016 have a positive deviation while the years 2012, 2013, 2014 and 2015 have negative deviations. Graphically, the study showed that the reservoir inflow has an positive trend. The study revealed that even though the direction of the rainfall was reduced between 1987 and 2017 but the generated runoff around the catchment area still increases the trend of reservoir inflow.

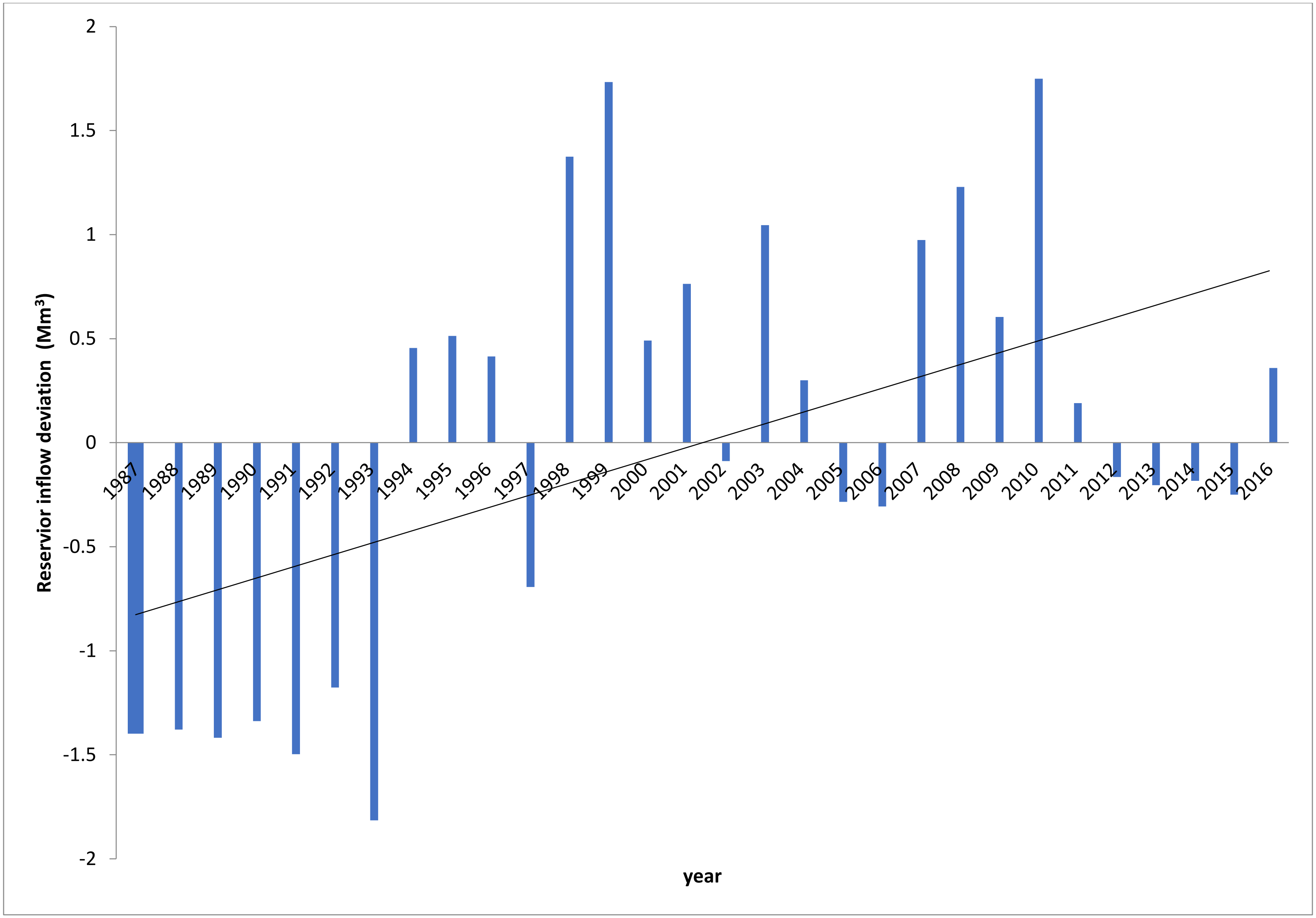


Figure 4.10 Reservoir inflow deviation

Table 4.5 shows the trend analysis of reservoir inflow over thirty years. The monthly reservoir inflow records between April and July have $Z\ values\ less\ than\ 1.96$ had no trend. This implies that the trends were insignificant. Furthermore, the months of August and March have Z values greater than 1.96 which shows that these months have significant trend. Properly the months that reservoir inflow is significant is due to increase in rainfall and runoff from other rivers outside Kainji, while months that reservoir inflow is insignificant may be due to very high rainfall that leads to erosion because of indiscriminate farming from the upstream which prevent runoff, these will lead to sedimentation deposit in the reservoir and these will reduce the life span of the reservoir and also have effect on energy generation.

Table 4.5 Trend analysis of reservoir inflow between 1987 and 2017

Month	tau	S value	Z value
Jan	0.3356	146	3.196
Feb	0.3793	165	3.6148
Mar	-0.3195	139	3.0417
Apr	0.1471	64	1.3886
May	0.1908	83	1.8074
June	0.1149	50	1.08
July	0.1655	72	1.565
Aug	0.3793	165	3.6148
Sep	0.3379	147	3.2181
Oct	0.4759	207	4.5406
Nov	0.3448	150	3.2842
Dec	0.3402	148	3.2401

4.6 Spatial variations of rainfall, reservoir inflow, reservoir elevation, evaporation and turbine discharge in Shiroro

4.6.1 Spatial variation of rainfall in Shiroro

Rainfall is the main driver of variability in the water balance over space and time, and changes in precipitation have very important implications for hydrology and water resources. Hydrological variability over time in a catchment is influenced by variations in precipitation over daily, seasonal, annual, and decadal time scales. Figure 4.11: Monthly rainfall distribution in Shiroro Dam

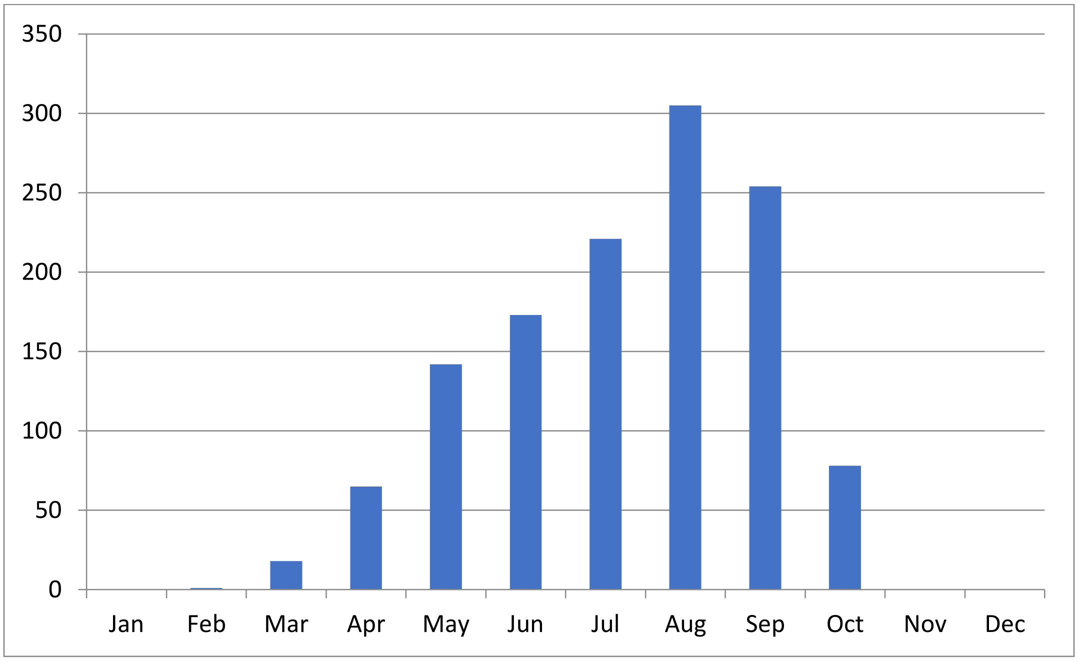


Figure 4.11: Monthly Rainfall Distribution at Shiroro Dam

The intra seasonal variation of rainfall over the catchments is shows that rainfall generally begins in March / April, increase until the mount of September and decrease thereafter until cessation takes place completely in November. About 50% of the annual rainfall total accumulates in two heaviest rainy months of July and August and lowest in the months of January, February and December. There is thus a marked dry and rainy seasons. The former generally lasts for about five to six months, while the latter lasts for about six to seven months. The sensitivity of the river Kaduna flow to rainfall does not usually start until July when traditionally, the months of September / early October marks the peak of the inflow. The peak inflow immediately following accumulated peak rainfall period may be attributed to the time-lag factor between rainfall and peak flow.

On a yearly basis, noticeable oscillations were recorded. Rainfall picked up in 1992. It went down in 1993 and picked up again for two consecutive years (1994 and 1995). The year 1996 witnessed a downturn in the amount of rainfall received. From 1997 to 2001 also marked another period of increase in rainfall amount. The years 2002 to 2005 showed rainfall oscillating downwards.It should be noted that the yearly distribution of rainfall over the Shiroro reservoir hovers between 1000mm and 1450mm with a mean of 1200mm. The implication of this rainfall scenarios is that no meaningful variation in recorded at this location during the study period. Figure 4.12: Annual Rainfall Distribution

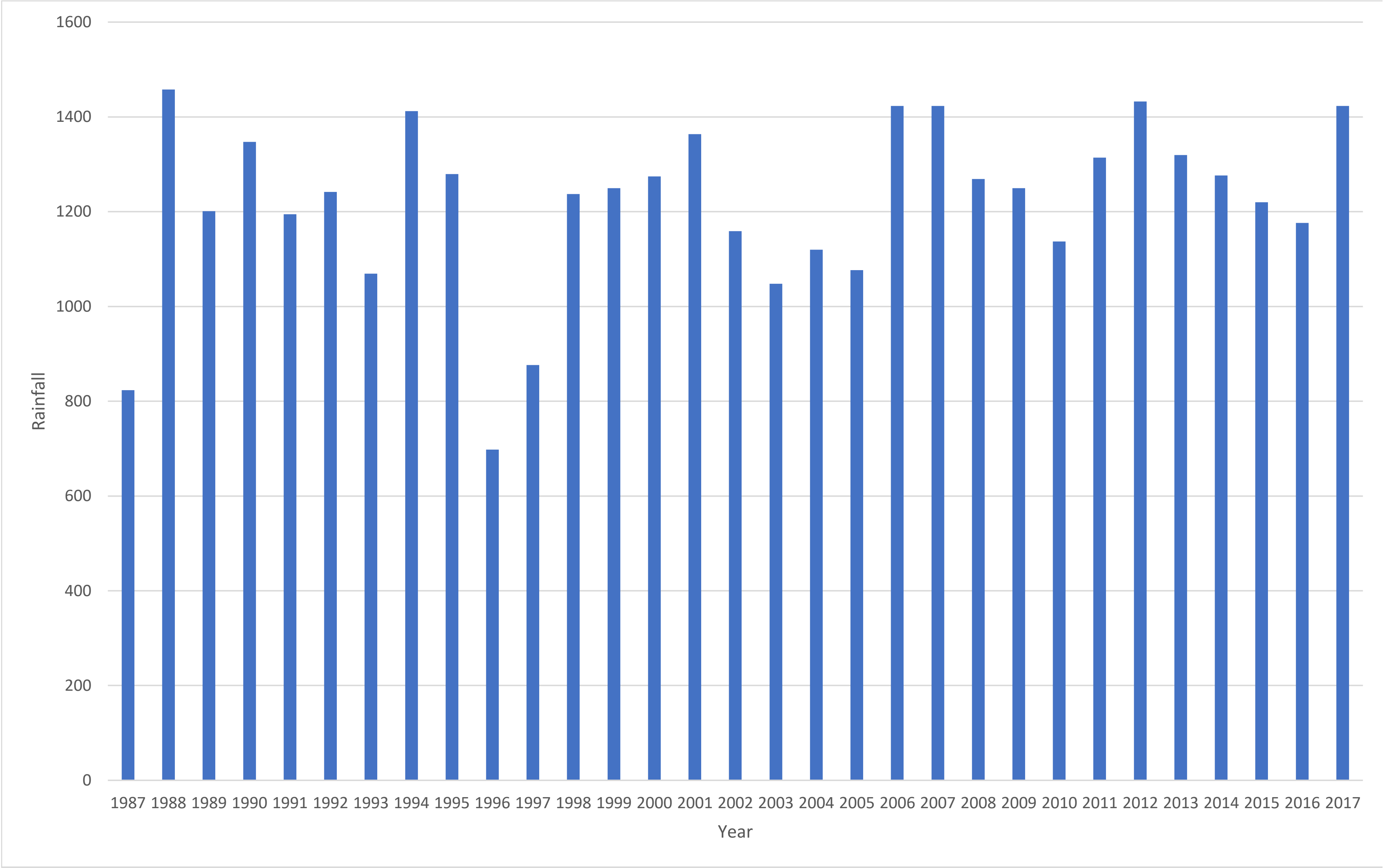


Figure 4.12: Annual Rainfall Distribution

4.4.2 Trend analysis of evaporation in Shiroro

Evaporation from the land surface includes evaporation from open water, soil, shallow groundwater, and water stored on vegetation, along with transpiration through plants. The rate of evaporation from the land surface is driven essentially by meteorological controls, mediated by the characteristics of vegetation and soils, and constrained by the amount of water available. Climate change has the potential to affect all of these factorsin a combined way that is not yet clearly understoodwith different components of evaporation affected differently.

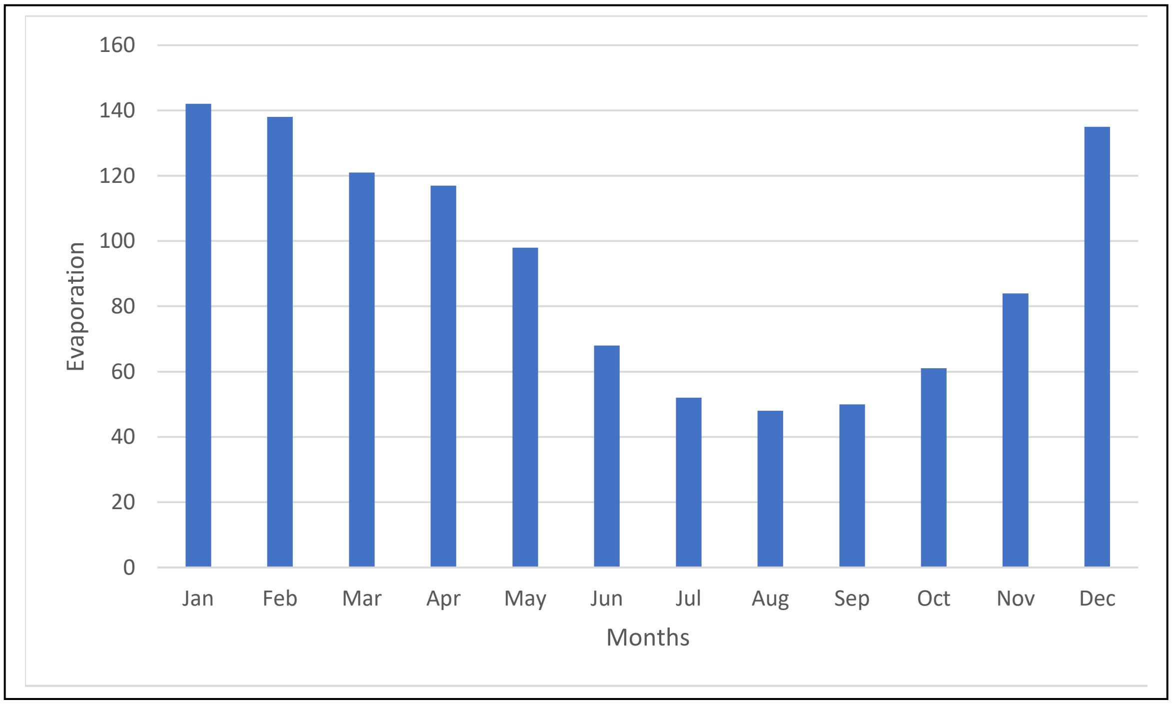


Figure 4.13 Illustrates of monthly evaporation in Shiroro dam

The primary meteorological controls on evaporation from a well-watered surface are the amount of energy available the moisture content of the air and the rate of movement of air across the surface. Increasing temperature generally results in an increase in potential evaporation, largely because the water-holding capacity of air is increased. Changes in other meteorological controls may exaggerate or offset the rise in temperature, and it is possible that increased water vapor content and lower net radiation could lead to lower evaporative demands.

The effects of climate change have concentrated on potential changes on streamflow and runoff. The distinction between "streamflow" and "runoff" can be vague, but in general terms Stream flow is water within a river channel, usually expressed as a rate of flow past a point typically in m3 s-1 whereas runoff is the amount of precipitation that does not evaporate, usually expressed as an equivalent depth of water across the area of the catchment. A simple link between the two is that runoff can be regarded as stream flow divided by catchment area at Shiroro Dam.

Table 4.6: Mean Monthly Rainfall and Evaporation at Shiroro dam

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Total**
Rainfall (mm)	0	1	18	65	142	221	173	305	254	78	0	0	**1253**
Evaporation (mm)	142	138	121	117	98	66	52	48	50	61	84	135	**1112**
Variation in Values	-142	-137	-103	-52	44	155	121	257	204	17	-84	-135	**141**

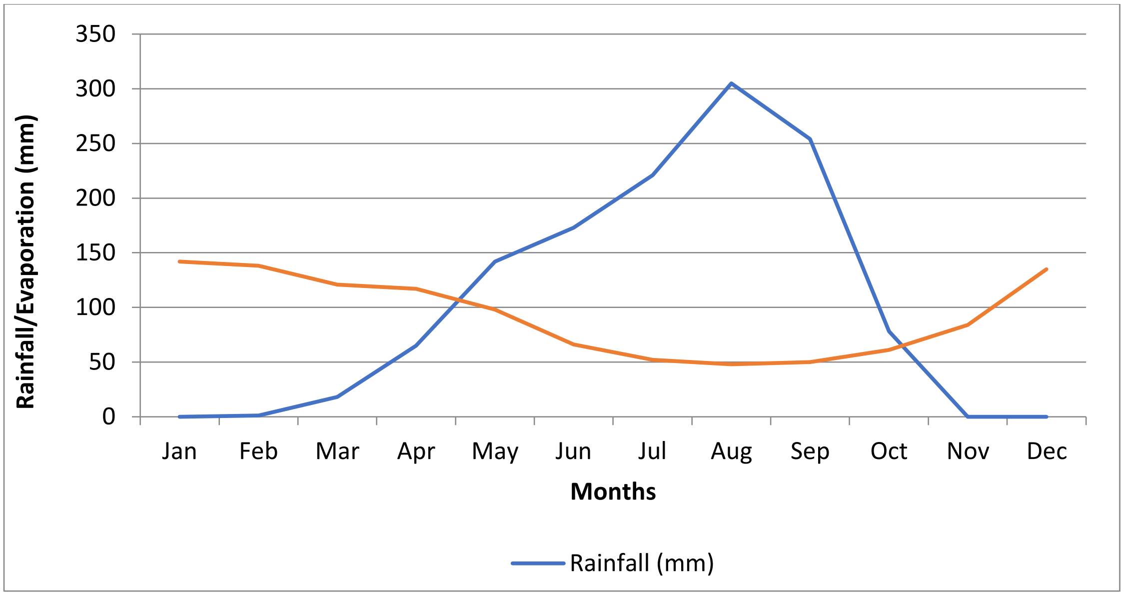


Figure 4.14: Relationship between Rainfall and Evaporation of Shiroro Dam

Figure 4.14 illustrate seasonal moisture distribution at Shiroro dam. Figure 4.14 indicates periods of moisture deficit which is between November and March and another period of moisture surplus which is between April and October when the rainfall is in excess of the evaporation. However, at any point in time, water is available in the reservoir.

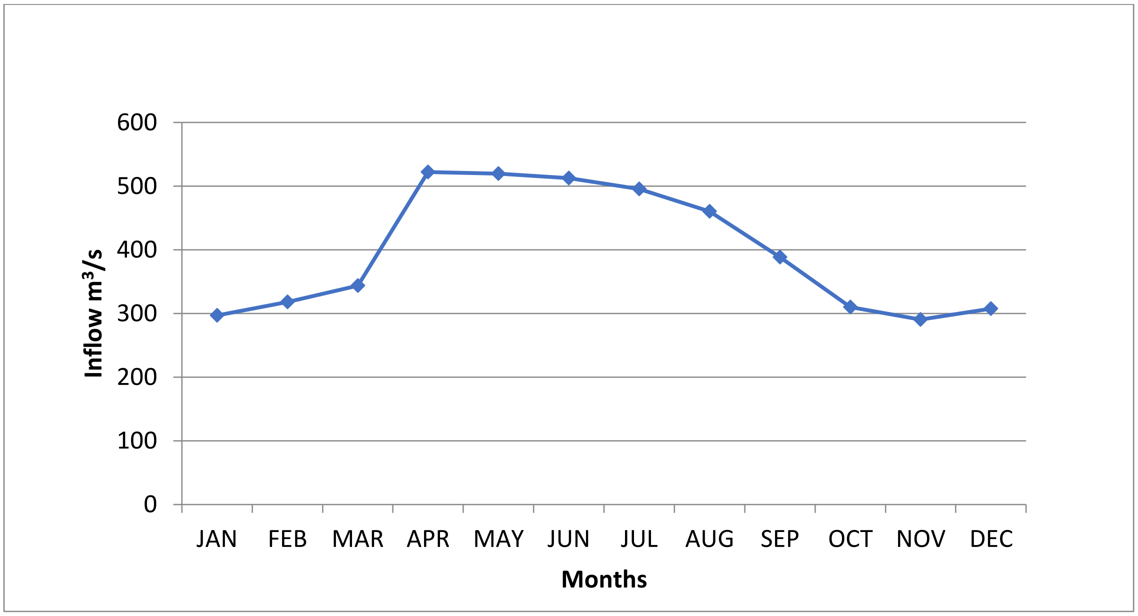


Figure 4.15 Average Monthly Inflow

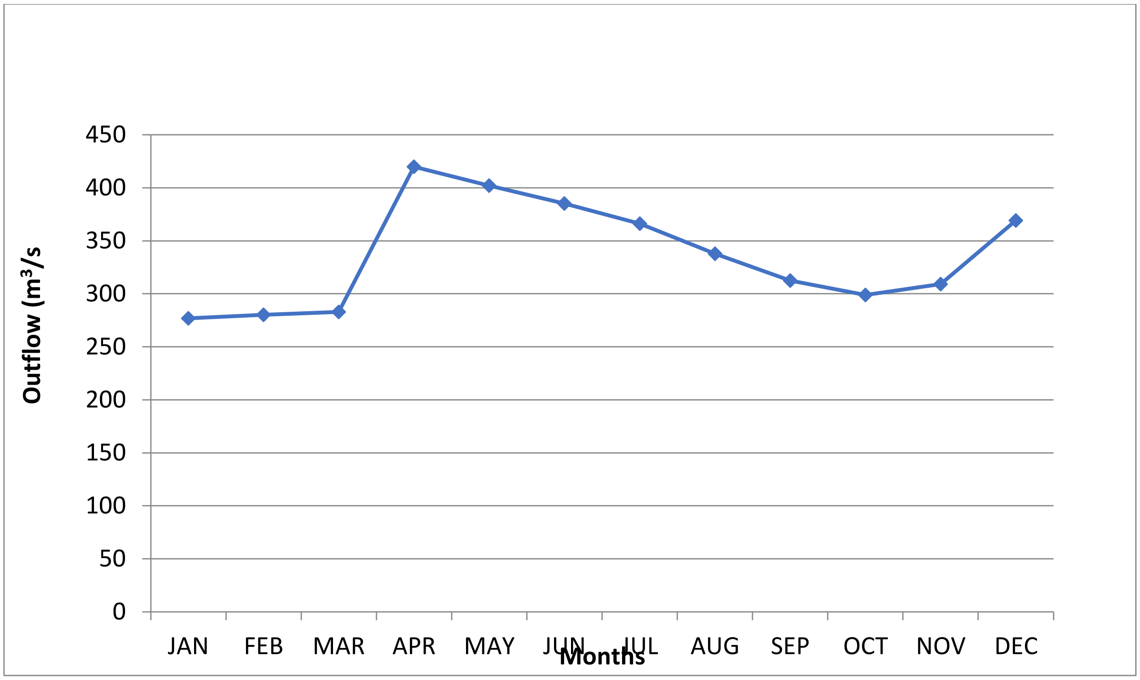


Figure 4.16 Monthly Average Outflow

Outlet usually is expressed as streamflow; over durations of a month or more, it usually is expressed as runoff. In some countries, “runoff” implies surface runoff only and does not include the contribution of discharge from groundwater to flow, but this is a narrow definition of the term.

Runoff tends to increase where precipitation has increased and decrease where it has fallen over the past few years. Flows have increased in recent years in Shiroro dam, Variations in flow from year to year have been found to be much more strongly related to precipitation changes than to temperature changes. A major and unprecedented shift in streamflow from spring to winter has been associated not only with a change in precipitation totals but more particularly with a rise in temperature: Precipitation has fallen as rain, and therefore has reached rivers more rapidly than before.

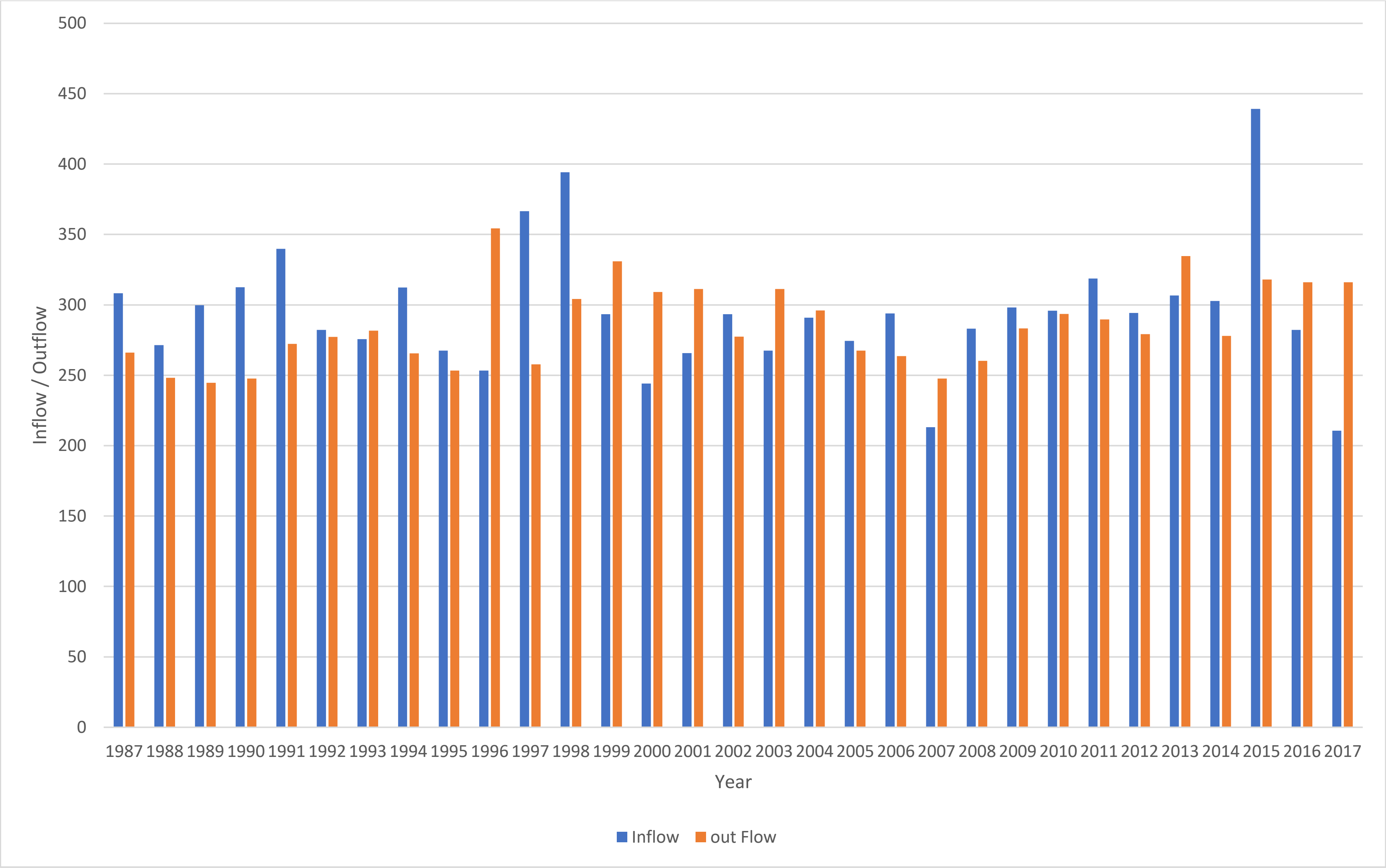


Figure 4.17 Annual Distribution of Inflow and Outflow into and from Shiroro Dam

However, it is very difficult to identify trends in hydrological data, for several reasons. Records tend to be short, and many data sets come from catchments with a long history of human intervention. Variability over time in hydrological behavior is very high, particularly in drier environments, and detection of any signal is difficult. Variability arising from low-frequency climatic rhythms is increasingly recognized, and researchers looking for trends need to correct for these patterns.

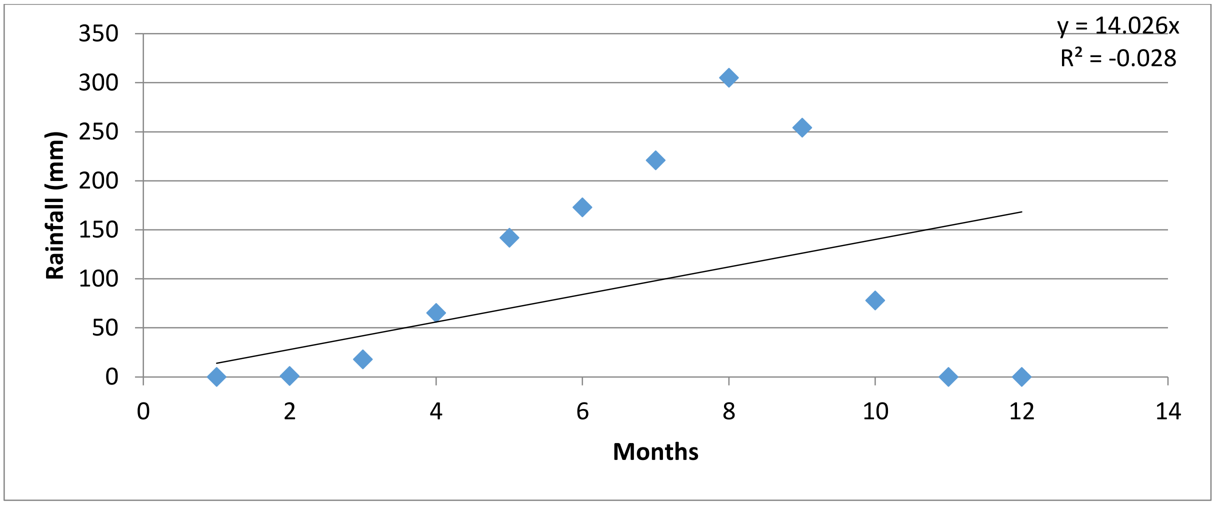


Figure 4.18: Monthly Rainfall Correlation

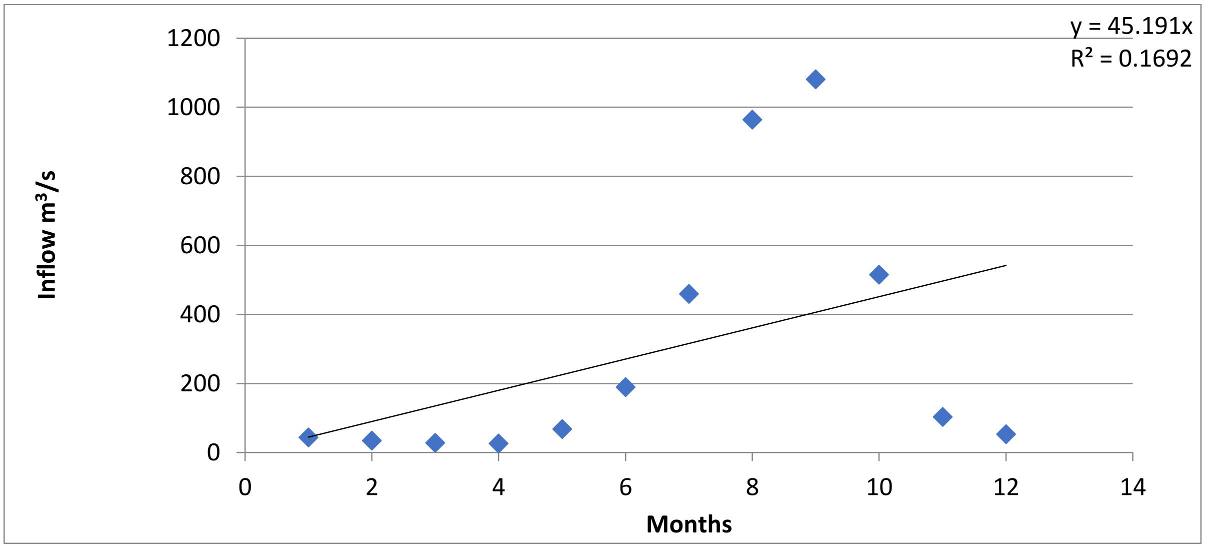


Figure 4.19: Monthly inflow

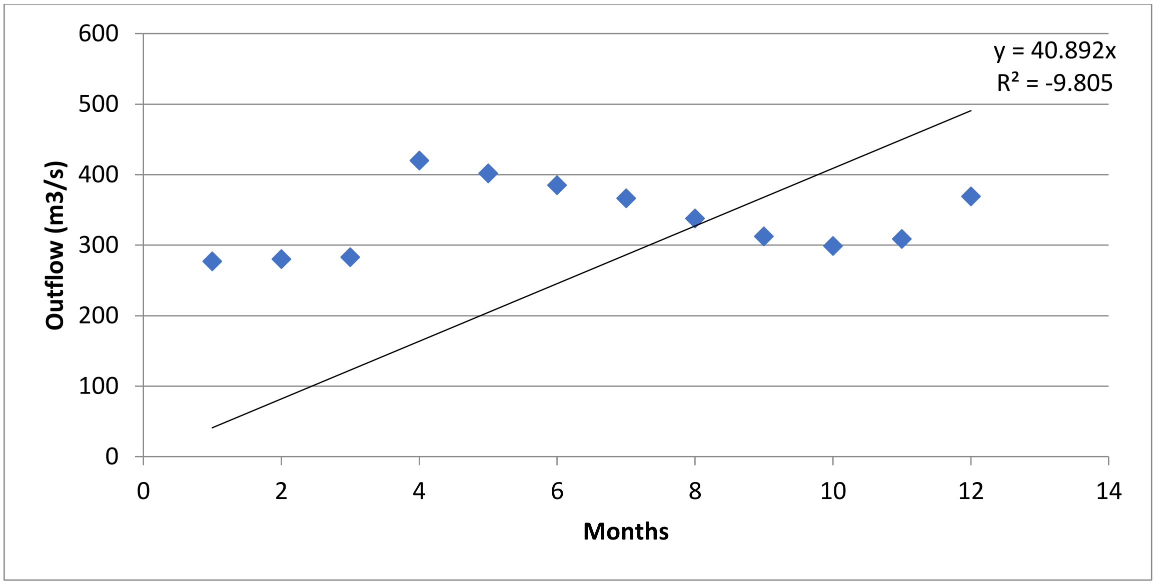


Figure 4.20: Monthly outflow

The effects of climate change on the magnitude of annual runoff and flows through the year are much less consistent than the effect on Dam flow timing because they depend not on the temperature increase but on the change in precipitation. In general, precipitation increases in high-latitude areas under most scenarios, but in lower latitudes precipitation may decrease. Hydrological regimes in these regions are dominated by the seasonal cycles of rainfall and evaporation; inflow and outflow are not important. Here, climate change tends to affect the magnitude of flows in different seasons by an amount that depends on the change in rainfall and may lead to an exaggerated seasonal cycle, but it generally does not affect the timing of flows through the year. Low flows tend to occur during raining, and changes in low-flow frequency are closely related to changes in the balance between rainfall and evaporation. Temperate, rainfall would decline with global warming, leading to a reduction in low flows.

The detailed effect of a given change in climate, however, depends to a large extent on the geological characteristics of Shiroro have indicated that in catchments with considerable groundwater, changes in dry flows are largely a function of the change not in rainfall but in rainfall during the winter recharge season. Dam are particularly vulnerable to changes in climate parameters. Variations in air rainfall and other meteorological components directly cause changes in evaporation, water balance, Dam level, hydrochemical and hydrobiological regimes, and the entire lake ecosystem. Under some climatic conditions, lakes may disappear entirely.

CHAPTER FIVE

5.0 CONCLUSION AND RECONMENDATIONS

5.1 Conclusion

The comparative analysis of spatial temporal variations in hydrological parameters at Kainji and Shiroro Dams in Niger State, Nigeria was conducted using data on rainfall, evaporation, reservoir inflow and outflow for the period of thirty years from Kainji and Shiroro Hydropower Station. The community which is the host of the dam water has been revealed to be expanding- causing fear of dam collapse, the natural vegetation is rapidly decreasing-putting, water hyacinth has recently captured some parts of the dam and despite numerous efforts by the government and research institute, the weeds as at 2017, still covered more than 40 km2 of the dam surface, intensive agriculture that was very minimal in 1985 was discovered to have captured more than 40% of the dam basin. The data collected was used to show the trend of each parameter for the time frame of study. Firstly summary statistics of all variables was conducted to know if the mean, annual mean, maximum minimum and overall total amount of each variable was computed to check if the data collected are evenly distributed. Mann Kendall's was used on all variables to show the trends and deviations for each variable using Excel package. The comparatively analyses rainfall, evaporation, and reservoir inflow in each of the dam. The findings of these research show that reservoir inflow experienced tremendous fluctuations over the years of study.

The rainfall, evaporation and reservoir inflow within Kainji and Shiroro dam were subjected to Mann Kendall, Design expert analyses. The trends of the variables for the time frame of study were shown using trend line. The analyses revealed that evaporation show a negative trend, and a slight decrease in rainfall. while reservoir inflow pattern shows a increasing trend, due to order river channel flowing from outside the dams but if there is a slight decrease it might not be noticeable

5.2 Recommendations

In relations to the findings of this study, the following recommendations became essential.

1. The Government should embark on Enhancement in the measurement, monitoring, forecasting, and knowledge of the hydrologic system.
2. It is recommended that dam operators optimize the release of water from Kainji and Shiroro dam and ensure continuous monitoring of changes in hydro meteorological variables to provide early warning systems for effective performance of the dam and to protect downstream environment.
3. The government should strengthen laws, policies and measures relevant to addressing climate variability, as this will help in limiting global warming, which is the reason behind drought and low precipitation.
4. Reduction of the current variability by means of increased storage capacity by constructing buffer dams and reservoirs in order to store excess runoff during the periods of high flows.
5. The government should carry out wide-ranging review of existing national water resources master plan. The new plan should seriously consider recent phased development and management of particular problems. While a financial plan should be adopted in setting out annual budgetary allocations to relevant water development and energy projects.

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APPENDIX I

ANNUAL RAINFALL IN THE STUDY AREA

2012	2011	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
280	277	426	258	214	488	192	115	253	335	234	297	249
287	285	335	233	109	367	183	72	298	335	216	251	251
283	291	317	264	127	318	194	112	344	337	208	270	258
280	283	280	260	126	312	205	138	337	355	233	270	259
286	289	280	261	129	318	204	131	501	343	286	337	253
276	276	291	283	176	325	196	110	375	337	289	292	264
294	288	284	343	227	368	167	128	373	300	319	258	247
284	287	282	332	241	312	201	324	600	324	283	248	269
233	269	289	275	314	349	214	211	374	326	209	247	270
291	276	277	252	312	347	241	280	158	338	219	255	287
272	212	286	271	340	334	297	75	156	322	220	238	252
289	173	267	293	303	340	189	183	156	341	273	344	247
291	282	305	298	307	319	189	68	153	338	183	401	242
286	286	295	306	276	360	187	73	158	339	186	380	245
286	285	290	291	107	340	186	67	164	337	205	279	233
284	288	281	253	111	366	206	74	159	334	253	224	262
291	228	280	317	291	410	208	71	156	339	237	230	335
281	279	276	259	239	353	214	108	158	334	274	222	321
305	288	291	274	346	330	204	77	158	342	218	222	264
290	286	285	236	306	341	232	143	158	348	230	222	230
273	290	296	229	215	336	193	105	175	347	309	239	171
298	289	296	248	139	365	179	301	163	348	252	247	224
296	290	294	215	292	370	219	280	163	339	261	239	189
297	252	294	289	132	392	188	63	188	341	233	249	150
305	290	294	276	198	434	180	82	224	346	233	254	125
284	294	316	278	109	347	187	124	150	352	214	230	192
304	290	304	280	164	404	257	79	154	356	235	270	221
304	285	338	276	241	405	199	85	150	351	261	242	181
234	293	298	236	93	409	185	66	154	346	229	276	115
303	292	350	255	164	487	202	46	164	341	223	247	150
296	182	302	274	163	407	210	60	156	354	219	244	159
196	141	389	185	232	337	226	65	176	352	226	225	146
192	74	346	177	110	326	211	64	176	346	229	230	277
300	144	311	211	147	343	214	67	177	345	248	227	241

256	140	362	289	147	335	254	70	158	288	224	197	167
289	214	304	254	254	332	207	173	155	314	219	230	387
272	290	240	280	304	339	210	139	156	299	232	243	505
288	260	292	272	313	331	273	71	60	284	228	224	357
266	297	300	337	152	341	192	64	162	280	219	236	147
264	298	327	289	106	340	429	66	162	281	219	243	265
295	285	477	270	105	295	220	70	149	304	259	237	196
303	282	391	278	114	300	211	67	160	256	231	252	163
297	287	307	271	198	319	223	73	160	288	250	249	157
266	126	182	310	143	292	225	69	160	287	260	269	194
309	130	323	332	287	292	246	59	159	294	208	247	181
310	121	343	275	214	326	286	59	158	230	209	244	228
305	110	341	256	166	311	261	77	156	210	194	211	245
270	61	309	168	147	309	285	167	140	219	236	230	307
298	63	378	160	261	312	227	78	140	237	226	238	283
310	74	354	145	310	312	213	70	151	278	261	242	245
308	136	409	151	300	314	260	69	151	300	254	302	339
262	137	387	161	313	314	315	88	148	118	242	225	471
299	137	329	147	281	314	333	54	155	387	210	247	326
294	193	307	222	316	314	414	88	154	346	229	255	326
293	444	302	163	216	310	419	63	154	371	249	241	293
297	421	306	82	315	311	193	114	154	293	252	253	278
303	435	300	296	309	332	224	184	149	267	271	245	280
303	433	301	246	312	320	228	226	149	307	246	238	257
312	459	294	246	312	319	213	324	153	341	281	221	287
306				180						227		

294	406	305	260	120	314	248	189	150	332	253	281	273
280	435	309	174	95	284	395	91	151	355	261	237	270
235	429	307	254	97	302	258	94	145	366	320	270	236
297	448	307	266	118	283	230	110	156	161	259	254	240
297	437	312	255	116	314	216	110	161	252	260	264	341
260	433	295	309	119	313	213	93	156	265	313	243	321
299	429	312	294	143	313	212	96	117	272	325	212	286
301	457	299	293	311	315	205	90	119	259	325	337	220
302	457	332	299	266	317	218	130	78	274	319	232	247
320	435	270	289	317	315	228	107	24	257	92	246	303
192	462	279	238	317	314	225	93	105	206	162	215	294
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309	418	292	169	247	314	268	76	144	267	169	314	271
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310	464	289	171	294	283	321	72	161	288	405	230	226
291	438	222	208	300	294	203	91	153	287	319	240	280
317	459	295	270	139	319	328	174	142	292	288	243	295
301	462	263	236	137	62	216	74	140	285	312	255	279
310	445	291	230	118	318	207	98	115	274	333	349	235
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88	390	307	319	321	73	220	69	144	246	338	217	275
113	437	216	305	281	47	210	107	120	259	363	221	288
74	434	296	329	312	46	222	313	110	251	312	246	288
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109	407	294	258	333	91	229	296	104	289	241	223	275
146	395	306	241	330	123	220	69	114	229	253	240	216
131	453	307	224	323	75	216	69	99	241	247	282	232
52	460	313	277	312	60	231	81	101	270	240	246	252
59	409	316	284	176	118	223	176	115	296	274	237	241

26	451	308	265	143	140	217	117	111	266	272	256	258
47	442	308	323	110	68	228	109	109	234	248	255	302
43	429	308	329	228	208	319	125	112	313	245	360	302
15	370	304	279	49	81	424	151	116	241	302	275	241
23	449	297	116	45	79	436	306	105	265	227	264	264
61	361	291	112	49	119	322	209	131	241	235	239	253
53	331	290	182	69	182	213	64	110	335	247	311	252
63	377	276	299	76	353	215	75	47	236	231	249	283
73	414	292	320	74	331	220	478	110	180	240	259	348
54	307	290	237	75	312	233	272	120	158	246	290	272
68	457	304	140	31	418	231	100	106	156	260	269	253
40	462	282	307	270	312	256	180	130	157	253	261	239
111	424	321	71	99	84	337	238	25	156	258	261	266
62	434	302	175	104	390	349	131	30	156	252	297	288
61	423	218	238	134	54	357	128	36	173	232	264	353
27	458	297	273	161	59	344	157	78	162	240	250	297
54	324	219	161	122	106	353	143	29	177	298	216	254
63	281	242	142	128	79	334	189	136	152	247	299	203
65	300	305	130	121	102	228	203	57	158	220	254	208
64	391	273	219	153	92	229	160	49	167	230	244	258
168	469	237	228	134	81	251	160	58	157	234	259	240
147	487	314	302	132	91	225	201	65	157	251	229	267
91	473	298	293	105	99	217	155	89	162	228	231	245

73	464	154	237	115	99	203		174	81	157	239	264	269
67	304	211	235	125	68	211		216	131	154	241	259	406
34	416	186	205	189	59	233		167	119	163	244	237	268
51	464	213	318	147	68	246		155	87	159	220	249	316
41	469	100	207	311	48	228		127	83	158	214	258	273
41	437	326	119	306	74	226		138	79	159	218	243	259
89	378	103	238	319	86	221		153	80	159	254	250	257
58	461	242	185	232	42	220		174	80	158	251	312	242
50	485	23	224	253	104	232		178	97	154	206	284	263
0	454	64	270	365	209	235		188	78	154	237	272	218
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47	329	137	330	5	98	216		461	76	253	290	214	235
47	339	76	298	180	81	278		352	75	304	320	216	264
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43	329	73	315	62	359	190		351	48	277	316	202	239
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36	0	58	321	24	182	206		222	92	254	309	186	259
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308	197	77	215	335	364	209		229	102	236	309	277	306
304	0	80	251	287	79	199		246	103	280	310	186	248
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282	0	264	322	51	227	368	171	117	285	283	183	284
309	10	283	253	61	438	371	179	90	263	300	191	243
347	72	296	252	46	183	362	170	76	114	293	186	266
277	104	321	313	55	83	180	165	149	303	309	197	286
362	323	319	253	22	79	198	177	95	172	309	202	274
495	331	368	289	25	71	200	182	251	158	291	202	237
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470	338	354	0	42	102	201	192	288	88	306	201	239
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425	24	314	289	236	159	296	248	294	90	246	213	260
497	21	378	1	99	114	242	238	422	96	310	178	255
477	0	436	161	350	202	363	205	283	96	306	112	151
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461	0	418	268	306	411	216	221	302	85	315	164	269
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368	331	369	0	242	349	292	220	328	245	312	328	205
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331	0	469	144	345	365	236	222	478	309	318	223	207
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488	311	460	102	245	298	207	371	466	235	308	477	150
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485	321	452	416	272	368	341	362	460	267	312	480	363
454	307	444	438	320	384	329	332	413	309	286	476	375
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489	303	478	421	213	355	347	366	437	233	193	315	279
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465	344	414	118	180	355	359	409	463	208	301	475	275
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459	351	388	331	57	362	329	432	459	154	307	467	303
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474	364	437	120	29	368	457	415	466	311	295	453	228
473	362	414	474	47	377	513	410	464	381	309	540	436
463	326	470	479	69	346	517	405	472	461	310	606	372
486	319	454	429	0	363	564	412	475	454	313	640	370
465	325	459	338	0	365	515	398	476	457	308	649	366
378	315	467	487	93	368	594	319	477	457	301	630	425
431	327	457	492	46	569	470	373	477	430	307	642	246
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416	292	468	498	70	386	491	406	448	464	308	586	383
446	496	455	497	0	344	471	166	465	476	310	618	354
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547	420	443	474	0	363	252	90	474	170	236	643	238
616	395	411	494	0	363	309	129	398	447	311	572	306
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577	505	404	498	142	357	228	98	471	464	317	407	142
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637	501	410	516	336	355	272	93	472	469	317	279	124
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610	462	428	411	354	362	230	71	471	420	315	360	348
576	7	460	459	361	404	221	94	449	474	316	350	339
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576	68	152	467	349	271	218	96	479	238	321	261	390
592	277	83	371	412	408	196	98	475	326	320	229	457
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591	288	430	464	464	382	207	0	457	330	321	201	542
573	308	443	482	545	452	210	91	475	394	321	231	291
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577	282	399	474	620	527	213	84	477	409	317	265	362
587	284	364	469	596	596	191	80	469	477	279	328	333
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607	255	359	465	583	472	213	72	467	351	316	339	563
582	298	355	464	616	349	205	86	456	476	294	235	275
575	295	369	434	630	444	305	74	475	476	316	231	189
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587	296	437	437	604	575	18	304	475	431	314	201	569
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596	459	418	444	575	485	317	60	389	452	287	169	286
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589	421	229	435	479	381	344	84	466	434	289	138	139
582	351	347	426	590	338	432	85	430	456	300	145	137
522	328	409	435	510	395	306	109	464	453	300	189	280
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416	278	289	288	227	320	437	95	302	260	301	287	253
317	275	187	288	235	321	483	134	297	254	301	300	226
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278	260	294	356	341	334	431	181	337	618	303	221	256
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265	284	288	362	297	235	317	178	252	442	153	204	263
295	290	237	321	288	288	316	160	299	471	218	224	247
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363	334	292	292	235	101	326	207	241	284	336	228	354
313	358	296	321	237	213	325	202	183	385	440	273	287
296	319	284	306	220	223	302	209	153	414	410	226	264
303	295	105	298	238	119	328	178	151	565	307	287	274
426	297	221	300	243	237	330	180	193	397	368	212	272
278	297	206	256	238	123	334	198	305	325	365	208	271
283	274	275	301	244	110	352	184	268	287	373	229	275
289	285	284	237	248	208	565	183	271	317	366	220	302