EFFECTS OF SOME WEATHER PARAMETERS AND RESERVOIR INFLOW PATTERN ON HYDROELECTRIC POWER GENERATION IN KAINJI DAM NIGER STATE, NIGERIA

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FACULTY OF SCIENCE

AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE (M.Sc) IN GEOGRAPHY

DEPARTMENT OF GEOGRAPHY
FACULTY OF SCIENCE
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MAY, 2016

DECLARATION

I declare that this dissertation titled "Effects of Some Weather Parameters and Reservoir Inflow Pattern on Hydroelectric Power Generation in Kainji Dam, Niger State" was carried out by me in the Department of Geography under the supervision of Prof E.O Iguisi and Dr. Yusuf Y. Obadaki.

This work is neither a duplication of another work nor has it been submitted before to Ahmadu Bello University or any other institution of higher learning for the award of any certificate. Texts consulted and other sources have been duly acknowledged.

………………….........   ….………………………….

Ayodeji Benjamin Adegbehin   Date

CERTIFICATION

The dissertation entitled “Effects of Some Weather Parameters and Reservoir Inflow Pattern on Hydro Electric Power Generation in Kainji Dam, Niger State”, by Ayodeji Benjamin Adegbehin meets the regulations governing the award of the degree of Master of Science in Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

Prof. E.O. Iguisi ________________________ ______________________
Chairman, supervisory committee Sign Date

Dr Yusuf Y. Obadaki ________________________ ______________________
Member, supervisory committee Sign Date

Dr A.K Usman ________________________ ______________________
Head, Department of Geography Sign Date

Prof Kabir Bala ________________________ ______________________
Dean, Post Graduate Studies Sign Date

DEDICATION

This work is dedicated to Almighty God, my late father Prof. J.O. Adegbehin who died on the 24th January 2016, my mother Mrs Yemisi Adegbehin, my wife, daughter, brother and sister and to all those who contributed to the success of this work in one way or the other.

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ABSTRACT

The focus of this empirical study is to investigate the effect of weather parameters and reservoir inflow patterns on hydroelectric power generation in Kainji dam Niger state, Nigeria. Investigation was conducted using rainfall, temperature, evaporation, reservoir inflow and the data on amount of power generated for the period of thirty years from Kainji Hydropower Station. Hypothesis was tested for relationship between the weather parameters (rainfall, temperature, evaporation) and reservoir inflow on the amount of power generated using Pearsons product moment correlation coefficient. The data collected was used to show the trend pattern of each parameter for the time frame of study. The amount of power generated for the period of study was analyzed to know the season that more electricity was generated. The seasons were divided into wet season (April-October) and then the dry season (November-March). The mean annual electricity in mega watts per hour in each season was found before getting the overall mean for the dry season and overall mean for the wet season for the thirty years period (1985-2014). The trends of the parameters for the time frame of study were shown using trend lines. The study reveals that dry season has more electricity generated (270 mwh) than the rainy season (202 mwh). The low flow period in Kainji reservoir is between March and July of each year, while April marks the beginning of the wet season period in the area, this must have contributed to the low amount of power generated during this period. Precipitation, evaporation and temperature show an increasing trend, while the reservoir inflow pattern show a decreasing trend, while all parameters exhibit fluctuations at various levels. The research indicated that rainfall and reservoir inflow have strong relationships with the amount of power generated, with 0.83 and 0.92 correlation coefficients while temperature with 0.21 and evaporation with 0.33 do not have significant relationship with the amount of power generated. It was recommended that the government should encourage the use of other alternative sources of electricity generation in order to meet the growing demand in electricity. Also, the remaining 4 turbines in Kainji reservoir should be installed as it would increase the number of the turbines in the station from 8 to 12 turbines as initially designed. This will help to increase the reservoir generating capacity to 960 Megawatts instead of only 760 Megawatts.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Weather is the condition of the atmosphere in a particular place at a particular time. The elements of weather are precipitation, wind, evaporation, humidity, pressure, sunshine and temperature (Farlex, 2013). In this study the weather parameters that are of interest are rainfall, evaporation and temperature. Water is a transparent fluid which forms the world's streams, lakes, oceans and ground water. It is also the major constituent of the fluids in all living things. It as a chemical compound, which contains one oxygen and two hydrogen atoms that are connected by covalent bonds (Gleick, 1993). Water is a liquid at standard ambient temperature and pressure, but it often co-exists on Earth with its solid state, ice; and gaseous state, steam (water vapor) (United Nations Environmental Programme, UNEP 2002).

Water on earth moves continually through the water cycle of evaporation and transpiration (evapotranspiration), condensation, precipitation, and runoff, usually reaching the sea. Evaporation and transpiration contribute to the precipitation over land. Water used in the production of a good or service is known as virtual water. Safe drinking water is essential to humans and other life forms even though it provides no calories or organic nutrients. Access to safe drinking water has improved over the last decades in almost every part of the world, but approximately one billion people still lack access to safe water and over 2.5 billion lack access to adequate sanitation (United Nations Children Funds, UNICEF 2012).

The sun powers the hydrologic cycle which gives the earth its water. In the hydrologic cycle, atmospheric water reaches the earth's surface as precipitation. Some of this water evaporate, but much of it either percolates into the soil or becomes surface runoff. Water from rain and melting snow eventually reaches ponds, lakes, reservoirs, or oceans where evaporation is constantly occurring. Thus, the water cycle is complete. According to United State Department of Interior nature ensures that water is a renewable resource (USDI, 2005).

Energy cannot be created or destroyed, but its form can change. In generating electricity, no new energy is created, but energy is transformed from one form to the other. Hydroelectric power comes from water at work, water in motion. To generate hydro electricity, water must be in motion. This is kinetic (moving) energy. When flowing water turns blades in a turbine, the form is changed to mechanical (machine) energy. The turbine turns the generator rotor which then converts this mechanical energy into another energy form, which is electricity. Since water is the initial source of energy, we call this hydroelectric power.

Temperature and reservoir inflow are also important in the generation of electricity, this is because an increase temperature causes stronger water evaporation from the continents and from all water surfaces. Evaporation reduces available river water, but at the same time more evaporated water results in more precipitation. Therefore this effect must be investigated precisely for each water basin, because the water evaporated from reservoir is a direct loss to the discharge and for the energy production (USDI, 2005).

Evaporation and discharge losses has a bigger importance in dry areas with relatively shallow reservoirs which has a large surface area, because this will affect the amount of water required for energy production. The term reservoir inflow refers to the amount of water entering a reservoir expressed in cubic meter per second. Water reservoirs are made to provide multiple benefits, like flood control, stabilized electricity through proper management of reservoir peak inflow, average outflow, discharge, and minimum inflow. In many cases, reservoirs provides domestic, drinking and industrial water supply for man (United State Department of the Interior, 2005).

Globally, hydropower is a very significant contributor to energy systems. Large dams became prominent instrument for economic development in the past century, as the number of large dams stood at 5000 around 1950s according to International Commission on Large Dams (ICOLD, 1998). Nigeria is endowed with abundant water resources and it is clear that the country is blessed with a huge hydropower potential (Okoro, 2006). Annual rainfall decreases from 3400 mm in the south central shores of the Niger Delta to 500 mm over the northern boundaries of the country, with a perched increase to 1400 mm over central Jos Plateau region. Similarly, the eastern ranges of Adamawa and Cameroon boundaries experience elevated precipitation as high as 2000 mm relative to contiguous low areas of the country. Rainfall duration is longest in the south and decreases progressively northwards. In the southern areas, precipitation lasts over 8 months of the year, whereas, at the extreme north, annual rainfall duration can be less than 3 months (Olaniran, 1986).

Kainji dam construction was carried out by Impregilo (a consortium of Italian Civil Engineering Contractors). It began in 1964 and was completed in 1968. The total cost was estimated at US$209 million, with one-quarter of this amount used to resettle people displaced by the construction of the dam and its reservoir, Most of the structure is made from earth, but the centre section, housing the hydroelectric turbines, was built with concrete. This section is 65 metres high. Kanji dam is one of the longest dams in the world. The Nigerian government has invested a lot on the dam. It was designed to have a generating capacity of 960 Megawatts; however, only 8 of its 12 turbines have been installed, reducing the capacity to 760 Megawatts. This might be another reason for the epileptic power supply experienced in the country (Ifabiyi, 2011). The dam generates electricity for all the large cities in Nigeria. The dam has a single-lock chamber capable of lifting barges 49 metres. The reservoir is about 135 km long and about 30 km across at its widest point with a surface area of 1,250 km^2. It is capable of storing 15.5 x 10^9 m^3 water of which 92 percent can be drawn down for power generation (Ifabiyi, 2011).

1.2 STATEMENT OF THE RESEARCH PROBLEM

According to (John and James 2011), worldwide energy consumption is projected to double between 2007 and 2035. Scientists predict that the global population will increase to over 10 billion by 2050. Our current population is already taxing current energy and water resources. These demands will grow with the global population. The next forty years promise to challenge energy and water resource management. Hydropower is one response to these challenges; in many areas of the world. Dams provide energy and regulate water supply. However, evaporation, temperature rainfall pattern will alter global hydropower production. The changes in these patterns are mostly caused by climate change.

Each region of the globe faces unique challenges as our climate changes. Floods, droughts, rapids glacial melt, increasing temperatures and variability in timing, location and amount of precipitation are all symptoms of climate change that will affect hydroelectric generation by increasing water resources and hydropower potential in some regions, diminishing them in others. Though all nations are susceptible to effects of global climate change, developing countries are inherently more vulnerable to the effects of climate change disruptions because they have fewer disposable resources to spend on unexpected extreme weather events and on adapting to long-term alteration (Evans, 1992).

According to Energy Commission of Nigeria hydropower is dependent on river discharge to create electricity. Generally, the lower the river discharge, the less electricity hydropower facility can generate (ECN, 2004). Amount of water in a hydropower station dam, is the normal hydrological and operational events brought about by factors such as rainfall, evaporation, seasonality in the river basin, variation in user water demand and natural river inflow into the reservoir.

In Nigeria, rainfall takes the centre stage from the birth of a new year moving from the southern to the northern part in late May and June. The northern part of Nigeria has the lowest amount of rainfall. The rain continues in some part of the country till even October and November, although Nigeria climate has its own variability. The peak of rainy season in most parts of Nigeria occur in August with more than enough for South as well as part of the Northern region of the country (Okoro, 2006).

After the rain, comes the dry season, which is mostly experienced in the northern parts of the country, wells and rivers are dry up, thereby reducing the water in the reservoir of many rivers which in the long run would diminish dam electrical output **(**Okoro, 2006). Many scholars have carried out studies on climate related issues on hydro power stations, all aimed at proffering solutions to meet the challenging increasing demand in electricity.

MCnally (2009), worked on hydropower vulnerability caused by climate change impacts in the Mekong River located in South Asia. The main purpose of the study was to assess how climate change impact hydroelectric production as the area is predicted to see massive climate change effects. Numerous hydropower facilities are situated along the Mekong River as well as along its tributaries. In fact, over 130 hydropower projects are either planned or operating along this river. The Mekong River flows through China, Myanmar, Thailand, Laos, Cambodia, and Vietnam all of which are rapidly developing countries with increasing energy, food, and water demands. The assessment was carried out through an extensive literature review that investigated current trends in hydropower as well as climate change effects predicted to influence hydroelectric production. The study reveals that climate change affects evaporation rates, annual river discharge, precipitation, and glacial melt. However, more emphasis was on the socioeconomic impact of power supply to the residents around the study area and its effect on their livelihood, and not hydropower generation. The study did not critically look into the issue of temperature, rainfall pattern and its effect on hydropower generation.

Bunyasi (2012) worked on vulnerability of hydro-electric energy resources in Kenya due to climate change and it was observed that the major challenges experienced in the hydro power station is high fluctuating river flows, sediment laden floods, scarce sporadic precipitation and extreme transpiration rate.

Salami and Olukanni (2012), worked on the assessment and impact of hydropower dam reservoirs outflow on the downstream river flood regime in Nigeria. Their focus was on the main cause of flood in the downstream regime which was identified to be the sudden release of water from the hydropower dams located upstream of the study area. The study revealed that the sudden release of flood water is not due to normal operation at the hydropower stations in Nigeria, but is due to sudden discharges at the reservoirs located in the Niger Republic and the Republic of Mali. This leads to excess releases at Kainji in order to create enough space for the incoming flood water. This automatically forces the release of water at Jebba and thus creating flood problem downstream. In that study, reservoir inflow and outflow were the main focus and not the amount of rainfall, temperature and evaporation received or power generated by the dam.

Abdul-Aziz (2014), worked on the nature and implication of water level fluctuations in Shiroro dam, Niger state, Nigeria. The study revealed that Shiroro dam causes loss of farmlands to those riparian communities that farm in water channels believed to be fertile for cultivation. It also shows that stability of agricultural activity depends on seasons and the crops produced. Lastly it shows that an increase in water level increases power generation while a decrease in water level decreases power generation. The study focused more on the inflow and outflow of water in the reservoir, its impacts on agricultural activities and the effects on the lives of the residents and not on the evaporation, temperature, rainfall pattern of the dam.

Salami, Sule and Okeola (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. They found out that there is slight decrease in reservoir inflow, which may lead to shortage of water for hydropower generation in future. The study is similar to this work however, the rainfall data used for the analysis covered just a period of nine years while this work, intends to use a rainfall, reservoir inflow, evaporation and temperature data for the period of thirty years since data from the upstream of the river is not accessible, this will help to get a more reliable conclusion of the effect of these variables on the hydroelectric power generation in Kainji reservoir, Niger state, Nigeria.

Hence, this research attempted to answer the following questions:

(1) What is the trend of rainfall, evaporation, temperature and reservoir inflow in the study area?

(2) What is the amount of power generated during the rainy and dry seasons within the last thirty years (1985-2014)?

(3) What are the effects of rainfall, evaporation, temperature and reservoir inflow variability on electric power generation?

1.3 AIM AND OBJECTIVES

The aim of this study is to examine the effect of some weather parameters and reservoir inflow patterns on hydroelectric power generation in Kainji reservoir, Niger State, Nigeria. This was achieved through the following specific objectives, to:

(i) determine the trend of rainfall, evaporation, temperature and reservoir inflow patterns in the study area.

(ii) quantify the amount of power generated during the rainy/dry season within the last thirty years(1985-2014) in the study area.

(iii) examine the effect of rainfall, evaporation, temperature and reservoir inflow patterns on amount of power generated in the study area.

1.4 RESEARCH HYPOTHESIS

There is no significant relationship between rainfall, evaporation, temperature and reservoir inflow patterns and hydroelectric power generation in Kainji dam

1.5 SCOPE OF THE STUDY

This study is based on the effect of rainfall, evaporation, temperature and reservoir inflow patterns on hydroelectric power generation in Kainji reservoir. The purpose is to analyze this parameters and their effects on hydro electric power generation, by using data collected from amount of power generated, rainfall, temperature, evaporation and reservoir inflow in the dam for the period of thirty years (1985-2014).

1.6 JUSTIFICATION OF THE STUDY

Energy is one of the commodities on which the provision of goods and services depend. Its availability and consumption rate is an economic index for measuring the development of any community (Nakicenovic, 1996). In Nigeria, there is a limitation to power supply from the National grid which has adversely affected the economic and social development of the populace. This really necessitates the need for decentralized power source as a viable alternative to which hydro power schemes readily fits in. Major rivers and dam's development provide an enviable energy potential for the exploitation of hydro energy in Nigeria.

Hydropower is derived from the potential energy available from water due to the height difference between its storage level and the tail water to which it is discharged. Power is generated by mechanical conversion of the energy into electricity through a turbine, at a usually high efficient rate, depending on the volume of water discharged and height of fall (or head). Hydropower can be large or small although, there may not be any international consensus on the definition of small hydropower, but an upper limit of 30 megawatts (MW) has been considered as the maximum rating under this dispensation. Small hydro power dams can further be subdivided into mini hydro (<1 MW) and micro hydro (<100KW). Thus, both mini and micro hydro schemes are subsets of the small hydro power (SHP) classification (Raghunnath, 1986). The Kainji dam is a large hydropower station, having an installed capacity of 760 megawatts (MW).

The problem of electricity generation in the country is on the increase on daily basis as both urban and rural dwellers need electricity. Kainji dam is one of the major producers of electricity in Nigeria though not enough to meet the demand of the growing population; this is why the need for the assessment of the water resources in this area becomes so important in order to meet internal and even external demands.

Ever increasing demand for electricity has intensified the quest for generation per kw and for an increase in production. The dam, river discharge and turbines alone will not improve productivity if significant deterioration of natural condition occurs. It is in the light of this that the study is justified.

1.7 ORGANIZATION OF THE STUDY

This research is divided into five chapters. Chapter one introduces the research work with a general background to the study, statement of research problem, aim and objectives, scope of the study, justification of the study and the organization of the study. In chapter two a review of similar research carried out in different parts of the world, including the works carried out in Nigeria. Chapter three presents the study area and research methodology, that is method of data collection and analysis. Chapter four contains the statistical analysis and interpretation and finally Chapter five contains summary, conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 HISTORY OF DAMS

The building of dams started long time ago. The Saddel Kafara dam built in Egypt is believed to be the oldest dam in the world. It was built in about 2700BC located on the Nile River about 32 km south of Cairo. Also by 1000BC, the Assyrians had built dams across the Tigris River near Samaria and other place in Mesopotamia. The Romans also built many dams; the best known is Cornaldo Earth Dam North of Merida in Southern Spain. The remains of the embankment built for diverting water to large community reservoirs can still be found in Srilanka and Isreal. After the fall of the Roman Empire, the act of building dams hardly advanced until the end of the sixteenth century (Schnitter, 1994).

The construction of dams of appreciable heights and storage capacity became possible after the development of cement concrete and the mechanization of earth-moving and material handling-equipment. The last century witnessed a dramatic increase in the construction of large dams been built word wide, with three quarters of them in industrialized countries. Recently, an estimated 50,000 large dams have been built worldwide especially in developing and emerging countries, and many more been planned. The current context of climate change serves to highlight the relevance of dams. Hydropower plants help to achieve climate change mitigation goals by generating clean renewable energy. Currently 15% of electricity worldwide and 75% of the total electricity from renewable sources is generated by hydropower according to International commission on Large Dams (ICOLD, 2014).

2.2 DAMS AND THEIR SIGNIFICANCE

Dam construction began at the same time as hydraulic engineering, in connection with the significant development of artificial irrigation among the farmer in Egypt, India and China. The erection of dams was necessary for the construction of water-power installations and later for hydroelectric power plants. The use of water resources for energy was the basic incentive for increasing the size and improving the design of dams, as well as for the appearance of hydraulic power systems on numerous rivers (Bazza, 2006).

Dams are built for specific purposes. In ancient times, they were built only for water supply or irrigation. Early in the development of United States, rivers were a primary means of transportation and therefore navigation dams with locks were constructed on the major rivers. Dams have become more complex to meet large power demands and other needs of modern countries. The significance of dams for water management is diverse. The raising of water level and the increase in depth in the upper pool contribute to navigation and timber flotation as well as retention for the needs of irrigation and water supply. The creation of a head at a dam makes possible the use of the river discharge to generate power (Bazza, 2006).

The initial studies to exploit the energy potentials of Niger River in Nigeria were conducted in the 1950s. Those studies culminated in the building of the Kainji dam with a power station having an installed capacity of 960MW in 1968 as well as the Jebba dam downstream which is capable of producing 540MW in 1985. These same studies gave rise to the decision to build a dam across river Kaduna which is a major tributary of the Niger in the area of Shiroro a village near Minna in Niger state. However the generation of hydroelectric power in the Nigerian river system actually started in 1929 when the British owned Nigerian Electricity Supply Company (NESCO) commenced operations as an electric utility with the construction of a hydroelectric power station at Kurra falls in Plateau State (Zarma, 2006).

Nigerian's Hydro Potential is high and hydropower currently accounts for about 32% of the total installed commercial electric power capacity (Zarma, 2006). This has led to an upsurge in dam construction in the past three decades in the country. Over 350 dams have been constructed in Nigeria and many more are under construction in different parts of the country. Between 1970 and 2014, three hundred (300) dams were constructed in Nigeria **(**Ezugwu, 2013). The effect of the Sahelian drought of 1972 -1975 aggravated the food shortage in the country prompting the various levels of government to embark on a rigorous policy to increase food production. To achieve this, impoundment of river basins was seen as inevitable to provide sufficient water for year- round irrigation which led to the continuous construction of these dams **(**Ezugwu, 2013).

According to Adams (1985), dams are constructed to retain water at a given point along a draining river without necessarily denying stream flow downstream. Its construction has been perceived as one of the most valuable ways of combating the problems of water shortage in virtually all semi-arid region of the world.

2.3 SOCIO-ECONOMIC IMPACT OF DAM CONSTRUCTION

2.3. 1 Inundation of Settled Areas and Destruction of Natural Habitats

The construction of storage dam and the subsequent inundation of the reservoir area effectively kill terrestrial plants, forest and displace animals (International Commission on Large Dams [ICOLD], 1998).Dam construction results in decrease in water quality and variable changes in the seasonal timing of water yield (Bruijnzeal, 1990). Dams raise the natural level of rivers, so flooding lands previously settled, farmed or periodically grazed. Dam construction results in the loss of productive land beneath the reservoir. The largest reservoirs in Africa include the Volta Lake formed behind the Akosombo Dam, which covers 8 500 square kilometres, flooding a substantial area of Central Ghana (Canter, 2005). The Kainji Dam in Nigeria impounded 1 200 square kilometres, including 15 000 hectares of farmland while the Lagdo Dam in Cameroon flooded 70 000 hectares, including floodplain land stretching 2-5 kilometres on both banks of the river (Adams, 2002). Dams also result in the destruction of natural habitats. According to Canter (2005) the shift from river to Lake Environment can result in the reduction of species diversity. Dams may lead to the loss of rare flora and fauna species. Impoundments lead to decreased woodland thereby adversely affecting wildlife communities. This leads to decreased hunting and associated uses of medicinal herbs are also lost. Furthermore, decreased forest plant communities lead to decreased timber production and attractiveness of an area to recreationists (Canter, 2005).

2.3.2 Resettlement of the Population displaced by Dams

The creation of large dams in Africa is responsible for the relocation of large numbers of people. The Kossou Dam in the Ivory Coast displaced 85 000 people, the Akosombo Dam 84 000, the Kariba Dam in Zimbabwe 57 000, the Kainji Dam 55 000 and the Lagdo Dam 35 000 people (Adams, 2002). The Aswan High Dam on the Nile displaced an even greater number of people, 120 000 Nubians, both in Egypt and Sudan (Adams, 2002). The economic and human costs of resettlement are huge. The financial costs of resettlement include compensation or rebuilding of settlements and infrastructure and the actual translocation. There is also the human cost of the stress caused by uprooting (Scudder, 2005).

2.3.3 Causes Spread of Diseases

Large dam projects often lead to the spread of schistosomiasis and other communicable diseases. Newson (2007) notes that devastating water borne diseases are introduced by reservoirs and their associated irrigation works. Furthermore, Newson (2007) argues that dams have reduced the quality of drinking water for hundreds of millions of people. Clarke (2001) states that when large new volumes of water are created, the risk of disease in tropical countries rises sharply. The diseases associated with dams include schistosomiasis, yellow fever, malaria, river blindness and liver fluke infections. Adams (2002) argues that although water borne diseases are widespread in African floodplains, dam construction can increase their prevalence. According to Tucker (2003) water resource development projects create additional habitats for disease vectors beyond those already present. Water borne diseases lead to debilitation and vulnerability to other diseases. This results in working hours being lost due to illness and medical costs increasing (Clarke, 2001). The Kariba Dam caused devastating diseases among the Tonga people (Bond and Manyanya, 2002). The Gezira Irrigation Scheme in Sudan increased the prevalence of schistosomiasis, malaria and yellow fever in the region (Canter, 2005). Moreover, Clarke (2001) notes that a survey after the construction of the dam to create Lake Volta showed that the incidence of infection with schistosomiasis among children under 16 years in the resettled areas rose from 3 to 37 percent in just one year.

2.3.4 Loss of Sites of Historical, Archaeological and Religious Importance

River valleys are important sources of African history. The construction of dams results in the loss of African historical, archaeological, cultural and religious sites. These sites are relevant in Africa, where local indigenous people were seen as inferior and culturally static by the European colonizers. African post independence governments are also playing an active role in attempting to discover more about the cultural history of the indigenous peoples as a way of promoting nationhood (Brokensha and Scudder, 2008).

2.3.5 Pollution and Flooding

Dam construction can lead to noise and visual pollution. Noise is generated at the impoundment construction site during the construction phase (Canter, 2005). Complaints of noise nuisance generally arise when a noise interferes with work, communication, recreation or sleep. Damming can also adversely affect the visual quality of an area. Furthermore, it can result in the water resource producing a bad odour. This reduces the attractiveness of the area to recreationists (Canter, 2005). Preservationists argue that free flowing rivers should be left intact in order to avoid spoiling the beauty of the landscape (Henwood and Coop, 2003). Dam construction can also alter seasonal flow distribution as shown by Baker and Wright (1978) in the study of Murray River in Australia; the alterations were such that winter spring flows are reduced, while the summer and autumn flows increased. The operation of hydropower dams often leads to environmental and ecological problems. When inflows are low, energy output from hydropower sources are limited, water may be released in adequate quantities from the reservoir, and this can affect ecological balance of the river downstream the hydropower dam on the other hand. Discharge from hydropower dams can entails large water outflow which can cause flooding to adjoining lands downstream of the dam, which if the flood plains are regions of economic, social and agricultural activities, extensive damages will be incurred in the process. In Nigeria, this is particularly so, as the river banks are used by farming communities. The operation of hydropower dams in Nigeria has been based on conventional water release rule instead of using scientific analysis to determine the reservoir regulation policies (Sule, 2003).

2.3.6 Social and Cultural Disruption

Canter (2005) notes that during the dam construction phase there can be social conflict between the local villagers and some dam construction workers that are foreign. Foreign construction workers may disregard and disrespect local culture and authority. People displaced by dam construction maybe moved to land claimed by others. Friction can occur, arising from the resentment felt by the original owners of the land towards the newcomers who have been foisted on them. The resettled people may also be angry over having had to leave their old lands (Brokensha and Scudder, 2008). Dam construction can also cause loss or damage of cultural heritage through land reclamation and irrigation projects. During the construction of the Bonsma dam, in south Afrrica, remains of human bodies buried under the reservoir site were exhumed and all buried in one hole which profoundly disturbed the locals communities (Ayanda, Ludwig and Robert, 2013).

2.3.7 Disruption of Transport, Communication and Increase in Occurrence of Drowning

Canter (2005) notes that a dam can be a barrier leading to the disruption of transport and communication. This results from the replacement of a relatively narrow river by a wide dam. While, the occurrence of drowning may increase due to dam construction as people may drown while fishing or swimming.

2.3.8 Constant Supply of Water for Domestic, Industrial, Energy Production and Irrigation Purposes.

Dams ensure a constant supply of water for domestic, industrial, energy production and irrigation purposes. Dams provide a balanced supply of water for all seasons and conditions (Clarke, 2001). Dam construction is of great significance as most parts of Africa have relatively undeveloped surface water, while most of the population lacks access to improved water supply. In fact forty percent (40%) of the population in Africa has no access to potable water (Mazvimavi, 2010). Lack of access to clean water increases the incidences of diseases making it difficult to achieve the millennium development goals. In many African countries dams have been built mainly to provide cities and towns with irrigation, domestic and industrial water. Like in Zimbabwe, Chivero and Manyame for Harare water supply, Mayfair for Bulawayo water supply, Gwenoro for Gweru water supply, Sebakwe for Kwekwe water supply and Mutirikwe for Masvingo water supply. Kariba Dam also harnesses the waters of the Zambezi River to generate hydro-electrical power (Chenje, Sola and Paleczny, 2008). Newson (2007) notes that the benefit of irrigation is stable yields, since weather conditions are largely controlled. The long growing season that permits several crops per year make irrigation economically feasible. Auret (2000) states that the need for irrigation development in

Zimbabwean communal areas is vitally necessary to supplement dry land cropping and to provide food security in grain deficient areas. Irrigation development is of great significance in the face of climate change and the associated increased frequencies of extreme climatic events, particularly El Nino and related droughts. Droughts have over time exerted a heavy toll on the inhabitants and the economy of Zimbabwe which are largely dependent on agricultural production (Yanda, 2010). Dams also provide a constant supply of water for livestock which is important in the face of increased incidences of droughts.

2.3.9 Creation of Employment and other Income generating Activities

Dam construction results in employment creation. People are employed to construct the dam and as management staff. Furthermore, labour needs during dam construction can lead to a population influx resulting in local villagers having an expanded market for their agricultural products (Canter, 2005). Fishing, recreation and tourism may also be enhanced by dam construction thereby creating employment and income. Dams in Nigeria like Kainji, Shiroro Jebba dams and Zimbabwean dams like Kariba, Mutirikwe, Manyame, Chivero, Mazvikadei and Mayfair are used as fishing, recreational and tourist resources (Chenje, Sola and Paleczny, 2008). Furthermore, fish provide communities with animal protein in their diets. A large number of Africa dams have been stocked with fish and are being fished (Chimbuya and Shoniwa, 2008). Volta Lake fish are also a major source of protein in Ghana. The fishing industry rates as one of the most significant benefits of the dam to the Ghanaian economy (Adams, 2002). Fishing and aquaculture also provide food and livelihoods for millions of resource poor people in Southern Africa, and may become even more important to regional food security as the climate changes and other sources of food increasingly become less reliable (Makungwa, 2010).

2.4 RELATED PREVIOUS STUDIES

Many scholars have carried out studies on hydro metrological related issues on dams and hydro power generation, a few that are relevant to this study are outlined below.

Garbrecht and Schneider (2008) worked on the impacts of decadal precipitation variations 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 metre from the top of the conservation pool. Thus, watershed runoff, reservoir inflow and flood releases were highly sensitive to decadal precipitation variations. Yet, the only reservoir operation that appeared to be impacted by decadal precipitation variations 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. The lowering of the conservation pool elevations during dry periods was moderate and did not impact reservoir operations or the water supply function of the reservoir, but can impact commercial and recreational activities that are associated with access to the shoreline, such as utilization of boat ramps, access to marinas, and use of beaches and waterfront campgrounds.

The findings also revealed that reservoir sediment load is sensitive to decadal precipitation variations, due to the exponential relationship between stream flow and sediment transport capacity. However, reservoir sedimentation cannot be controlled by reservoir operations and must be addressed by soil conservation measures and stream stabilization in the watershed itself with regard to hydrologic and environmental modeling. In conclusion the study demonstrated the important role that decadal precipitation variations may have on watershed hydrology and suggested that decadal precipitation variations deserve careful consideration in hydrologic and water quality in Central Oklahoma.

Contreras and Cuba (2008) researched on the potential impact of climate change on the energy sector in the Caribbean region. The study revealed that the Caribbean region faces a unique and challenging situation with respect to energy for sustainable development. The findings reveals that climate change is expected to have great environmental and socio-economic consequences for the Caribbean countries, where changes in temperature and precipitation patterns and changes in the intensity and frequency of extreme weather events are observed (IPCC, 2007). Some of these effects has tangible and increasing implications for the region's energy security, particularly with regard to energy production and use.

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.

Renwick, Mladenov, Purdie, Mckerchar and Jamieson (2010) carried out a research on the effects of climate variability on renewable electricity in New Zealand. The study focused on the influences of large scale climate signals (the El nino Southern oscillation, the inter decadal pacific oscillation, and anthropogenic climate change) upon renewable electricity supply, and demand for electricity. The researchers noted that climate change presents the energy sector and the renewable component especially, with significant risks, challenges and opportunities. The larger the magnitude of global and regional changes in the climate system, the greater the challenges for New Zealand. Beyond the gradually changing background climate, a major issue for the sector will be the changing seasonality of the climate for renewable generation, changing patterns of demand, and the changing risk profile of extreme weather and climate events.

Lastly the study suggested that for improvements, information from this work must be in a form that enables those who produce, sell, transmit, distribute and consume electricity to make good decisions. Innovative solutions will be required to provide not just the quantity of energy required, but to ensure it is available in the right place at the right time to meet user needs. A key part of this process will be the availability of information to energy users so they can configure their demand to meet their needs and minimize costs. New technologies, management approaches and information on climate change variability should be used, as this is a vital tool to help energy companies to define, deploy, and operate an effective and efficient electricity industry.

Harrison, Whittington and Gundry (1998) looked at climate change impacts on hydroelectric power in Edinburgh, United Kingdom. They focused on anthropogenic emissions of greenhouse gases, which are expected to lead to significant changes in climate over the next century. According to the researchers one of the many potential effects is that river catchment runoff may be altered and this could have implications for the design, operation and viability of hydroelectric power stations. Also Droogers (2009) worked on climate change and hydropower, impact and adaptation costs in Tana basin Kenya, the overall objective of the study was to undertake a rapid assessment on the impact of climate change on hydropower generation in the basin using the WEAP (water evaluation and planning tool) approach. The analysis showed that the impact of climate change without any adaptation strategies leads to rise in the cost of about $ 2 million to of $ 66 million for maintaining the hydropower, irrigation and drinking water sector.

Mumba and Thompson (2005) studied the hydrological and ecological impacts of dams on the Kafue flats floodplain system, Southern Zambia. They looked at the changes and their potential consequences which include wetland ecosystems been impacted by dams and other hydrological interventions resulting in both foreseen and unexpected consequences. The study revealed that hydrological and vegetation changes impacted the habitat of wildlife and colonization of parts of the floodplain by the invasive alien plant, *Mimosa pigra*.

Similarly, Martin, Simon and Kigomo (2013) examined sustainable catchment management: assessment of sedimentation of Masinga reservoir and its implication on the dam's hydropower generation capacity. The study reveals that Masinga dam is the largest Dam of the seven forks hydro electric power project with a design capacity of 1,560 million m^3. It has a full operation surface area of 125 km^2 and was commissioned in 1981. Masinga catchment covers about 6,255 km^2. The study reveals the roles of the dam which are electricity generation with an installed capacity of 40MW, regulating water flow into subsequent dams and controlling downstream flooding. However loss of water storage capacity due to increased dam sedimentation associated with watershed activities, river characteristics, and reservoir design threatens its functionality. It further reveals that Masinga dam had lost about 215.26 M m^3 (13.59 %) of its design storage capacity to sedimentation in 2011. This informed the need to develop an effective catchment management strategy to improve the dam's sedimentation regime, while Masinga catchment rivers and Masinga dam are jointly affected by varied catchment parameters, including but not limited to precipitation, temperatures, vegetation cover and anthropogenic activities.

Martinus (2003) assessed the impact of land use and climate changes on river flow and electricity generation: case study at Citarum watershed of Bandung district, Indonesia. The study was aimed at evaluating the impact of land use and climate changes scenarios on river flow at Nanjung (Upper watershed) and on electricity generation. The result of analysis revealed that if the forest cover were not increased to more than 25%, the frequency of producing electricity power of less than 100 Gwh during dry season will increase.

Batalla, Gomez and Kondolf (2005) worked on hydrological effects of dams and water diversions on rivers of Mediterranean climate regions using California as the case study. The study revealed that rivers in Mediterranean climate and other semi arid regions tend to be more heavily impounded and thus their hydrology more strongly affected than rivers in humid climates because demand for water is greater (to supply irrigated agriculture) and runoff is out of phase with demand. The impounded runoff index (ratio of reservoir capacity divided by mean annual runoff) is 0.8 on the Sacramento and 1.2 on the San Joaquin Rivers of California, much higher than rates encountered in humid Atlantic climate regions. As a result of these high levels of impoundment, the overall magnitude and seasonal distribution of flows has changed substantially. Flood peaks tend to be reduced on the Sacramento and San Joaquin river basins, while on many rivers, summer base flows have increased to supply irrigation diversions downstream, creating a flatter hydrograph that no longer supports dynamic channel processes and the aquatic ecosystem that depends upon such channel dynamics and vegetation encroaching in the formerly active channels of many rivers in response to reduced flood scour and sediment supply.

Similarly, Hamududu and Killingtveit (2012) assessed climate change impacts on global hydropower; the aim of the study was to evaluate the changes in global hydropower generation resulting from predicted changes in climate. The study used ensemble simulations of regional patterns of changes in runoff, computed from global circulation models (GCM) simulations with 12 different models. Based on these runoff changes, hydropower generation is estimated by relating the

Fig 3.1: Niger State showing Kainji Reservoir

Source Modified from Nigeria Topographical Map

runoff changes to hydropower generation potential through geographical information system (GIS), based on hydropower generation data obtained from the United States Energy Information Administration (EIA), Food and Agriculture Organization of United Nation (FAO) and United Nations Environment Programme (UNEP) investigating many countries. The study revealed the possibility of substantial variations across regions and even within countries. Globally, hydropower generation computations show a very slight increase around year 2050 of about 0.46 TWh per annum. However, different countries and regions of the world will have significant changes, some with positive and others with negative changes. This study therefore provides general estimates of regional and global perspectives of the probable future hydropower generation scenarios.

Oyebande (2012) worked on combating climate change impacts on water availability and energy production. It was observed that enhancing energy security and reducing climate change intensity and its impacts are conflicting objectives that require tradeoffs, as long as the quality, quantity and accessibility of water resources are declining, the promotion of supply of reliable, affordable and sustainable energy is at stake. Therefore, water security is an additional dimension that must be taken into account when planning future energy systems. Thus the study revealed that the challenges surrounding water and energy consumption in the production of energy include developing and making available new technologies and demand management approach that will reduce higher thermal consumption, improve methods for predicting water and energy related impacts of climate change, increase the use and reuse of impaired water for cooling and process requirements, decrease the energy required for water treatment and remedy situations in which water supply limits energy production (inter-basin water transfer, rainwater harvesting, desalination, water treatment and recycling evaporation suppression on reservoirs, lakes). The study reveals that Nigeria is endowed with abundant renewable energy resources like solar radiation 3.5 – 7.0 kWh/m^2-day, wind 2 – 4 m/s, large hydro power (11,250MW), small hydropower (735MW) as well as biomass among others, which have minimal or zero supply logistic problems (ECN, 2007).

The study suggested that hydropower should also target more micro and mini projects that is more environmental friendly and less financially attractive, as proper harnessing of these resources could lead to decentralized use and local implementation and management, thereby making sustainable rural socio-economic development possible through self-reliance and the use of local natural resources. Policy makers must make renewable energy development a priority policy of government at all levels. Lawmakers should also develop appropriate legal, regulatory and institutional frameworks that de-emphasize over-dependence on fossil fuels.

Enete and Alabi (2011) also examined on the potential impacts of global climate change on power and energy generation. The aim of the study was to examine the influence of climate change on power generation. Literatures were identified for review through a comprehensive search by using electronic and non-electronic databases, related published literature and documents were searched in a systematic way using a range of key words relating to climate change impacts and energy. The study revealed that climate change undermines power and energy production by increasingly depleting renewable and non-renewable sources, creating resources scarcity as well as damage to infrastructure. The findings also reveals that climate change undermine environmental dimensions by increasing sea-level rise, extreme weather events, land degradation and pollution.

In order to reduce climate induced threats on power sector, the study suggested that efforts should be geared towards ensuring that our energy sector withstand the changes to our climate that are already underway by optimizing energy mix, developing low carbon and renewable energy, formulating relevant law, regulations, promoting technology advancement and economic engineering.

Cole, Elliott and Strobl (2014) worked on climate change, hydro-dependency and the African dam boom. The study examined Africa's increasing reliance on hydropower in view of climate change induced variations in rainfall and the potential power outages that may result, using a continent wide river flow model and IPPC (Intergovernmental Panel on Climate Change) climate change scenarios which shows that current plans for African dam building are fairly matched with river flow predictions. The study reveals predictions of an increase in extreme weather events and reduced rainfall for certain countries which means there are still viability concerns for certain planned hydropower investments. Mukheibir (2007) also carried out research on possible climate change impacts on large hydroelectricity schemes in Southern Africa. The researcher noted that there is need for developing countries, such as South Africa, to reduce their coal dependence on energy generation, and embrace other cleaner technologies like hydroelectricity which is one of the options. Potential numbers of large hydro sites have been identified in Southern Africa, which form part of the Southern African power pool. However, limited information exists on the impact of climate change on these sites and its effect on the viability of the hydroelectric schemes. This made the researcher use the downscaled global circulation model information, to discuss projected climate impacts and the potential impact these may have on future hydro schemes. The study reveals that the

(a) African continent has been warming through the 20th century at the rate of about0.05°C per decade, with slightly larger warming in the June to November seasons than in December to May.

(b) In year 2000, the 5 warmest years in Africa had all occurred since 1988, with 1988 and 1995 being the two warmest years.

(c) The 2070 projections for temperature in Southern Africa indicate an increase everywhere, with the greatest increase in land and the least in the coastal regions.

(d) Temperature is expected to increase by approximately 1°C along the coast and 3 – 5°C in land of the coastal mountains, while as temperature increases, changes in evaporation are anticipated and increases in temperature will have a corresponding increase on evaporation.

(e) Using the results of the simulated change for 2070 in seasonal rainfall, it can be observed that both RCM (Regional Climate Models) predict dryness over the tropical western side of the sub-continent, for the months of October, November and December. For January, February and March, the models indicate dryness to the west in the tropics, and an increase in precipitation to the east and south east.

(f) The greatest loss of potential water resources from hydroelectric facilities comes from the evaporation of water from the surface of reservoirs. This lost water would have been available for downstream uses as well as for the generation of electricity, while evaporation losses per annum were calculated to be on an average 1.1 metres of depth per square kilometre of surface area.

Bajracharya, Acharya and Ale (2010) worked on changing climatic parameters and its possible impacts in hydropower generation in Nepal (A Case Study on Gandaki River Basin). The main objective of the research is to identify the possible impacts of the climate change and glacier melting on hydropower generation in Nepal. This was carried out by computing hydrological and meteorological data for the Gandaki basin, collecting and computing the hydrological and energy production data from the major hydropower stations, while studying climate change related research which correlates the data in an overall energy perspective. The study revealed that the major impacts of climate change is the change in hydrology of the rivers resulting from anomalies in hydro resources. Water has a significant effect on hydropower development, especially in the dry season.

The condition will affect the dependability of flow and assurance in the long run. The changing climatic parameters results in an unavoidable factor, in the forecasting system of hydropower projects. Investigations shows that,

a. An increasing trend of temperature, enhance glacier melting and formations of glacier lakes in the high Himalaya. This has increased vulnerabilities to hydropower stations and hydro energy generation.

b. Shift of the rainfall seasons also increased the hydrological impacts and challenges dry season flow. Most of the rivers are decreasing and one of the reasons behind this is changing climatic parameters.

c. The flow curve of the analyzed period and rivers shows the flow is decreasing not in a pattern. This will result in the decrease in the full capacity power generation of the plant, which is seen from the power production fluctuations.

d. One of the major impacts of climate change is the change in river hydrology.

Bekoe and Logah (2013) assesed the impact of droughts and climate change on electricity generation in Ghana. The paper analyzed thirty seven years of rainfall in the Volta basin and water level intake in the dam site, on the Volta Lake for hydropower generation to establish whether in reality the main causes of the power rationing due to low water levels in the Akosombo dam was due to drought. The paper revealed that the 1983, 1997, 2006 and 2007 power rationing was truly as a result of hydrologic drought whereas the 2003’s was not. This may be due to effects of previous drought years of 2001 and below average rainfalls in 2002. The paper also reports consequences, resulting from low output in power generation such as loss of revenue, loss of jobs, extra power generation through diesel plants and many more which in monetary terms amounted to several million of United States dollars at a time when the nation was termed a highly indebted poor country according to the Bank of Ghana and World Bank. The paper also suggests that if climate change effects on the water resources of the country are not managed sustainably, drought and floods could affect hydropower generation in the future.

Malley (2011) examined climate change and water resources for energy generation in Tanzania. The objective of the work was to analyze the link of climate change to water shortages for hydro-power generation in the Mtera reservoir, which supply 50% of the hydro-power to the national grid. Literature survey, records collection, analyses and observations were research tools used. The study revealed that, 64% of increasing variability in rainfall over years in the watersheds described declining water levels in Mtera dam. This strong relationship means that climate change is main driver of water shortages for hydropower generation. This suggests a need for national adaptation strategies to water supply shortages. Improvements in the present hydropower sources for water recycling and development of micro-dams for storage of excess water need exploration. Rain water harvesting and recycling seems important adaptation strategies to improving hydrological patterns for water supply to the hydro energy plants in Tanzania.

Similarly, Bunyasi, Onywere and Kigomo (2013) studied sustainable catchment management: assessment of sedimentation of Masinga reservoir and its implication on the dam's hydropower generation capacity. The findings revealed that;

(a) A steady decline in the reservoir inflow rates and the dam inflow is the medium of sediment transfer from the dam's catchment. The sediment loads per cubic meter are greatly influenced by catchment's anthropogenic activities. During the rainy season more sediment loads runs into the dam due to increased stream flow volume and runoff wash effects of the exposed soils. Further reduction in reservoir inflows directly threatens the hydropower generation future of the seven forks project, because Masinga reservoir plays regulatory functions which include storing and releasing water to subsequent plants to sustain optimal power generation especially during low inflows, flood control and sediment trapping. Variations in inflows are brought about by alternating scarce and abundant rainfall pattern.

(b) Precipitation is a key factor controlling the hydrology of the catchment. Precipitation, runoff and sediment yield presents the most intricate hydrological trend due to immense spatial variability of catchment uniqueness and rainfall patterns. Masinga catchment average annual precipitation based on the closest weather station indicates that the amount of precipitation between 1981 and 2011 is steadily declining. Masinga catchment precipitation is decreasing by 3.93 mm annually, therefore for a period of 30 years (1981 to 2011) the annual average precipitation has dropped by 117.9 mm on average. The decreasing catchment precipitation adversely affects both the reservoir sediment load trend and river base-flows especially during the dry spells. It was observed that Masinga catchment mean precipitation fluctuates between 587 and 1,622mm per annum. Even though the average shift in rainfall pattern in the area may not seem significant, the change in precipitation pattern endangers the water resources and limits electricity generation potentials.

(c) Lastly, for the time frame of study (thirty years) temperatures in Masinga catchment has shown an increasing trend resulting to the increase in the mean minimum and maximum catchment temperatures to a value of about 0.260C and 0.150C respectively after every decade. The dry spell is mostly between January and March with the highest mean maximum temperature of 26^0C and 27^0C for the entire study period and since this follows the wet season it results in rapid depletion of water resources. This increases the possibility of soil erosion occurrence during the rainy seasons as soil is left bare and vulnerable while it increases reservoir sedimentation thereby lowering the reservoir capacity which will eventually affect hydroelectric power 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 variation inflow to the reservoir, inter-annual variation 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 variation 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.

Jimoh and Ayodeji (2003) assesed 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 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.

Ifabiyi (2011) also investigated the contributions of reservoir elements to monthly electricity generation in the Jebba hydropower reservoir, Nigeria. The research examined the contribution of ten reservoir elements in electricity generation in Jebba dam, Nigeria. These elements include peak inflow, storage balance, evaporation, minimum inflow, average outflow, peak outflow, average inflow, reservoir level, discharge and minimum outflow. Data on these ten elements were obtained from the hydrology department of the Jebba business district, power holding company of Nigeria, Jebba dam Nigeria. The data collected span for ten years (1989-1999). The results of the cumulative contributions of the factors range from 79.3% in April to 92.3% contributions in December. Frequency analysis showed that storage balance has the highest appearances, featuring in 8 of the 12 months of study, while reservoir level appeared in 2 months of the 12 months. Also, December has the highest elements contributing to the explanations of electricity generation (5 elements). Generally, months of high runoff are known to have lower numbers of elements contributing to electricity generation. This suggests that reservoir management in dry period is more challenging.

The study also observed that outflow variables are more prominent in the months of high runoff, while inflow variables are more prominent in low flow period. The paper recommends that reservoir management should be reviewed along this scenario for better results.

Similarly, Salami, Raji, Sule, Abdulkareem, and Bilewu (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.

From the review presented, it is obvious that a lot of related research works has been carried out on hydro power generation with references to different climatic parameters in many parts of the world, though none has critically looked at the parameters the research wants to investigate simultaneously in the study area. The research intends to provide detailed results on these parameters (rainfall, temperature, evaporation) and reservoir inflow pattern and their impact on hydropower generation in Kainji dam, Niger state, Nigeria.

CHAPTER THREE

THE STUDY AREA AND METHODOLOGY

3.1 THE STUDY AREA

3.1.1 Location

The study area is the Niger River. The river is the principal river of Western Africa extending about 4,180km. Its drainage basin is 2,117,700km^2 in area. The river extends from Latitudes 10^0 00´N to 15^0 00´N and Longitudes 5^0 00´W to 5^0 00´E. The Niger River is the third-longest river in Africa. Its source is in the Guinea highlands in the southeastern Guinea, and runs in a crescent through Mali, Niger, on the border of Benin and through Nigeria (see Fig 3.1). However Kainji reservoir is the main focus.The Kainji reservoir is across the Niger River in Niger State of Nigeria. The reservoir is located on latitude 10^{0} 08´N and longitude 4^{0} 37´E (see Fig 3.2). Kainji lake extends for about 10 kilometres, including its saddle dam, which closes off a tributary valley. The primary section across the outflow to the Niger River is 550m long.

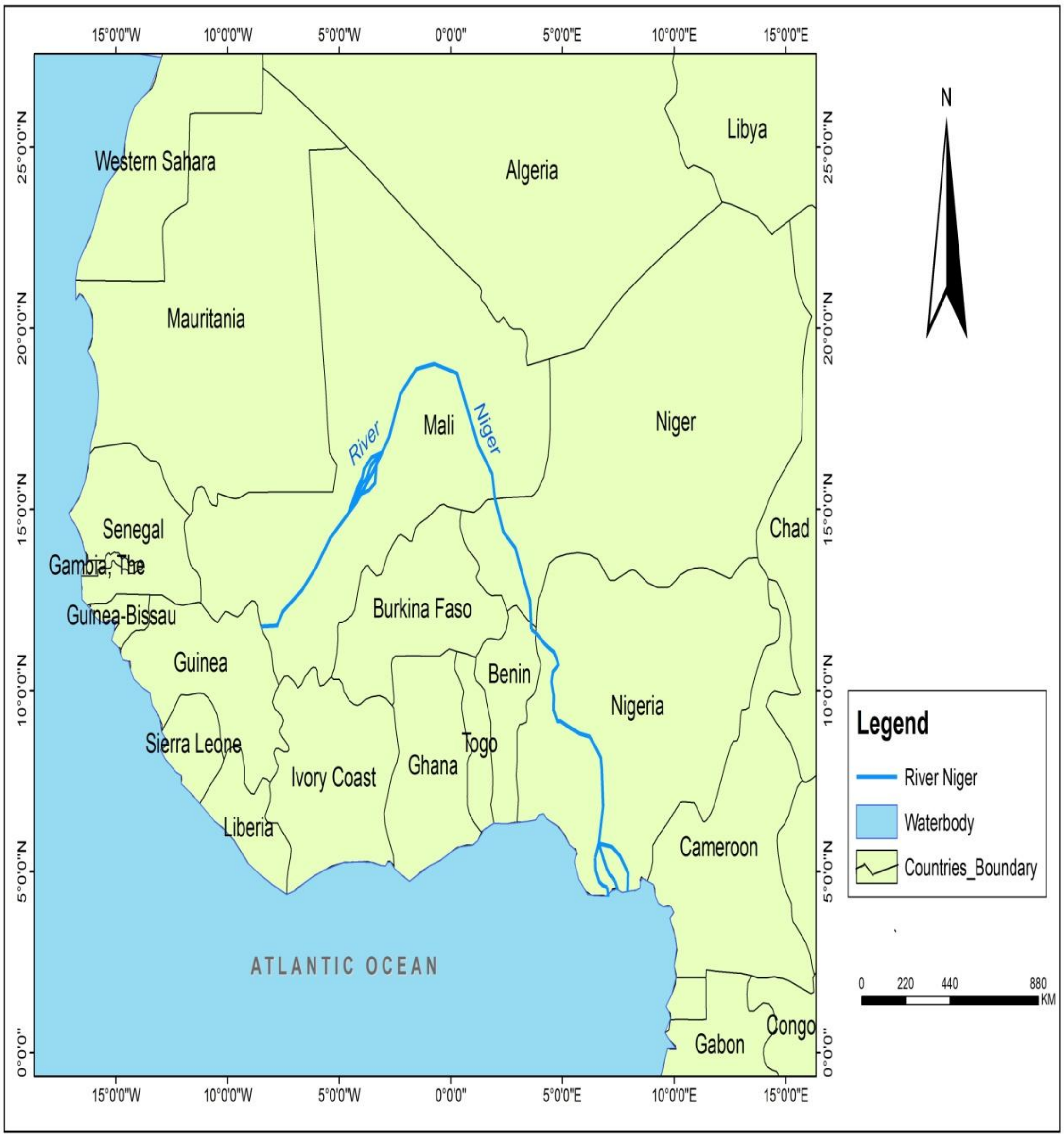

Fig 3.1: Niger State showing Kainji Reservoir
Source Modified from Nigeria Topographical Map

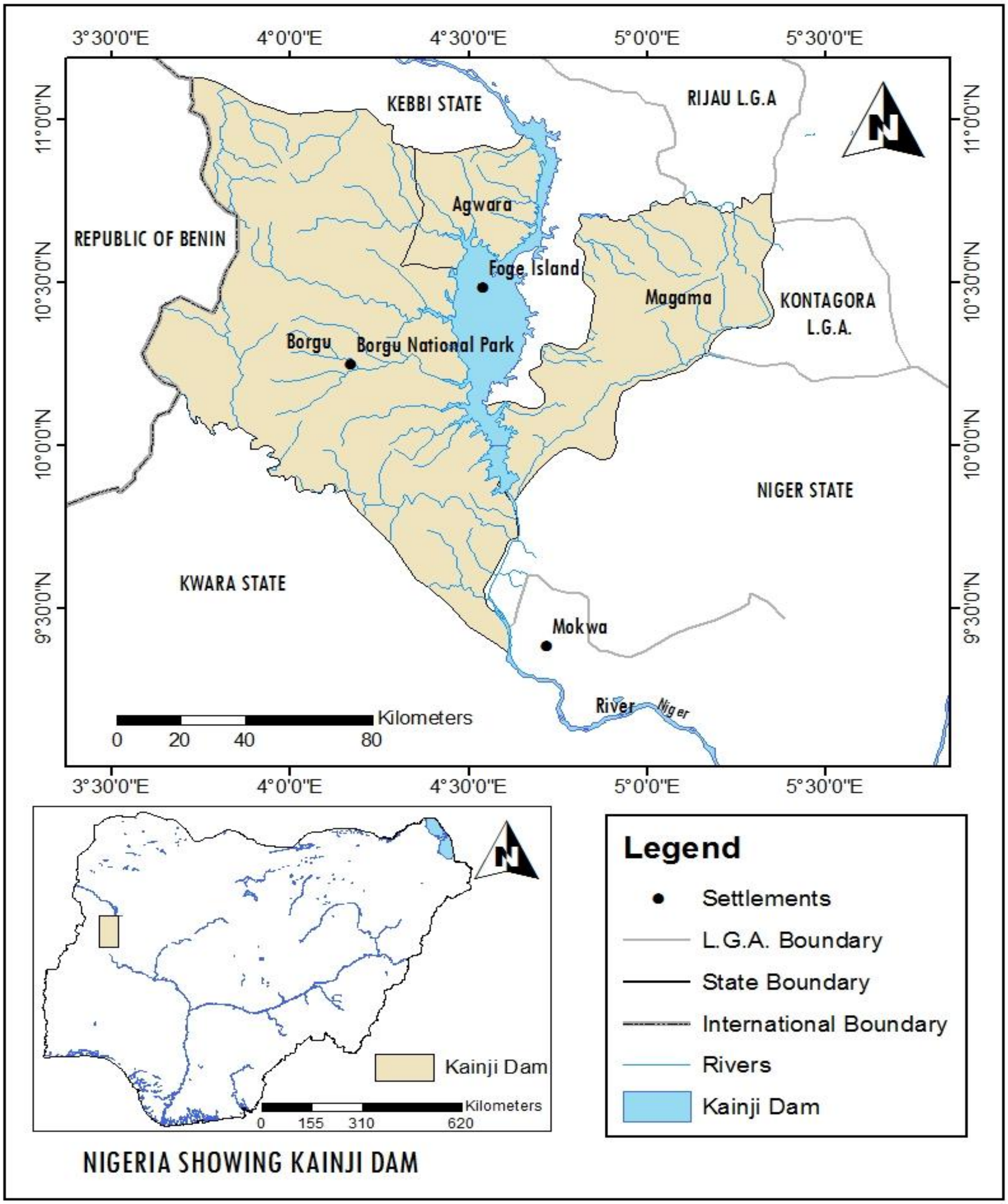

Fig 3.2: Niger State showing Kainji reservoir
Source: Modified from Nigeria Topographical Map

3.1.2 Climate

The basin is characterized by savanna vegetation. The months of April to October are rainy with maritime air blowing from the south. The months of November to March are on the other hand dry with Saharan air from the north. The chief features of the climate are the result of a transition in climatic factors between the northern area with a single peak rainfall regime and a southern zone which has a well defined dual peak regime. The climate is described as equatorial with high maximum temperatures and an average daily maximum of 33.5^0C in the warmest month while the mean annual temperature is about 30^0C. The months of April and May are the hottest month while December and January are the coldest. This climatic type is sub divided into dry monsoon in which the annual rainfall is between 44 to 100% of the annual evapotranspiration while the mean annual is about 1,300mm (Okoro, 2006).

Rainfall distribution in the study area decreases from southern fringe to northern fringe. The mean annual is about 1,300mm. The duration of rainy season is about 6months with 120 days average number of rainy days. The onset of the wet season is usually in April/May, attains it single maximum peak in August and terminates in the month of October. Rainfall intensity ranges from 60mm/hour to 90mm/hour. Weather conditions resulting in the incidence of dark cumulonimbus clouds are common with thunder and lightening followed by strong winds and rainfall of very high intensity, such rainfall may last for up to half an hour, and is then followed by drizzle of several hours duration. strong winds and rainfall of very high intensity, such rainfall may last for up to half an hour, and is then followed by drizzle of several hours duration. This weather is then replaced by few days of bright clear sky (Okoro, 2006).

3.1.3 Geology and Relief

Henderson (1973), described and mapped the geology of this area. The lake basin area is a broad alluvial valley with rock formation of the Pre Cambrian basement complex which forms series of rapids. Those very rapids at the former site of Bussa were notable for their association with the death of Munngo park in the early 19^{th} century. The relief of the reservoir is seen to resemble a valley lake with a middle enlargement (Imevbore, 1970). The catchment area are divided into three sections by the morphometric characteristics of the present river system. In the north, from Yelwa to Agwarra, there is a long and narrow strip about 0.8 to 3.2 kilometers wide and 48.3 kilometer long. Here even at the highest level, the reservoir will lie within the flood plain of the river. In the centre is an extensive flat area which includes Foge Island. In this section an extensively flooded area will appear seasonally, which will be of great importance to local fisheries. In the southern part between Kainji town and Bussa, there is another relatively narrow channel here the shores are steep and rocky with no flats except along the mouths of the tributary streams.

3.1.4 Vegetation

The basin is extensively covered by forest especially the north-eastern part of Foge Island, where as many as 300 trees per acre have been recorded before the impoundment of the lake. Most of the vegetation in the area consists of mixture of grasses, woodlands and some species of trees which include *Isoberlinia tomentosa,, Isoberlinia doka, Tridax procumbens, Butyrospermum spp. and Parkia clappertoniana* . The Northern Guinea savanna type and a substantial part of the region especially around Yelwa show features which are more transitional between that of the Northern guinea ecological zone and Sudan zone. In the South of Foge Island, the river banks are also wooded especially around Kainji Island. The original vegetation of the present lake draw down area ceased to exist after the first flooding. The unforested part or the area consists of grasslands and fadamas (swamps), with the largest fadama being in the west of Foge Island ((Imevbore, Ofoezie and Obot, 1986).

3.1.5 Soil Type

The soil cover of the lake bed is rather variable in composition, ranging from stony to sandy or from loam and clay-loam to clay in the land bordering the river throughout the lake area. The river bedrock is covered by a layer of coarse to medium sand of a variable thickness, fine sand and clay (Orire, 1991).

3.1.6 Hydrology

The average maximum discharge of the River Niger is between 6000- 8000m^3/sec and this occurs during the months of September and October when the white flood dominate the river. A subsidiary flood, the black flood arising from conditions outside Nigeria, Reaches the reservoir area around February and exerts a noticeable effect on the discharge (1750m^3/sec). The lowest flow occurs during the month of June (500m^3/sec). At this time great portions of the river bed are dry and fields of sand and are exposed (Orire, 1991).

3.1.7 Population and land use

The Kainji lake region covers three emirates, Borgu in the former Ilorin province, Kontagora in the former Niger province and Yauri in the former Sokoto province. According to National Population Commission (NPC, 2009), the entire region has an estimates population of 172,835 and is projected to have a population of about 296,756 in 2014. The region is occupied by twelve different ethnic groups. No separate or discrete territory can be said to belong exclusively to any ethnic group in the area hence no map of ethnic distribution is feasible. There is considerable natural harmony and intermarriage among the communities in spite of the fact that the various ethnic groups tended to be concentrated in certain localities to the extent that one can speak of the Lopwa as riverine dwellers, the Gunguwas as islanders and the Fulani as nomads. Hausa is largely spoken by all and were all under the same political structure (Northern regional Government) until 1967 when all the three emirates came to belong to separate states.

Furthermore the ethnic groups can be divided broadly into two, the riverine and the lowland. The former includes the Gunguwa, Yaurawa, Bakarawa, Lopwa and Shangawa who occupy low lying often marshy areas on the islands and banks of the middle Niger. The later (lowlanders) comprises the Kamberi, Dukawa, Salkawa as well as Hausa and Fulani who occupy a rather varied environment embracing the fadama alluvial soils of the Niger and its tributaries as well as contiguous rolling plains and uplands whose major occupations are farming and animal husbandry (Orire, 1991). The riverine people especially the Gunguwa and Yaurawa are often referred to as Reshe (Bareshe) known for their watery environment. Most of them are engaged in fishing and canoe-making usually on a cooperative basis. The Gungawa however have developed a relatively unique system of irrigation for rice and onion cultivation (Orire, 1991).

3.2 METHODOLOGY

3.2.1 Reconnaissance Survey

A survey of the study area was carried out in order to get the researcher acquainted with the study area and the data required for the study.

3.2.2 Types and Sources of Data

3.2.2.1 Types of data

The types of data required for this study include:

(i) Rainfall data from 1985-2014.

(ii) Amount of power generated from 1985-2014.

(iii) Temperature data from 1985-2014

(iv) Reservoir inflow data from 1985-2014

(v) Evaporation data from 1985-2014

3.2.2.2 Sources of data

Rainfall, evaporation, temperature, reservoir inflow and amount of power generated data for the period of thirty years were obtained from Kainji hydropower station.

3.2.3 Methods of Data Analysis

Determination of the trend of rainfall, evaporation, temperature and reservoir inflow patterns in the study area. This addresses the first objective. This was achieved by using trend analysis in which a trend line was displayed on the graph. The mean for each variable for each year was computed to actualize this using simple statistics.

Analyzing the amount of power generated during the rainy and dry season within the last thirty years (1985-2014) in the study area. This was the focus of objective two. This was achieved by getting the overall mean of power generated for the time frame of study (1985-2014) in each season; this was presented using trend analysis.

Examination of the effect of rainfall, evaporation, temperature and reservoir inflow patterns on amount of power generated was objective three. This was achieved using Pearson Product moment correlation co-efficient, by using Statistical Package for Social Scienctist (SPSS) version 20 software package. The test was at 0.05 level of significance.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter deals with data analysis of field investigation on weather parameters and reservoir inflow patterns effects on hydroelectric power generation in Kainji dam Niger state, Nigeria. It shows the trend of the weather parameters in question, the period with high and low amount of electricity generated and results aimed at revealing the relationship between the rainfall, temperature, evaporation and reservoir inflow pattern and their effects on electricity generation in the Kainji hydropower station.

4.2 TRENDS OF VARIABLES

4.2.1 Trend of rainfall

The rainfall data collected from the study area was subjected to time series analysis in order to show the trend of rainfall for the time frame of study (1985-2014). The trend in fig 4.1 shows that rainfall in the study area has been fluctuating and the pattern shows gradual increase over the years although there were drop in amount of rainfall received in 1991, 1996 and 2001 with 60mm, 64mm and 60mm respectively. The study area does not seem to have a major shortage in amount of rainfall as indicated in figure 4.1. The result is supported by the findings of Salami, Sule and Okeola (2011) who worked on assessment of climate variability on Kainji hydropower reservoir. They found out that there was increase in rainfall because the value of S (Mann-Kendall) was positive which demonstrates an existence of a positive trend that is statistically insignificant, The value of Z is 1.25

(less than Z 0.025) where with Z 0.025 = 1.96 at 5%,which makes it statistically insignificant, indicating that the increase in rainfall may not be noticeable.

Fig 4.1 shows the trend of rainfall in the study area for the period of thirty years (1985-2014).

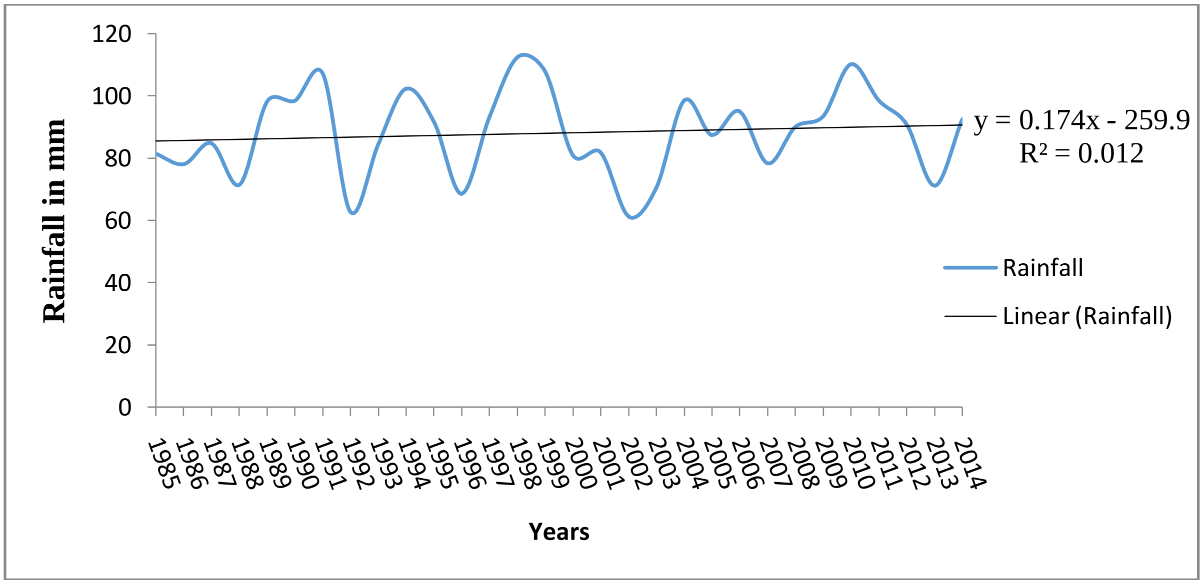

Fig 4.1 Trends of Rainfall in Kainji Dam from 1985-2014

4.2.2 Trend of Temperature

The temperature data collected from the study area was subjected to time series analysis in order to show trend of change for the time frame of study.

Fig 4.2 shows the Trend of Temperature in the study area for the period of thirty years (1985-2014)

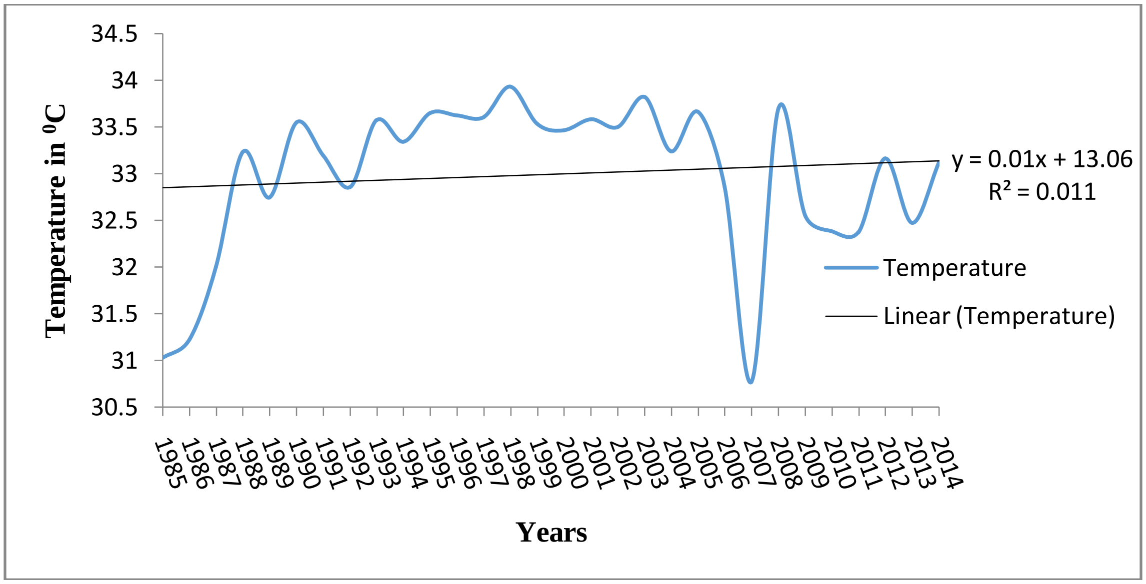

Fig 4.2 Trend of Temperature in Kainji HEP Station from 1985-2014

Fig 4.2 shows that the temperature of the study area has been on the increase and has been fluctuating, with the mid 80s and 2009 showing a sharp drop to 31^{0}C below average. This increase could be as a result of climate change. An increase in temperature is capable of increasing evaporation rate and it is also capable of increasing precipitation which might lead to flooding thereby causing destruction and break down of equipments required for electricity generation. This further proves the claim made by Cole, Elliot and Strobl (2014) as discussed in the literature review.

Similarly, Salami, Sule and Okeola (2011) who worked on same Kainji dam noted that the value of (Mann-Kendall) was positive which demonstrates an existence of a positive trend that is statistically significant and indicates that an increase in temperature would be noticeable. In view of the above it is important to note that regulating global temperature will amount to checking and maintaining the factors responsible for climate change more seriously as suggested by Salami, Mohamed, Adeyemo and Olanlokun (2015).

4.2.3 Trend of Evaporation

The evaporation data collected from the study area was analyzed in order to show the pattern of change for the time frame of study.

Fig 4.3 shows the Trend of Evaporation in the study area for the period of thirty years (1985-2014)

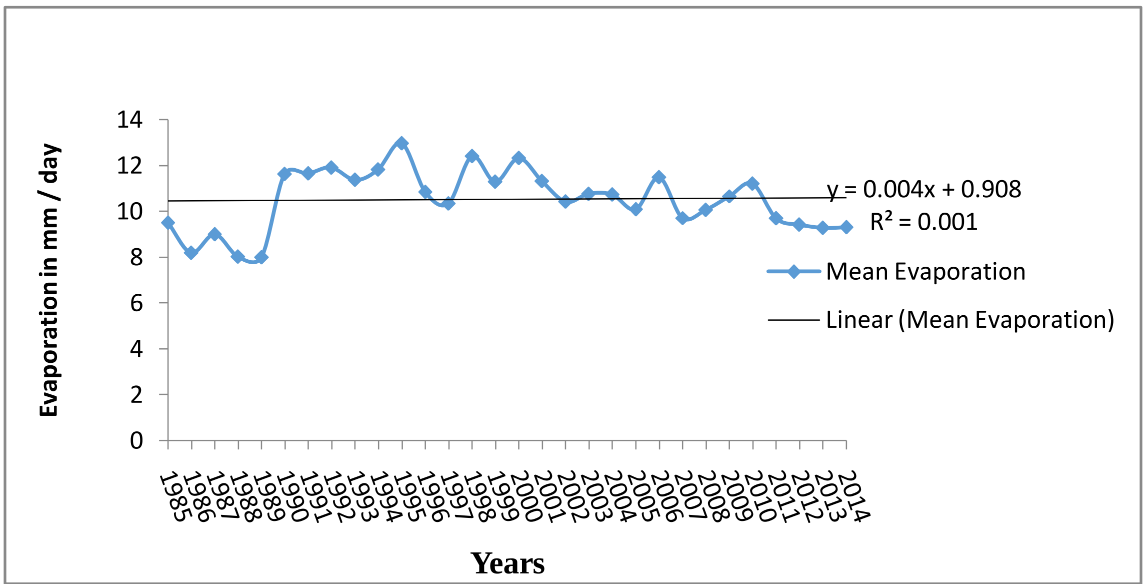

Fig 4.3 Trend of Evaporation in Kainji HEP station from 1985-2014

Fig 4.3 shows that the evaporation in the study area for the time frame of study has been fluctuating and gradually increasing though not too significant because at the year 1995, despite increased evaporation rate of about 13mm, the station was still able to generate an annual mean power generation of 305.92mwh (see Table 4.1) which is high when compared with the average amount the station has been generating using the time frame of study. Similarly, evaporation at year

2009 droped to an average of 9mm and the power still generated was still about 271.7mwh which is above average. Also, the average evaporation for 2004 is 10mm while the amount of power generated in 2004 is one of the highest with 328.33mwh in the time frame of study. High rate of evaporation is capable of reducing the amount of water in the reservoir, thereby resulting to shortage in power generation. Though, it can cause increment in precipitation. Cole, Elliott and Strobl (2014) also observed that the greatest loss of potential water resources from hydroelectric facilities comes from the evaporation of water from the surface of reservoirs.

4.2.4 Trend of Reservoir Inflow

The reservoir inflow data collected from the study area was subjected to time series analysis to show the pattern of reservoir inflow for the time frame of study.

Fig 4.4 shows the Trend of Temperature in the study area for the period of thirty years (1985-2014)

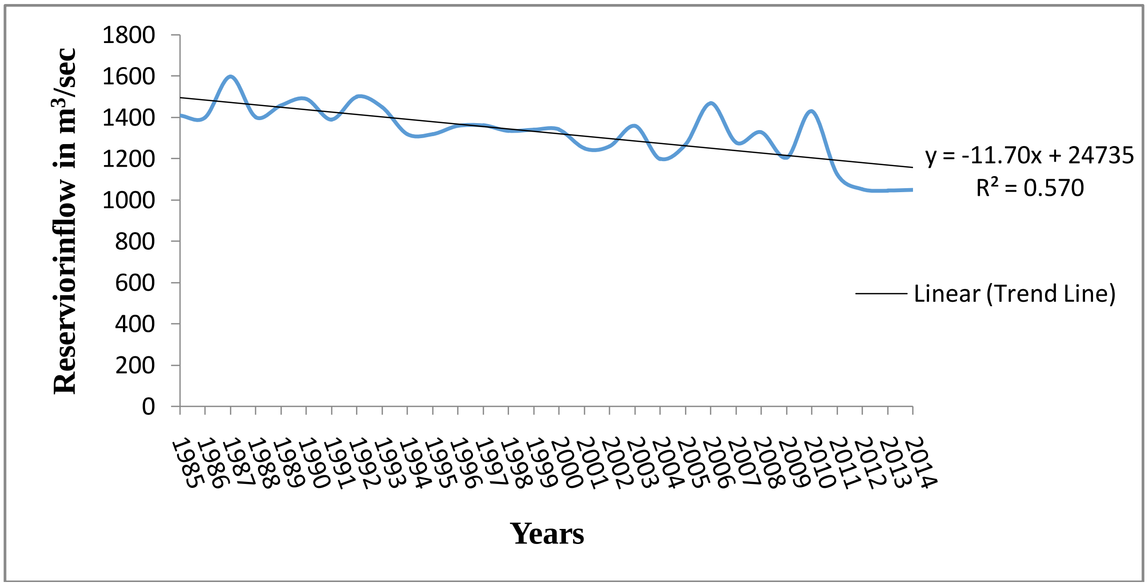

Fig 4.4 Trend of Reservoir inflow in Kainji HEP station from 1985-2014

Fig 4.4 shows that reservoir inflow pattern has been within and out of the country. It is important to note that reservoir inflow in Kainji dam is a major factor that determine the amount of power generated because precipitation and flows covering 4,000 km and over nine countries across West Africa is being received at the dam.The study reveals that the reservoir inflow exhibit a negative trend though with various degrees of fluctuation from the year 1985 to 1993, with an increase in 1994 and a sudden decrease in 1999 while year 2000 to 2014 exhibit tremendous fluctuation at various level.

4.3 Amount of Power Generated

Analysis the amount of power generated during the rainy and dry seasons within the last thirty years in the study area was carried out by getting the overall mean of power generated for the time frame of study (1985-2014) in each season in Mwh, and then finally the overall mean for the wet season and overall mean for the dry season. See Table 4.1

Table 4.1 Seasonal mean power generated (continued)

Y		**Wet season months mwh**							**Dry season months mwh**						M
ears													nnual total	ean total	
		A		J		A	S					F			
	pril	ay	une	uly	ug	ept	ct	ov	ec	an	eb	ar			
2		3		1		1	2					2			2
006	19	29	84	70	21	03	04	54	15	24	94	26	143	61.92	
2		4		1		2	3					4			3
007	16	33	47	0	24	43	10	05	78	03	12	77	838	19.83	
2		3		1		2	3					4			3
008	53	52	64	22	05	15	40	88	96	85	01	82	703	08.58	
2		2		1		1	2					3			2
009	95	37	82	20	36	87	84	03	70	69	52	86	521	93.42	
2		2		2		1	2					2			2
010	84	66	50	54	59	15	38	95	71	45	49	18	244	70.33	
2		3		1		7	1					1			2
011	27	73	64	59	9	98	71	20	95	96	56	64	702	25.17	
2		1		7		7	1					8			1
012	88	23	9	9	8	68	58	20	21	43	2	74	023	68.58	
2		1		5		1	1					1			1
013	38	06	3	2	09	37	02	42	42	40	03	2	286	07.17	
2		1		2		1	1					2			1
014	26.9	43.1	07.3	64.6	60.6	40.8	50.9	46.4	23.2	22.1	10.9	80.9	977.7	64.81	
M															
onthly		7		5		5	6					7			
total mwh	727.4	028.6	376.7	401	213.4	604.1	971.5	526.8	439.5	815.6	391.6	279.2			
M		2		1		1	2					2			
ean monthly mwh	57.58	00.95	79.22	46.7	73.78	20.14	32.38	84.23	81.34	60.52	46.39	75.97			

Total mwh	1410.75	1348.45	2775.4	8 897.1

4.3.1 The Seasonal Mean Power Generated

The seasonal mean power generated was derived by obtaining the mean of months of April to October and months of November to March for the years in the time frame of study from Table 4.1 and presented in Table 4.2.

Table 4.2 Seasonal Mean Power Generated in MWH

ALL MEAN FOR TIME FRAME OF STUDY(1985-2014)		
YEARS	WET SEASON (MWH)	DRY SEASON (MWH)

1985	140.343	207.56
1986	184.143	254.8
1987	161.943	210.26
1988	155.471	216.68
1989	190.2	195.84
1990	110.857	115.129
1991	207.871	203.58
1992	130.642	284.06
1993	128.5	266.9
1994	252.571	287
1995	276.429	347.2
1996	206.286	287
1997	172.571	255.2
1998	270.714	258.2
1999	259.714	288.6
2000	229.143	213.2
2001	172.714	180.6
2002	200.714	297.8
2003	269.043	382.98
2004	306.714	358.6
2005	248.714	325
2006	218.571	322.6
2007	280.429	375
2008	250.143	390.4
2009	234.43	376
2010	209.429	355.6
2011	195.857	266.2
2012	126.143	228
2013	99.571	117.8
2014	156.314	176.7

TOTAL	6053.612	8094.54
OVER ALL MEAI	201.54	269.69

4.3.2 The Mean Monthly Power Generated

The mean monthly power generated was obtained after analyzing data on the amount of power generated and used to plot the graph in fig 4.5.

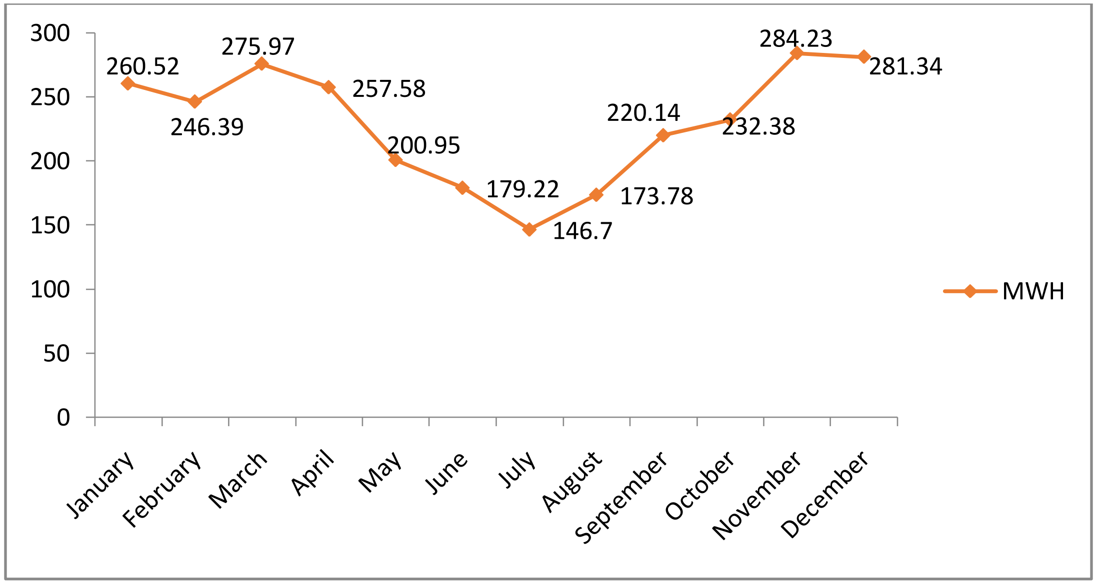

Fig 4.5 The mean monthly power generated from (1985-2014) in Kainji dam

From figure 4.5, various degree of fluctuation can be observed. January, February, March and April with an average mean of 260.52mwh, 246.39mwh, 275.9mwh and 257.58mwh respectively have high amount of power generated. While, the month of May with 200.95mwh marks the period of decline in the amount of power generated to the month of July with an average of 146.7mwh which is the lowest as the study reveals. Although, the month of June generates 179.22mwh while the month of August with a mean of 173.78mwh marks the period of increase in power generation and this increase continues to December with September, October, November and December having an average of 220.14mwh, 232.38mwh, 284.23mwh and 281.34mwh respectively. This is so because of the inflow pattern of the Kainji reservoir which is as a result of the river flow regime characterized by two distinct flood periods occurring annually, namely the white and black floods. The black flood derives its flow from the tributaries of the Niger outside Nigeria (flows from October-May, though the flow will have been drastically reduced in May). It arrives Kainji reservoir in November while the White flood is a consequent of flows from local tributaries especially the Sokoto-Rima and Malendo River systems. The White flood is heavily laden with silts and other suspended particles (flows from June to September) and arrives Kainji in August. So the low flow period in Kainji reservoir is between April and July of each year and April is the beginning of the wet season period in the study area. This must have contributed to the low amount of power generated during the April to July period.

4.3.3 Variations in Amount of Power generated in the Wet and Dry seasons.

Analysis was carried out on the amount of power generated in Table 4.1, and used to plot the wet and dry season graph, in order to show the trend of electricity generation.

Fig 4.6 shows the trend of electricity generation in the wet and dry season for the time frame of study (1985-2014) in the study area.

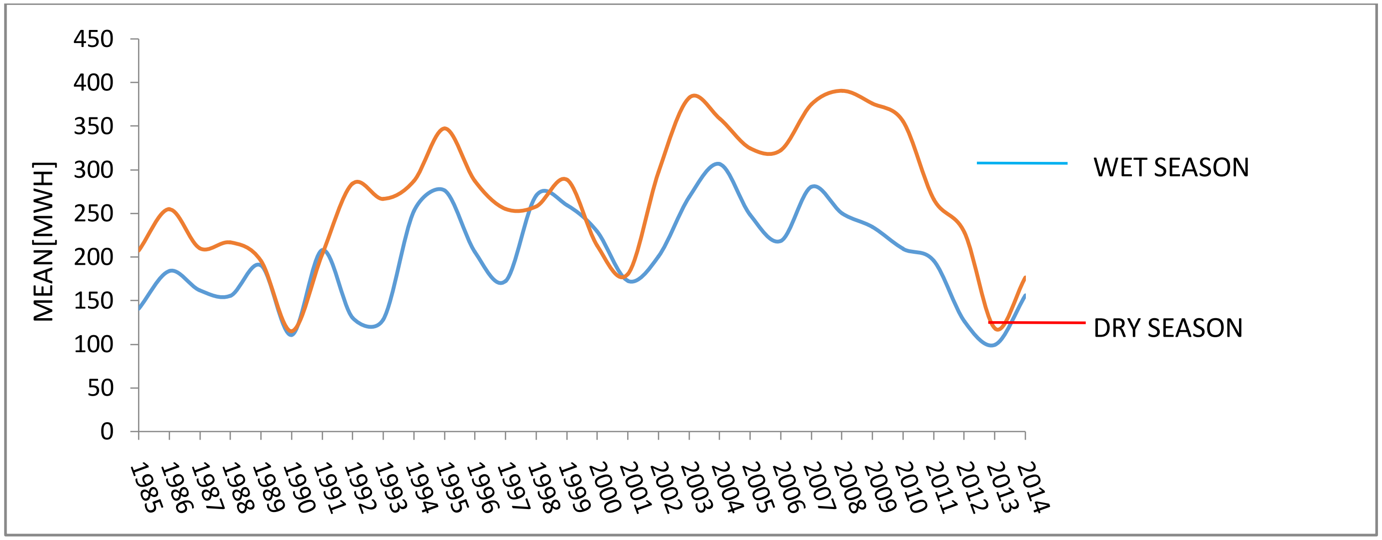

Fig 4.6: Variations in Amount of Power Generate in the Wet and Dry season.

The trend in fig 4.6 shows the variations in the amount of power generated during wet and dry season. In the late 80s an average of 250mwh was generated during the dry season. This later reduced to an average of 100mwh in 1992 where the first sharp drop was been noted, thereafter this season experienced tremendous increment between the year 1991 to 1998 after which there was another sudden drop in the amount of power generated in 1999 and 2000. The season also experienced an increase of about 370mwh to 380mwh from year 2002 to 2012, although with a little drop of about 300mwh around year 2008. While the wet season exhibit an average of about 150mwh to 200mwh in the mid-80s, a major drop of about 110 mwh around 1992 and 1993 and a major increase in the amount of power generated in 1995, 2000, 2005 and 2007 having 270mwh, 270mwh, 290mwh, and 260mwh respectively.

More power is generated in the dry season months than the wet season while the two seasons exhibit fluctuations at various levels. However, Jimoh (2008), worked on operation of hydropower systems in Nigeria using records of monthly inflow from 1970-2005 from Kainji reservoir to analyze the seasonal variation inflow of the reservoir. Findings revealed that the month of January, February, March, April, May, June, July, August, September, October, November and December receive an average of 3200mm^3, 2800mm^3, 1900mm^3, 1600mm^3, 1500mm^3, 1300mm^3, 1400 mm^3, 3100 mm^3, 3800 mm^3, 3600mm^3, 2900mm^3 and3100 mm^3 respectively. Investigation reveals that months with higher inflow is expected to have high amount of power generated.The study however backs the findings of this work because since more inflow is been received towards months of dry seasons it is expected that more electricity will be generated at this period. The reasons for the low electricity generated during the wet season might be as a result of the low inflow from the month of April to July. Although it is important to note that the amount of power generated during the months of August, September and October is high and can be compared to the amount generated during the dry season months. While looking at this analysis, it should be remembered that electricity is being generated all year round at the power station because the reservoir experiences an uninterrupted flow for most part of the year. Fig 4.7 shows the mean monthly inflow to the Kainji reservoir carried out by Jimoh (2008), as it further explains these phenomena.

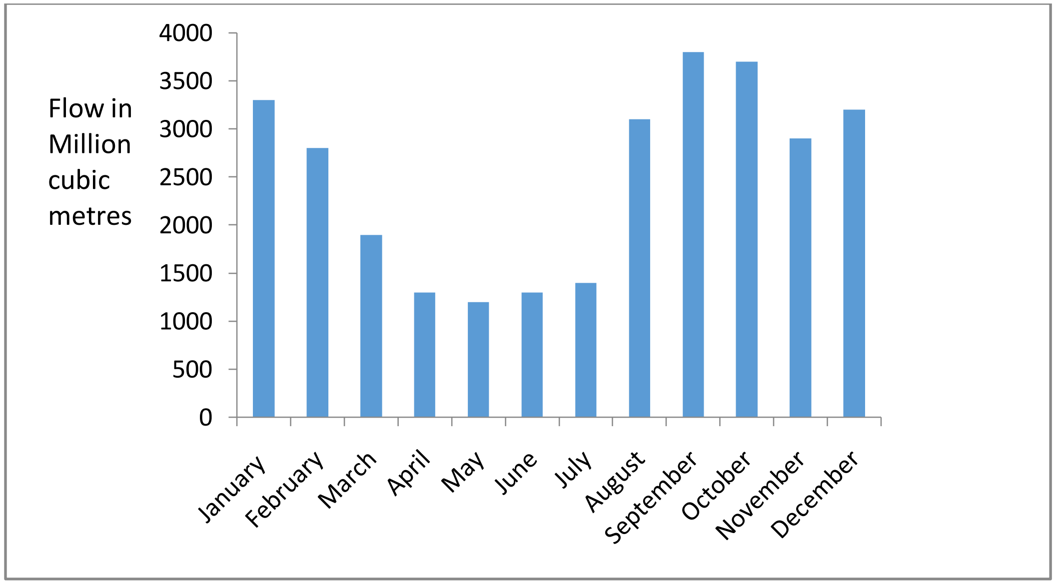

Fig. 4.7 Mean monthly inflow to the reservoir.

Source: Jimoh (2008)

4.4 RELATIONSHIP BETWEEN RAINFALL, TEMPERATURE, EVAPORATION, RESERVOIR INFLOW AND POWER GENERATION (HYPOTHESIS TESTING)

The effect of rainfall, evaporation, temperature and reservoir inflow patterns on amount of power generated was assessed using the Persons Product Moment correlation co-efficient using SPSS version 20, software package at 0.05 level of significance and result presented in table 4.3

Table 4.3 Relationship Between Rainfall, Temperature, Evaporation, Reservoir Inflow And Power Generation

Varriable	**Correlation(r)**
Rainfall	0.83*

Temperature	0.21
Evaporation	0.33
Reservoir Inflow	0.92*

*Significant at 0.05 level

Table 4.3 shows that the correlation between rainfall amount and power generated is 0.83. This shows a positive significant relationship between rainfall and power generated which implies that an increase in rainfall will lead to an increase in the amount of power generated and vice versa.

Evaporation has no significant relationship with power generated at 0.05 level of significance as the correlation between them is 0.33. This means that evaporation has little or no impact on the amount of power generation in the reservoir.

Table 4.3 also shows that the r value between temperature and power generated in the study area is 0.21. This implies that there is no significant relationship between the amount of power generated and temperature at 0.05 level of significance and changes in temperature does not lead to changes in the amount of power generated. This means that temperature does not really affect power generation in the study area.

Lastly table 4.3 shows that reservoir inflow and power generated have correlation of 0.92. The result shows a significant positive relationship at 0.05 level of significance. This implies that a change in reservoir inflow will definitely affect the amount of power generated. This findings is in agreement with Jimoh (2008), who revealed that reservoir inflow in Kainji dam is a major factor that determines the amount of power generated because precipitation and inflow covering 4,000 km and over nine countries across West Africa is being received at the dam.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

The investigation of effect of some weather parameters and reservoir inflow patterns on hydroelectric power generation in Kainji dam, Niger state, Nigeria was conducted using data on rainfall, temperature, evaporation, reservoir inflow and the amount of power generated for the period of thirty years from Kainji Hydropower Station. Time series analysis was conducted on the variables and the hypothesis was tested for relationship between the weather parameters (rainfall, temperature, evaporation) and reservoir inflow and the amount of power generated using Pearson's product moment correlation coefficient at 0.05 level of significance. The data collected was used to show the trend of each parameter for the time frame of study. The amount of power generated for the period of study was analyzed to know the season in which more electricity is generated. The seasons were divided into wet season (April – October) and then the dry season (November- March). The mean annual electricity in megawatts per hour in each season was found before getting the overall mean for the dry season and overall mean for the wet season for the thirty years period (1985-2014). The study reveals that dry season has more electricity generated than the rainy season. This might be as a result of the river flow regime characterized by two distinct flood periods occurring annually, namely the white and black floods. The black flood derives its flow from the tributaries of the Niger outside Nigeria (flows from October-May, though the flow would have been drastically reduced in May). It arrives at Kainji reservoir in November while the White flood is a consequent of flows from local tributaries especially the Sokoto-Rima and Malendo River systems. The White flood is heavily laden with silts and other suspended particles (flows from June to September) and arrives Kainji in August. The low flow period in Kainji reservoir is between April and July of each year, while April marks the beginning of the wet season in the area, this must have contributed to the low amount of power generated during this period. In reservoir operation, during the rainy season, the reservoir starts filling and may attain full capacity when spilling starts. The onset of the rainy season starts with full capacity which depletes until rain arrives again. The result of the research indicated that rainfall and reservoir inflow have their correlation coefficient values of 0.83 and 0.92 respectively. This means they both have positive significant relationships at 0.05 level with the amount of power generated, with reservoir inflow having higher level of significant relationship. Temperature and evaporation with r values of 0.21 and 0.33 do not have significant relationship with the amount of power generated. Based on this outcome, the null hypothesis was accepted for evaporation and temperature but rejected for rainfall and reservoir inflow pattern.

5.2 CONCLUSION

The hydro meteorological parameters within Kainji reservoir were subjected to various analyses. The trends of the parameters for the time frame of study were shown using trend line. Precipitation, evaporation and temperature show an increasing trend, while the reservoir inflow pattern show a decreasing trend. All the parameters exhibit fluctuations at various levels while statistical analysis revealed that there is increased electricity generation during the dry season than the rainy season. However, the amount of power generated in August September and October is high and can be comparable to the amount generated in the dry season months.

Lastly, Pearson correlation co-efficient shows that rainfall and reservoir inflow have significant relationship with the amount of power generated, while temperature and evaporation does not have significant relationship with the amount of power generated.

5.3 RECOMMENDATIONS.

Sequel to the findings of this study, the following recommendations became imperative.

1. The study reveals that Kainji reservoir experience inflow throughout the year, as a result of annual white and black floods. So if the government increases the water carrying capacity of the reservoir or probably finds a means of storing water, electricity output in the periods of low inflow will increase, as their will be a enough water to produce electricity.

2. The government should carry out comprehensive review of existing national water resources master plan. The new plan should seriously consider recent phased development and management of identifiable problems. While a financial plan should be adopted in setting out annual budgetary allocations to relevant water development and energy projects.

3. The government should strengthen laws, policies and measures relevant to addressing climate change, as this will help in limiting global warming, which is the reason behind drought and low precipitation.

4. The Nigerian government should try to install the remaining 4 turbines in Kainji reservoir, thereby increasing the number of the turbines in the station from 8 to 12 turbines as initially designed. This will help to increase the reservoir generating capacity to 960 Megawatts instead of only 760 Megawatts.

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