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Impacts of Climate Variability on Hydroelectric Power Generation in Shiroro Station, Nigeria

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A B S T R A C T

Hydro Electric Power (H.E.P.) is a critical infrastructure that powers industrial growth and economic development of any developing nation. However, variability in climatic condition is already having serious impacts on H.E.P. in Nigeria. The study examined the effect of climate variability on hydroelectric power generation in Shiroro Station Nigeria. Data used for this study were acquired mainly from secondary source. The climatic, Hydrological and power generation data used are already prepared document from 1990 to 2014 (25 years) period. The data were sourced directly from the production and Hydrological department of North South Power (N.S.P.). Relevant literature, journals and internet materials were also used for the study. Data collected were subsequently analyzed using inferential statistics such as trend analysis, reduction pattern analysis, spearman rank correlation and multiple regression analysis. Result revealed that there is variability in climatic elements and hydrological variables from year to year. Multiple linear regression analysis revealed that climatic/hydrological variables can only explained 75.4% variability in the amount of hydro power generated in Shiroro Station. The study calls for the development of pumped water systems so that the tail water can be reused particularly during periods of little or no rainfall and low inflow.

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INTRODUCTION

Variability in climatic condition is already resulting in wide ranging impacts especially on water resources and Hydro Electric Power (H.E.P) in Africa. Power is very important to the infrastructural growth and economic development of any nation. All societies require energy service to meet basic human needs and to serve productive processes. It is believed that an appropriate level of energy generation has always gone hand in hand with industrialization and economic development.

Based on Renewable Energy Policy Network for the 21st Century [1] report, hydropower is the most widely used form of renewable energy, it accounts for 16 per cent of global electricity generation – 3,427 terawatt-hours of electricity production in 2010, and is expected to increase by about 3.1% each year for the next 25 years. Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 per cent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use [2].

Climate variability is the way climate fluctuates yearly above or below a long term average value, this occur over seasons and year. It is also the variation in the mean state and other statistics of climate on all temporal and spatial scales beyond that of individual weather events [3]. Climate variability may be due to natural internal processes within the climate system, or to variations in natural or anthropogenic external factors. According to the World Meteorological Organization (WMO) the term "Climate Variability" is often used to denote deviations of climatic statistics over a given period of time (e.g. a month, season or year) when compared to long-term statistics for the same calendar period. Climate variability is measured by these deviations, which are usually termed anomalies.

Climate change on the other hand, is referred to as the permanent departure of climate patterns from mean values of observed climate indices or of weather elements overtime, these weather elements includes temperature, rainfall, dew, humidity, wind, sunshine, mist and cloud, and the variations in the element put in place a change in climate.

Climate change is defined by the Intergovernmental Panel on Climate Change [4] to be any change in climate over time, whether due to natural variability or as a result of human activity. Also, the United Nations Framework Convention on Climate Change (UNFCCC), defined

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climate change as a change of climate which is attributed directly or indirectly to human activity which alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Ayoade [5] affirmed that variability is an inherent attribute of climate and that global climate or the climate of any part of the earth has never been static, what is crucial according to him is the degree of variability that climate is subjected to as well as the duration of such variability. A number of climatological research and studies based on circulation models such as Regional Climate Models (RCMs) and General Circulation Models (GCMs) have found and proved evidence of variability and changes in the climate system. It has been revealed that global average temperature increases mask considerable differences in temperature rise between land and sea and between high and low latitudes, precipitation increases are also very likely in high latitudes, while decreases are likely in most of the tropics and subtropical land regions [4].

Climate variability has many elements affecting physical and biological/human systems in different ways. The impacts of considerable spatial heterogeneity of climate variability has been widely studied, in the tropics for instance during the dry season, increase temperature would increase electricity demand for air conditioning and refrigerator, whereas, decrease in flow of water would reduce hydroelectric generation and stress electricity supply. It is widely projected that as the planet warms, climate and weather variability will increase.

Changes in the frequency and severity of extreme climate events and in the variability of weather patterns will continue to have significant consequences for human and natural systems. Increasing frequencies of heat stress, drought and flooding events are projected for the rest of this century, and these are expected to have many adverse effects over and above the impacts due to changes in mean variables alone [4].

In Africa, it is recorded that the effects of climate variability and climate change are severely affecting HEP plants especially in areas that experience low annual rainfall [6]. For instance, the early 1970s Sudano-Sahelian drought was devastating and yet recurrence of such events is on the increase as witnessed in the mid-1980s, 2000 and 2009 in Kenya [7-10]. Snow and glaciers on mountains like Mt. Kilimanjaro and Mt. Kenya which acts as water towers are receding fast due to continued rise in continental temperatures for the past 100 years as illustrated by IPCC [4] and this is greatly attributed to climate change effects. Hastenrath [10] ascertained that the hydrological behavior of rivers in the West Africa sub-region is influenced by a climate that is dependent on an annual cycle of two air masses which are the Northeast trades from the Sahara Region and the Southwest Monsoon from the Atlantic. Hence, lack of adequate water in river flows especially during dry season is severely impacting HEP generation, leading to either reliance on diesel power or power rationing. According to Ifabiyi [11], electricity came to Nigeria in 1896, 15 years after it got to England but despite its long history in Nigeria, electricity generation is still at its low ebb with power outages being the order of the day. In the light of this, the need for reliable and manageable source of power supply is highly needed. This study examines the effects of climate variability on power generation in Shiroro Power Station, Nigeria.

Study Area

Niger state is located in the North central region of Nigeria and the largest state in the country (Figure 1). It lies within latitudes 8^0 20'N and $11^0$30'North of the Equator and longitudes 3^0 30'E and 7^0 20'East of the Greenwich Meridian, sharing boundaries with Zamfara State in the North, Kebbi State and Republic of Benin in the Northwest, Kwara State in the Southwest, Kogi State in the South, and Federal Capital Territory and Kaduna State in the Southeast and Northeast respectively. The study reservoir is the Shiroro hydroelectric dam. It is situated on lower Kaduna River Basin in Shiroro Local Government Area (L.G.A.) of Niger State. The lake basin area is about 320km^2 with total storage volume of about 7 billion cubic meters. The lake has a maximum length of about 32km. Shiroro L.G.A. which serves as the host community to the hydroelectric station occupies an area of about 5015km^2 with a population of 235,404. (NPC, 2006 provisional results). The drainage pattern is the dendritic type, landscape is made interesting by valleys which have been carved by River Kaduna and its tributaries, and further moulded and subdivided by the numerous rivulets, most of which dry up during the dry season. The climate of the study area is Tropical Monsoon, characterized by alternate wet and dry season; it is controlled by two air masses, the South westerly and the Northeast harmattan dry wind. The former is due to hot and humid tropical maritime air mass blowing in from

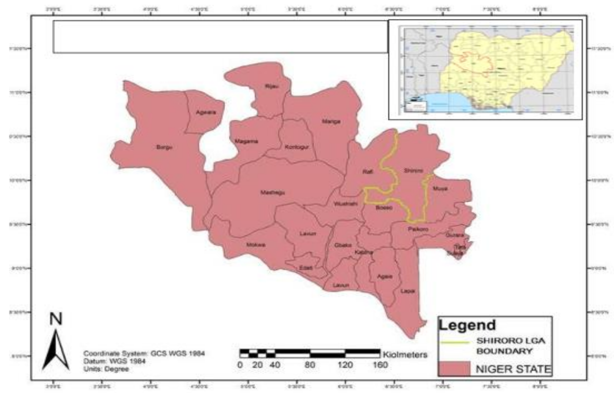

Figure 1. Study area source**:** Niger state ministry of lands and housing, Minna 2015

the Atlantic Ocean while the latter is due to tropical air mass. It is a cold, dusty and dry air mass from the Sahara Desert. The Northeast winds of the study area are characterized by the dry season, which lasts from November to March while wet season, which begins in April and ends in October, is characterized by southwest moisture ladened wind.

METHODOLOGY

Data used for this study were mainly acquired from secondary source. The Climatic, Hydrological and Power generation data used are already prepared document from 1990 to 2014 (25 years) period. The data were sourced directly from the Production and Hydrological Department of North South Power (N.S.P), the current operators of Shiroro Hydroelectric Power Station. Relevant literature, journals and internet materials were also consulted. Data collected were subsequently analyzed using inferential statistics such as trend analysis, reduction pattern analysis, spearman rank correlation and multiple regression analysis.

RESULTS AND DISCUSSION

Pattern of rainfall amount, temperature and evaporation rate in shiroro hydropower station

The highest annual mean rainfall of 145.775mm was recorded in 1990, while the lowest of 85.025mm was observed in 2004 (Figure 2). The long term mean of rainfall amount for the period of study was 110.121mm. Figure 2 also shows 1990, 1997, 2006 and 2012 was the year that the annual mean rainfall amount received in the Shiroro hydropower station was greater than 120mm. While twelve years of the study period are equal or above the established long term mean of 110.121mm, thirteen years were below the long term mean rainfall during the twenty-five years period of study. It was revealed that annual rainfall amount recorded in Shiroro hydropower station also fluctuates.

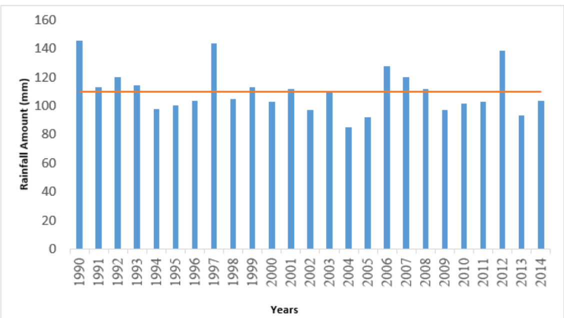

Figure 2. Mean annual rainfall amount in Shiroro hydropower station, Nigeria (1990-2014)

The highest annual mean temperature of 28.8°C was recorded in Shiroro hydropower station in 1997, while the lowest of 21.6°C was recorded in 1991. The long term mean temperature for the period of study is 26.6°C. The study also revealed that seventeen years out of twenty-five years under study, recorded annual mean temperature that is above the established long term mean of 26.6°C. While the remaining eight years recorded annual mean below the long term mean temperature for the period of study. However, out of the seventeen years' record that is above the long term mean temperature, 12 of those years occurred between 2002 -2013. This is an indication that the temperature of Shirorois on the rise, and this is in tune with the global temperature rise experienced in the last decade (Figure 3).

The highest annual mean evaporation rate recorded in Shiroro hydropower station was 14.00mm which was recorded in 1990, while the lowest was 8.97mm recorded in 2014. The long term mean for the period of study is 10.95mm. Figure 4 revealed that 10 years out of twenty-five years of record, recorded annual mean evaporation that is above the established long term mean of 10.95mm. While the remaining 15 years recorded annual mean evaporation rate that is below the long term mean for the period of study.

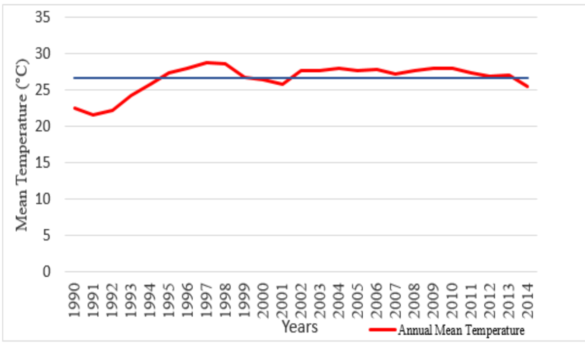

Figure 3. Annual mean temperature in Shiroro hydropower station, Nigeria (1990-2014)

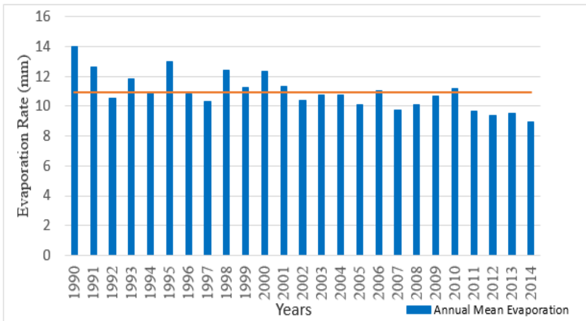

Figure 4. Annual mean evaporation rate in Shiroro hydropower station, Nigeria (1990-2014)

Pattern of reservoir elevation, inflow, turbine discharge rate and dam spillage in Shiroro hydropower station

The highest annual mean reservoir elevation recorded in Shiroro hydropower station was 374.42m, which was recorded in 1992, while the lowest was 366.40m recorded in 2014. The long term mean reservoir elevation during the period of study is 370.82m. Figure 5 shows 13 years were equal or above the established long term mean of 370.82m, while 12 years were below the long term mean reservoir elevation during 25 years period of study.

However, it was revealed that annual reservoir elevation recorded in Shiroro hydropower station varied from year to year. In the last twelve years, ten years' period recorded reservoir elevation that is less than the established long term mean of reservoir elevation during the twenty-five years' period of study. It can be attributed to the decreasing nature of rainfall amount in the study area.

The highest mean annual inflow of 14339.50m/s, was recorded in 2012, while the lowest inflow of 294 m/s recorded in 2009. The long term mean inflow during the period of study is 8573.92m/s. The result also shows that 15 years are equal or above the established long term mean of 8573.92m/s, while ten 10 years were below the long term mean inflow during 25 years period of study (Figure 6).

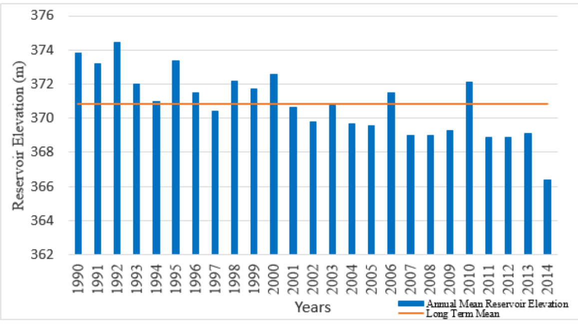

Figure 5. Annual mean reservoir elevation in Shiroro hydropower station, Nigeria (1990-2014)

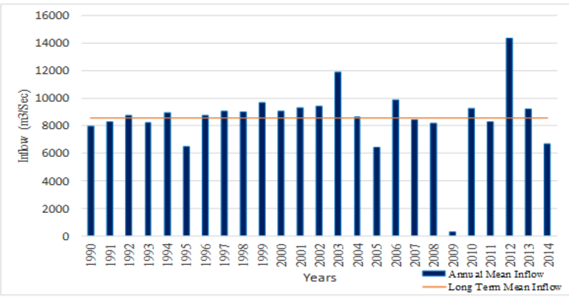

Figure 6. Annual mean in flow in Shiroro hydropower station, Nigeria (1990-2014)

However, it was revealed that annual inflow recorded in Shiroro hydropower station varied from year to year during the twenty-five years' period of study. It can also be attributed to the decreasing nature of rainfall amount in the study area.

The highest annual mean turbine discharge recorded in Shiroro hydropower station was 0.90 $(\times 109m^3)$, which was recorded in 2012, while the lowest was 0.35$(\times 109m^3)$ recorded in 2005. The long term mean turbine discharge during the period of study is 0.73 $(\times 109m^3)$. The computed result also revealed that seventeen years are equal or above the established long term mean of 0.73 $(\times 109m^3)$, while eight years were below the long term mean turbine discharge during 25 years period of study. However, it was revealed that annual turbine discharge recorded in Shiroro hydropower station is highly varied from year to year during the twenty-five years' period of study.

There was dam spillage in 12 years out of the twenty-five years' period of study. The study shows that spillage is not experienced every year in Shiroro hydropower station. However, it was revealed that the highest annual mean dam spillage recorded in Shiroro hydropower station was 1.7251(x109m^3), which was recorded in 2012, while the lowest was 0.0024(x109m^3) recorded in 1991. The long term mean dam spillage during the period of study is 0.64(x109m^3). It observed that four years are equal or above the established long term mean of 0.64(x109m^3), while eight years were below the long term mean dam spillage during the twelve years period of dam spillage during the twenty-five years period of study (Figure 7).

Power generated in Shiroro hydropower station

The highest annual mean power generated in Shiroro hydropower station was 7288.32MWH, which was recorded in 2012, while the lowest was 5276.82MWH recorded in 2008.

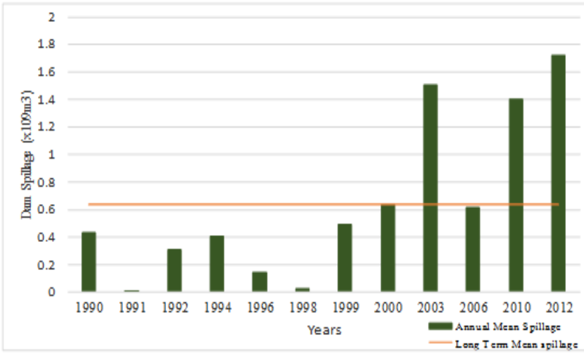

Figure 7. Annual dam spillage in Shiroro hydropower station, Nigeria (1990-2012)

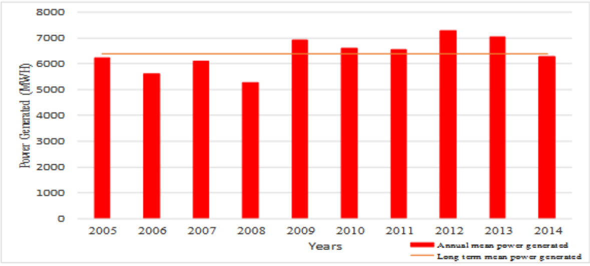

Figure 8. Mean annual power generated in Shiroro hydropower station, Nigeria (2005-2014)

The long term mean power generated during the ten years' period of study is 6384.17MWH. The study also showed that 5 years are equal or above the established long term mean of 6384.17MWH, while the remaining 5 years were below the long term mean power generated during the period of study. It was further revealed that annual power generated in Shiroro hydropower station varied from year to year during the period of study. This can be attributed to the fluctuation detected in the climatic variables recorded in the study area (Figure 8).

Multivariate relationship between climatic or hydrological variables and hydropower generation

Spearman rank correlation analyses were carried out between climatic/hydrological variables and the amount of power generated. This is to reveal the degree of association and relationship between these variables. The results are presented in Table 1. The results of the Spearman rank correlation revealed a strong negative relationship (r= -0.682) between rainfall amount and evaporation rate in Shiroro hydropower station which is statistically significant at 95% confidence level. This suggest that, there is an inverse relationship between rainfall and evaporation rate, which implies that as rainfall increases, evaporation decreases and vice versa. However, rainfall amount and relative humidity exhibited a very strong positive relationship (r=0.807) which is statistically significant at 99% confidence level. The strong positive relationship between these two variables is expected because the higher the relative humidity, the higher the probability of rainfall. Thus, this result indicates that there is a direct proportional relationship between rainfall and relative humidity. In other words, when there is an increase in relative humidity, there is also an increase in rainfall received in Shiroro hydropower station.

There is also a strong positive relationship (r=0.718) between rainfall amount and inflow at 95% confidence level. This is also an indication of direct proportional relationship between rainfall amount and inflow recorded in Shiroro hydropower station. This suggests that the higher the rainfall amount, the higher the inflow recorded in Shiroro hydropower station and vice versa. However, there is a very weak relationship (r=0.29) between rainfall amount and amount of power generated which is not statistically significant at both 95 and 99% confidence level. This shows that there is a causal relationship between rainfall amount and power generation in Shiroro hydropower station but the relationship is weak and insignificant. It can be concluded that rainfall amount does not have direct impact on power generation in Shiroro hydropower station. Table 1, further revealed that a strong positive relationship (r=0.729) is exhibited between inflow and turbine discharge in Shiroro hydropower station at 99% confidence level. This is an indication of a direct proportional relationship between inflow and turbine discharge. In other words, when there is an increase in inflow in Shiroro hydropower station, there is also an increase in turbine discharge and vice versa. Also, inflow exhibits a strong positive relationship (r=0.723) with the amount of power generated in Shiroro hydropower station at 99% confidence level. This result suggests that whenever there is an increase in inflow in Shiroro hydropower station, all things being equal, there is also a significant increase in the amount of power generated and vice versa. Lastly, there is a strong positive relationship (r=0.732) between turbine discharge and the amount of hydropower generated in Shiroro hydropower station at 99% confidence level. All things being equal, this result suggests that there is a direct proportional relationship between turbine discharge and hydropower generation in

TABLE 1. Association between climatic/hydrological variables and hydropower generatio

Parameters	Rainfall	Temperature	Evaporation	RH	Reservoir elevation	Inflow	Discharge	Spillage
Temperature	0.067							
Evaporation	-0.682*	-0.203						
RH	0.807**	0.179	-0.418					
Reservoir Elevation	-0.396	-0.357	0.347	-0.12				
Inflow	0.718*	-0.501	-0.339	0.568	0.109			
Discharge	0.382	-0.427	-0.252	0.305	0.531	0.729**		
Spillage	0.25	-0.384	-0.455	-.497	-0.358	0.091	0.527	
Power Generated	0.29	-0.535	0.141	0.444	0.549	0.723**	732**	0.60

.*Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed).

the study area.This is an indication that whenever there is an increase in turbine discharge, there is a proportional increase in hydropower generated and vice versa in Shiroro hydropower station.

Impacts of climatic/hydrological variables on hydropower generation in Shiroro hydropower station

Multiple regression analysis was carried out on the climatic/hydrological variable and amount of hydropower generated in Shiroro hydropower station. The dependent variable is the amount of hydropower generated while the independent variables are rainfall amount, mean temperature, evaporation, relative humidity, reservoir elevation, inflow, and turbine discharge. The results obtained are displayed in Tables 2 and 3.

This multiple linear regression model, with eight explanatory variables, has an R squared value of 0.754. This signifies that 75.40% of the variation in the amount of hydropower generated can be explained by this model. That is an indication that these climatic/hydrological variables can only explained 75.40% variability in the amount of hydropower generated in Shiroro hydropower station. This is an indication that there are other factors contributing about 25% to the variation in the amount of hydropower generated in the study area besides these climatic/hydrological variables. However, for every 1% decrease in mean temperature and inflow, there is -89.17% and -0.035% decrease in amount of hydropower generated respectively in the study area. Table 3 revealed that for every 1% increase in rainfall, evaporation, relative humidity, reservoir elevation and turbine discharge, there is 7.16%, 209.091%, 26.686%, 83.13% and 109.55% increase in amount of hydropower generated respectively in Shiroro hydropower station. between climatic/hydrological variables and hydropower generated in Shiroro hydropower station can be given as:

$$\begin{aligned} Hydropower = {} & -34793 + 716_{RainF\,all} 209.09_{evaporayion} \\ & - 89.18_{temp} + 26.69_{Rh} \\ & + 83.13_{Re\,serveir\,Elevtn} \\ & - 0.035_{\inf low} + 10955_{discharge\,e} \end{aligned} \quad (1)$$

CONCLUSION

decreasing trend in rainfall amount in the last fifteen the Shiroro hydropower station has witnessed years.

TABLE 2. Model summary of the relationship between climatic/hydrological variables and hydro power generated

Model	R	R square	Adjusted R square	Std. error of the estimate
1	0.824	0.754	0.726	9.2965

a. Predictors: (Constant), Turbine Discharge, Relative Humidity, Reservoir Elevation, Mean Temperature, Evaporation, Inflow, Rainfall amount

TABLE 3. Relationship between climatic/hydrological variables and hydropower generation

	Unstandardized coefficients		Standardized coefficientsT		Sig
Model	B	Stand. Error	Beta		
(Constant)	-34793	26885.9		-1.294	0.265
Rainfall	7.163	7.902	0.417	0.907	0.416
Evaporation	209.091	53.99	0.481	3.873	0.018
Temperature	-89.175	159.392	-0.075	-0.559	0.606
RH	26.686	15.737	0.25	1.696	0.165
Reservoir Elevation	83.134	68.399	0.306	1.215	0.291
Inflow	-0.035	0.07	-0.187	-0.498	0.045
Discharge	10955	2977.91	0.755	3.679	0.021

a. Dependent variable: power

This can be attributed to global climate change which is becoming evident in Nigeria every day. The increasing trend in temperature in the last twenty years can be attributed to the geographical location of the study area which is in the northern part of Nigeria with tropical monsoon climate and the increasing trend in the global surface temperature in the last decades. The high percentage of variability in the decreasing trend of reservoir elevation over time can be attributed to the decreasing trend in rainfall amount and increasing trend in mean temperature. Although, rainfall amount exhibits a positive relationship with the amount of hydropower generated, it is not statistically significant, which draw a conclusion that rainfall amount does not have direct impact on power generation in Shiroro hydropower station. The increasing trend and percentage increase in hydropower generated in Shiroro hydropower station especially in the last five years may not be as a result of climate variability, since there is about 25% of variability in the amount of hydropower generated that is unaccounted to the climatic and hydrological variables used in this study. The runoff discharge in this area should be channeled into the inflow and the dam/reservoir so as to increase the amount of inflow, which will indirectly increase the amount of hydropower generation in Shiroro hydropower station. The study revealed a decreasing trend in rainfall and there is a very strong positive relationship between rainfall and inflow, therefore, a pumped water storage system should be developed so that the tail water can be re-use particularly during periods of little or no rainfall and low inflow.

REFERENCES

1. Renewable Energy Policy Network for the 21st Century (REN21's 2014) Annual Report.

2. Bunyasi M.M. (2012). Vulnerability of Hydro-Electric Energy Resources in Kenya Due to Climate Change. Effects: The Case of the Seven Forks Project Journal of Agriculture and Environmental Sciences, 1, pp 36-41
3. Keely, Dinse, 2011. Climate Variability and Change; what is the different? Retrieved on 24th March, 2016 fromwww.miseagrant.unich.edu/climate
4. IPCC (2001): Climate Change 2001: Synthesis report, Cambridge University Press, Cambridge Intergovernmental Panel on Climate Change (IPCC).Climate Change 2001,
5. Ayoade J.O., 2003. Climate Change: A Synopsis of its nature, causes, effects and management. Vantages Publishers, Ibadan.
6. Enete, I. C. and Ezenwaji E.E. 2011 "Implications of Climate Variability on Water Resources of Nigeria: A Review. Journal of Geography and Regional Planning. 4, pp 68-80.
7. Ogallo L. A., 1993 Dynamics of Climate Change over Eastern African, Indian Academy of Sciences. 102. 1; 203 – 217.
8. Tarhule, A. and LambP. J., 2003, Climate research and seasonal forecasting for West Africans: "Perceptions, Dissemination and Us" Meteor. Soc. 84(12): 1741 – 1759.
9. United Nations Development Programme (UNDP), (2007). Human Development Report 2007/2008: Climate Change and Human Development in Africa; Assessing the Risks and Vulnerability of climate Change in Kenya, Malawi and Ethiopia.
10. Hastenrath S. 1990. Decadal-scale changes of the circulation in the tropical Atlantic sector associated with Sahel drought. International. Journal of Climatology; 10 459-472
11. Ifabiyi, I.P. and Ahmed, Y.A. 2011. Determination of Household Water Demand in a traditional City: Examples from Western axis of Ilorin Nigeria. Asian-African Journal of Econometrics and Economics, 11(2):395-408.

Persian Abstract

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چکیده

نیروی برق هیدرولیکی (H.E.P.) زیرساختی حیاتی است که رشد صنعتی و توسعه اقتصادی هر کشور در حال توسعه را تقویت می کند. با این حال، تغییرات در شرایط آب و هوایی در حال حاضر دارای اثرات جدی بر H.E.P. دارد. در نیجریه این مطالعه به بررسی تأثیر تغییرات اقلیمی بر تولید برق آبی در ایستگاه شیررو نیجریه پرداخت. داده های مورد استفاده برای این مطالعه به طور عمده از منابع ثانویه به دست آمد. داده های اقلیمی، هیدرولوژیکی و تولید برق در حال حاضر از سال ۱۹۹۰ تا ۲۰۱۴ (۲۵ سال) سند تهیه شده است. داده ها به طور مستقیم از تولید و بخش هیدرولوژیکی نیروی برق شمال (N.S.P.) تهیه شده است. مطالعات مربوط به آن، مجلات و مواد اینترنتی نیز برای مطالعه مورد استفاده قرار گرفت. داده ها جمع آوری شده و سپس با استفاده از آمار استنباطی شامل تحلیل روند، تحلیل الگوی کاهش، همبستگی رتبه اسپیرمن و تحلیل رگرسیون چندگانه مورد تجزیه و تحلیل قرار گرفت. نتایج نشان داد که متغیرهای متغیرهای آب و هوایی و هیدرولوژیک از سال به سال متغیر هستند. تجزیه و تحلیل رگرسیون چندگانه نشان داد که متغیرهای آب و هوا / هیدرولوژیکی تنها می تواند ٪۷۵/۴ تغییر در میزان نیروی آبی تولید شده در ایستگاه شیررو را توضیح دهد. این مطالعه نیاز به توسعه سیستم های آب پمپاژ دارد تا آب های دم را می توان به طور خاص در طول دوره های کم و یا بدون بارندگی و جریان کم استفاده کرد.