Characterization of Climatic Parameters and River Flow Capacity on Electricity Generation in Jebba Dam, Nigeria

Hadiza Muhammad Liman
Department of Geography
Ibrahim Badamasi Babangida University, Lapai, Nigeria

Peace Nwaerema
Department of Geography
Ibrahim Badamasi Babangida University, Lapai, Nigeria
Email: pnwaerema206@gmail.com, pnwaerema486@gmail.com

Jacob Yisa
Department of Geography
Ibrahim Badamasi Babangida University, Lapai, Nigeria

Jibrin Matane AbdulAzeez
Department of Geography
Ibrahim Badamasi Babangida University, Lapai, Nigeria

Adama Christiana Kolo
Department of Geography,
Ibrahim Badamasi Babangida University, Niger State, Nigeria.

D.O.I: 10.56201/ijgem.v9.no2.2023.pg1.9

Abstract

This study examined the characterization of climatic parameters and river flow capacity on electricity generation in Jebba Dam, Nigeria. It is a known fact that climatic parameters of rainfall, temperature and evaporation have the capacity to influence reservoir inflow and outflow as well as hydropower generation. The study collected secondary data of climatic parameters, reservoir inflow and outflow as well as hydropower generation from Mainstream Energy Solution Limited in 2018. The data were analyzed using averages and represented in graphs and charts. The results showed that there was rise in power generation from July to December with November having the highest power generation of 432.5MWH. Reservoir inflow and outflow rose from July to December with September having the highest discharge of 4860m^3/sec inflow and 4858 m^3/sec outflow. There was noticeable rise in rainfall pattern from May to November with September having the highest rainfall regime of 330.4mm in the Jebba river basin. However, February and November had the highest temperature regime of 36^{0}C each in the Jebba river basin. The highest evaporation rate was recorded in March having 25m^3/sec during the period. Finally, the study has revealed the effects of these climatic parameters on the reservoir flow and hydropower generation in the Jebba dam. Therefore, the government should

strictly consider the phenomenon of climate change as it affects hydroelectric power generation in Nigeria without further delay.

1. Introduction

Globally, there is the urgent need for electric power generation due to industrialization, overpopulation and urbanization. Also, climatic parameters such as rainfall, temperature and evaporation have the capacity to influence any reservoir inflow and outflow as well as hydropower generation of a dam [1]. Indeed, precipitation and other climatic variables have direct influence on the performance of reservoir inflow and outflow which is capable of affecting hydropower generation [2]. According to [3] hydroelectric power generation has a close relationship with precipitation as 43% rise in precipitation may give rise to 39% hydroelectric power generation. Resultantly, climate change and global warming phenomena have direct impact on climatic parameters such as precipitation that is linked to hydropower generation [4]. It is important to explore the correlation and influence of climatic parameters such as rainfall, temperature and evaporation on the changes of hydropower discharge of dams across the world. The need to undertake study on effects of climatic variables on hydropower generation is due to the fact that there is rising global energy demand which will double from the year 2007 to 2035 [5]. Thus, the population of the world will rise to 10 billion persons in the year 2050 and above 11.2 billion in the year 2100 [6].

The importance of the use of hydropower can be in the form of home and industrial lightening, heating, cooling, operation of appliances, use of electronics, machinery and public transport. Today, the United States has a total electric power consumption rate of 3.93 trillion kwh and 13 times greater than electricity use in 1950 [7]. This is an indication that countries across the world are in great need of electricity supply which the hydropower dams can contribute immensely to actualize this electricity goal. However, some of the failures of hydropower generation can be in the form of natural causes, human error and overload [8]. Thus, any interruption between power generation point and supply point can result to power outage. Most importantly, weather conditions have the basic effects to the operations of hydro electric dams [9].

In Africa especially Nigeria and other developing countries, the effects of climate change will lead to gross loss of hydroelectric power generation. Africa and other sub-Sahara Africa are already experiencing intense heating that requires the intervention of electric supply for cooling. Also, African countries will continue to receive the worst hit of climate change and global warming since there is less preparedness by Africans to properly manage their hydroelectric power dams [10]. The issue of greenhouse gas will continue to degrade the natural atmospheric balance thereby causing alteration of rainfall, temperature, pressure, humidity, evaporation and other climatic parameters. Solar radiation is on the rise thereby altering the heat budget of the environment leading to more consumption of electricity and other energy sources. These climatic conditions will influence the reservoir performance hence affecting the operations of hydroelectric power dams [11]. Therefore, this study explores the characterization of climatic parameters and river flow capacity on electricity generation in Jebba Dam, Nigeria.

2. Methodology

Jebba Hydroelectric Power Station is located within within latitudes 9°10'N to 9°55' N and longitudes 4°30'E to 5°00'E (Figures 1 and 2). The area where the Jebba Dam is situated is 76 meters above Sea Level (SL). This location is approximately 100 kilometers downstream of Kainji dam [12]. Thus, Jebba hydro electric dam is the third dam in Nigeria with power generation capacity of 578MW, having six turbines producing 96.4MW each. The turbine power output is distributed to over 364,000 households having operating-head of 27.6m. The Jebba turbine is connected to a generator of 119MVA maximum continuous rating and 103.50MVA base load rating. [12]. Data for this study were collected from Mainstream Energy Solution Limited, Hydro-Power Plant, Jebba in 2018 for analysis. The data sets were reservoir inflow and outflow, power generation, rainfall and temperature as well as evaporation conditions of the Jebba hydropower reservoir station. The data were converted to averages and displayed in charts and graphs as well as discussed.

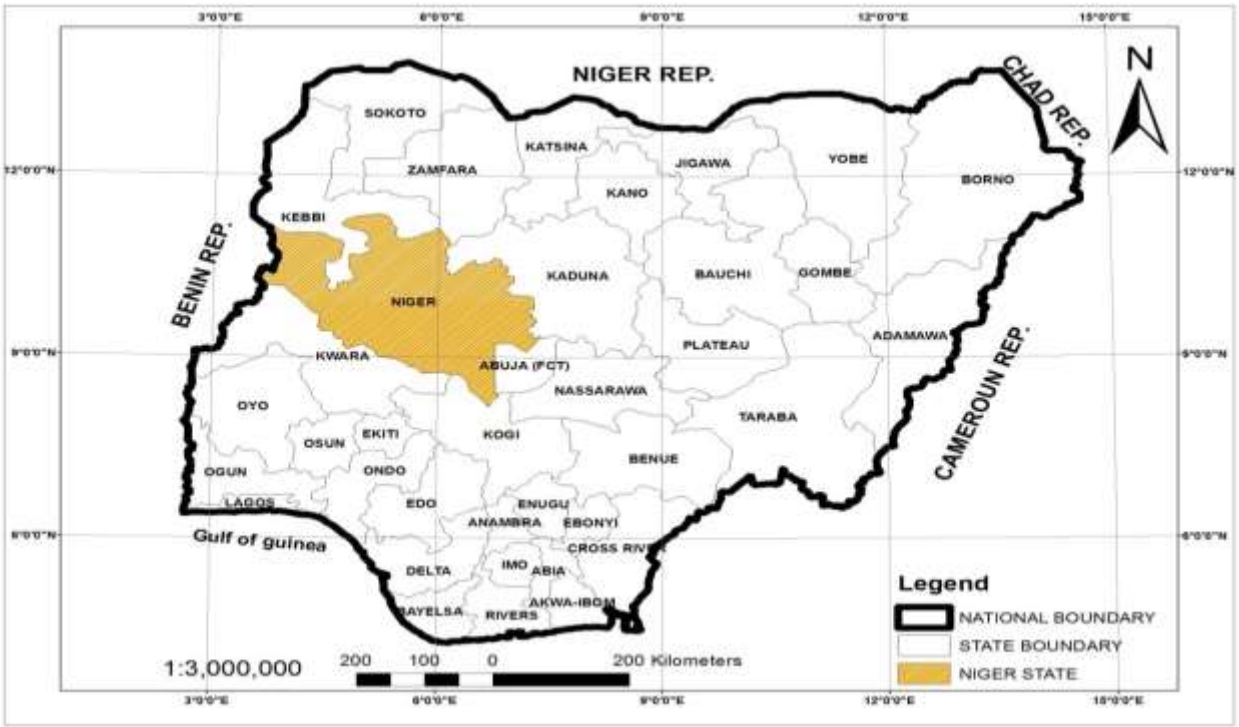


Figure 1. Map of Niger State in Nigeria

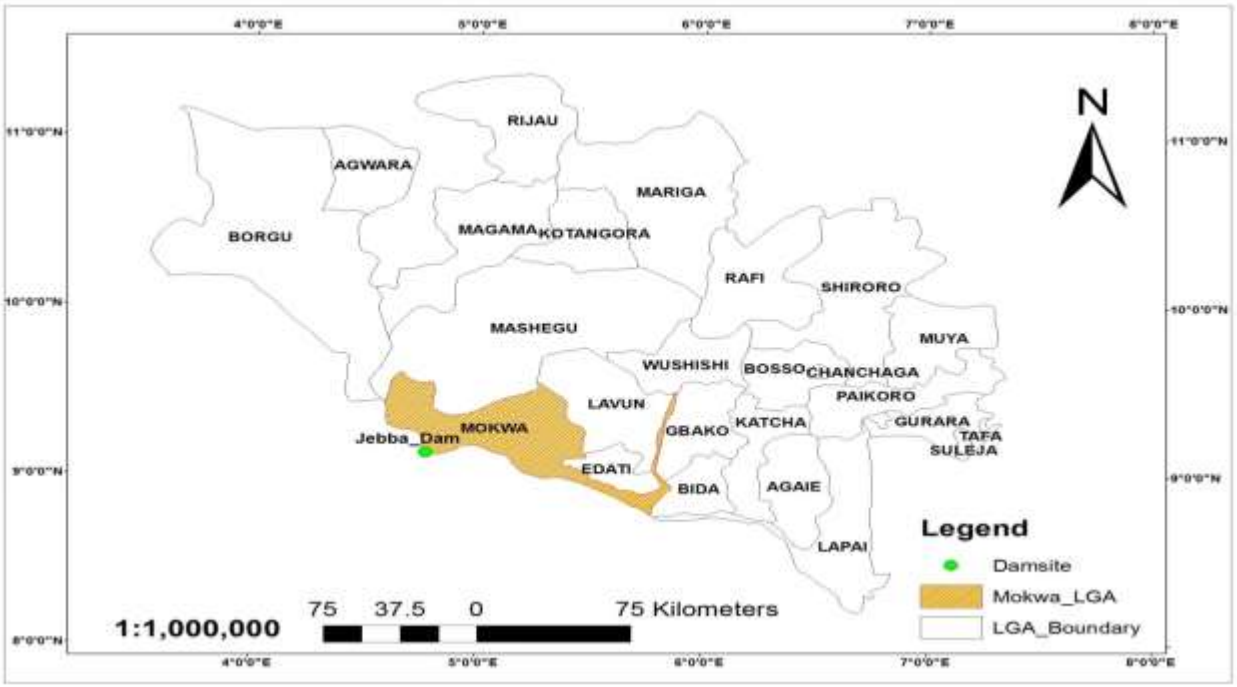
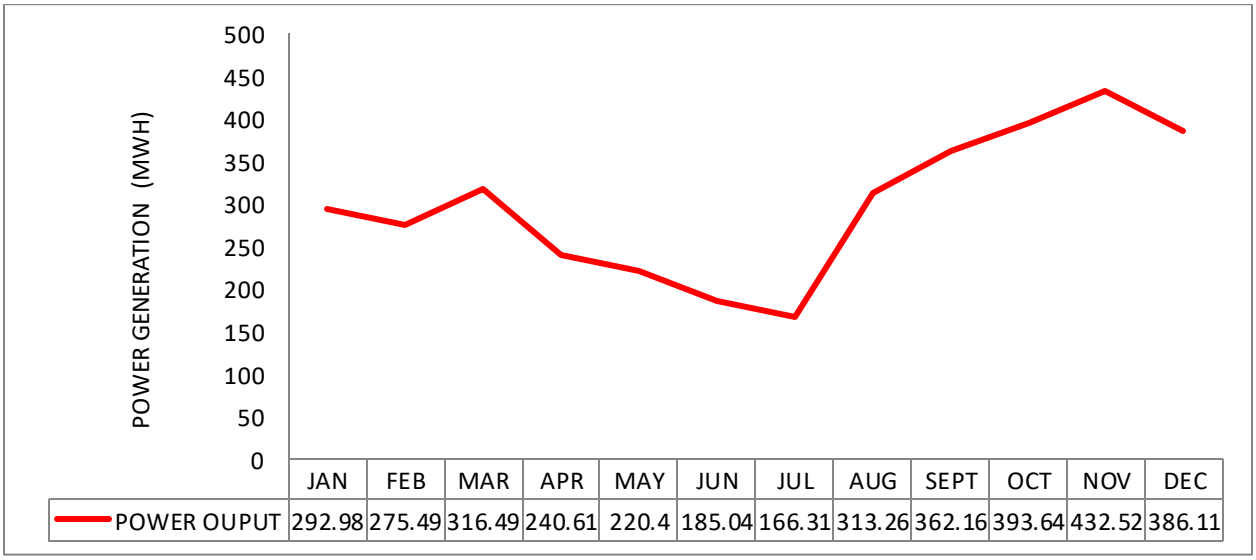


Figure 2: Location of Jebba Dam in Mokwa LGA of Niger State

3. Results

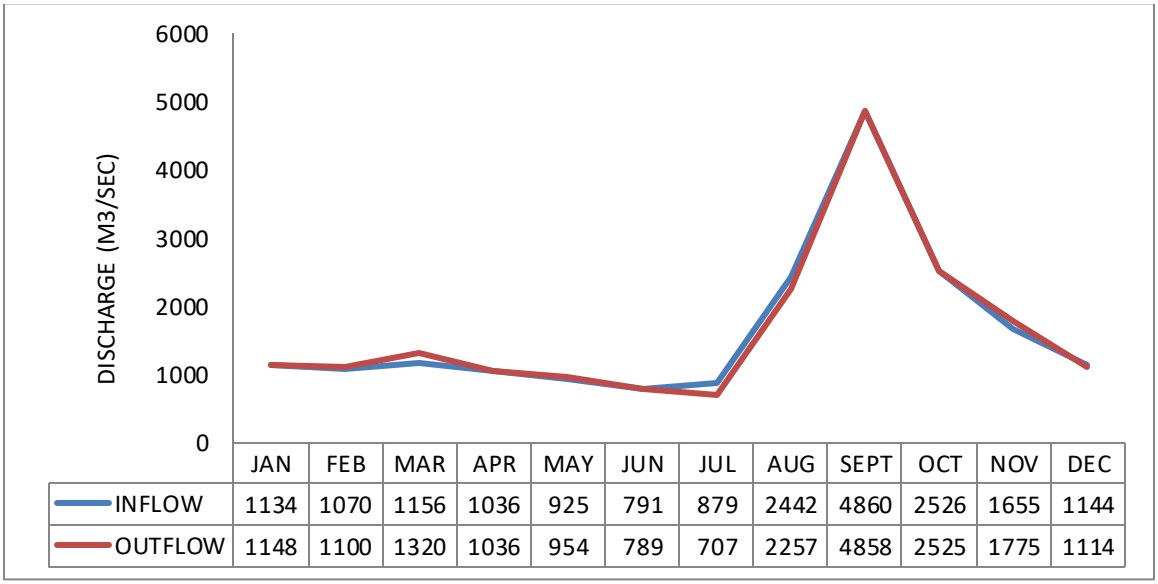
The result in Figure 3 showed the trend in power generation from January to December. There was rise in power generation from July to December with November having the highest power output of 432.5 MWH. In Nigeria This period use to be raining season indicating that there was increased power generation during the season. However, from January to June had low power generaation with the month of June having the least power output of 185MWH indicating that dry season affected the amount of power generation in the Jebba dam.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
POWER OUPUT	292.98	275.49	316.49	240.61	220.4	185.04	166.31	313.26	362.16	393.64	432.52	386.11

Figure 3. Power Generation from January to December (2018)

The result in figure 4 indicated the river inflow and outflow pattern. Reservoir inflow and outflow rose from July to December with September having the highest discharge of 4860 m^3/Sec inflow and 4858 m^3/Sec outflow. These months with highest inflow and outflow are majorly raining season months in the river basin. However, January to June had very low inflow and outflow with June having the least regime of 791 and 789 m^3/Sec. These months are found in the dry season of the year indicating that season influences the rate of Jebba dam water inflow and outflow conditions. The result indicated that inflow and outflow of the dam had the same pattern as they were skewed to July and December of the study period.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
INFLOW	1134	1070	1156	1036	925	791	879	2442	4860	2526	1655	1144
OUTFLOW	1148	1100	1320	1036	954	789	707	2257	4858	2525	1775	1114

Figure 4. River Inflow and Outflow from January to December (2018)

The result of Figure 5 showed the rainfall pattern of the Jebba dam catchment area. Thus, December to April had the lowest pattern of rainfall in the river basin. However, there was noticeable rise in rainfall pattern from May to November with September having the highest rainfall regime of 330.4mm. There was fluctuation of rainfall pattern as the rainfall rose from May to July, dropped in August and rose again in September and finally reduced to zero in November. Thus, rainfall regime had the capacity to influence the Jebba hydroelectric power generation.

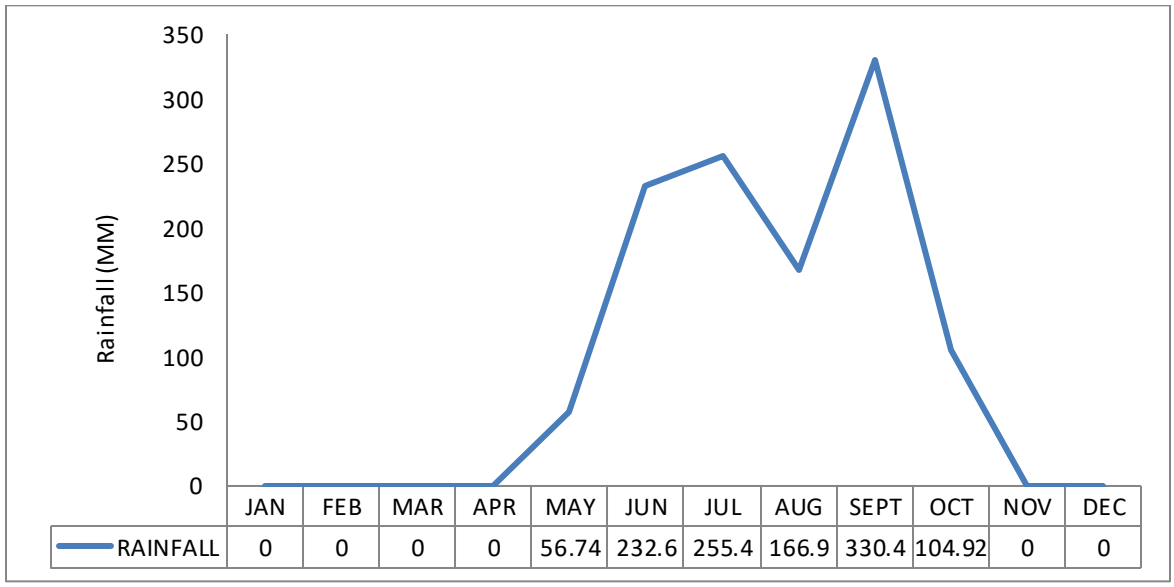


Figure 5. Rainfall Pattern from January to December (2018)

According to the result obtained in figure 6 indicating the temperature pattern of the Jebba river basin; February and November had the highest temperature regime of 36^0C each. However, July and August months had the least temperature regime of 30^0C each respectively. The annual temperature pattern showed that it rose from January to February and dropped in July and August and rose again from September to November and continually dropped in December. The temperature of a river basin has the capacity to influence the inflow and outflow as well as the power generation capacity of a dam at a particular period in time.

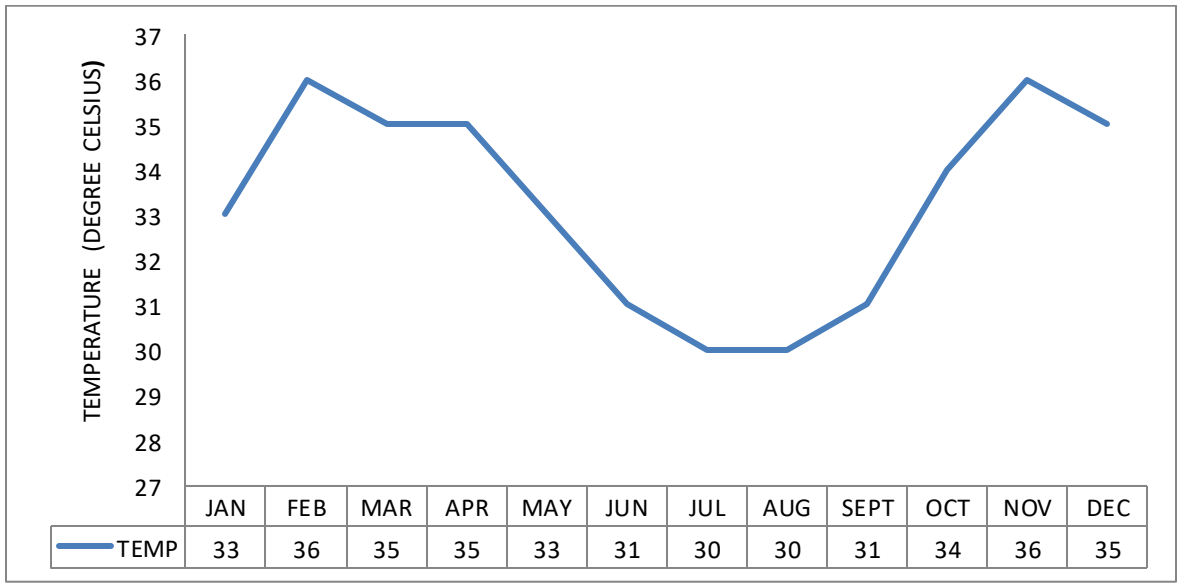
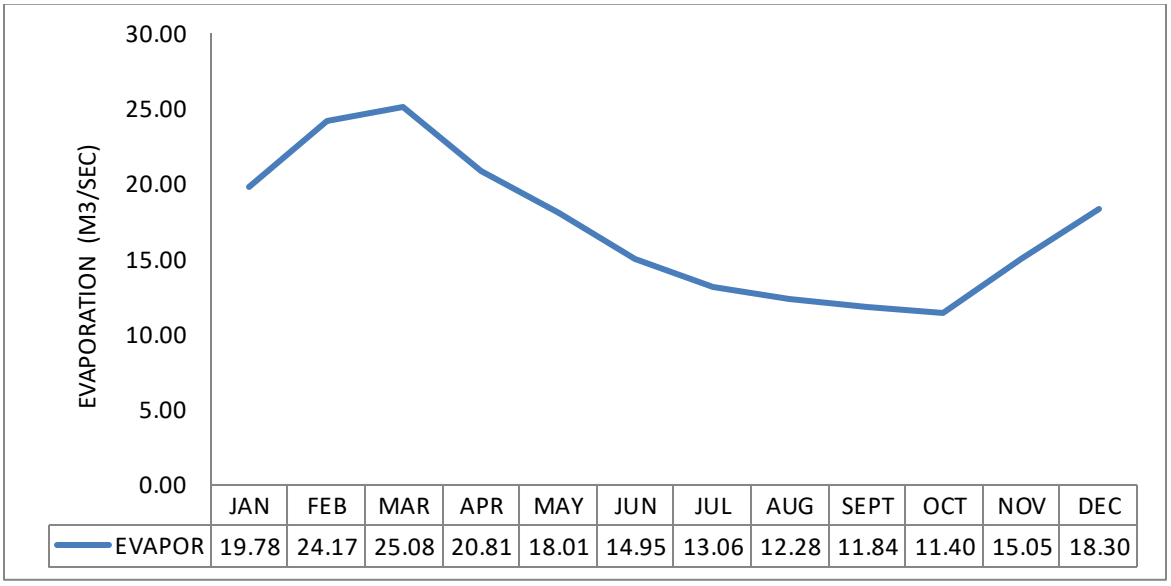


Figure 6. Temperature Pattern from January to December (2018)

Figure 7 showed the evaporation pattern of the Jebba river basin. The highest evaporation rate was recorded in March having 25m^3/sec, due to the fact that March is the month of intense dry season. The least evaporation rate was recorded in October having 11.4m^3/sec, showing the beginning of the hamattern season in northern Nigeria usually with low temperature regime. The annual evaporation pattern showed that it started rising from January to March and dropped to October and rose again from October to November.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
EVAPOR	19.78	24.17	25.08	20.81	18.01	14.95	13.06	12.28	11.84	11.40	15.05	18.30

Figure 7. Evaporation Pattern from January to December (2018)

4. Discussion

This study has shown the trends in climatic parameters (rainfall, temperature and evaporation) in the Jebba dam river basin of Nigeria in 2018. The fluctuation of inflow and outflow as well as power generation is influenced by the trends of the climatic variables. In the same vein, [13] investigated the effects of change in climate on the Jebba river basin. The research showed notable changes in the Jebba river basin where rainfall and relative humidity actually influenced the availability of water in the river basin. Thus, this revealed that climatic variables have very great influence on reservoir characteristics. The result indicated both positive and negative effects of climatic parameters on reservoir performance for hydropower generation. During the period of this study, the result showed that there was increased power generation during the raining season (July to November). The months of January to June marked the months with low generation of electricity. This is similar to the findings of [14] which showed that months of high reservoir flow will influence the amount of electricity generation within a given period of time of dam's operation.

River inflow and outflow (July to November), rainfall pattern (May to October), temperature (October to April) and evaporation (November to April) showed that the patterns of these climatic variables influenced the Jebba power generation. Similarly, [15] investigated the influence of climatic variables on reservoir performance in Jebba dam. It was noted that over the

decades, rainfall, river discharge and flooding had strong influence on the hydropower generation. Also, [16] studied the effects of climatic parameters on the performance of hydroelectric power dam using a simulation model. The result indicated that negative climatic parameter such as rainfall will result in decrease and shortening of hydroelectric power peak period with decreasing value which will make power to drop within 12% from June to December and rise by around 4% in the rest of the months. These are indications that performance of reservoir in a dam basin is impacted by various climatic parameters, inflow and outflow conditions at a given period of operation.

5. Conclusion

This study undertook the characterization of climatic parameters and river flow capacity on electricity generation in Jebba Dam, Nigeria. The study has revealed the level in which climatic parameters have influenced the Jebba hydropower generation. The pattern and interaction of rainfall, temperature and evaporation have impacted on reservoir inflow and outflow as well as hydropower generation. These climatic variables have shown important reservoir inflow and outflow conditions. The result has established that Jebba dam does have hydropower generation throughout the year with peak generation toward the third and fourth quarters of the year due to upstream flow from the Kaiji dam reservoir that causes flooding especially during the raining season. There is identical trending pattern between reservoir inflow and outflow of the Jebba dam as influenced by the activities of rainfall, temperature and evaporation regimes. The result shows that trend and pattern of power discharge by the dam is affected by the characteristics of the climate variables in the river basin. Climate change has severe impact on the operations and power generation of dams across the world. Therefore, the Nigerian government should endeavor to place high priority to drainage basin laws for effective reservoir management framework to enable the hydropower dam to generate electricity at optimum capacity. Though, some of the factors that contribute to optimum capacity of hydropower dams go beyond climatic variables such as maintenance and spare parts problems, inadequate funds, human resources and policy issues should be considered to enhance performance of the Jebba dam. Thus, both climate and human efforts should be harmonized to bring about optimum power generation in the dams across the country without further delay.

References

[1] Ali, S. A., Aadhar, S., Shah, H. L. and Mishra, V. (2018). Projected increase in hydropower production in india under climate change. Sci. Rep. 8, 12450.

[2] Berghuijs, W. R., Woods, R. A. and Hrachowitz, M. (2014). A precipitation shift from snow towards rain leads to a decrease in stream flow. Nat. Climate Change, 4, 583–586. doi: 10.1038/nclimate2246

[3] Chilkoti, V., Bolisetti, T., and Balachandar, R. (2017). Climate change impact assessment on hydropower generation using multi-model climate ensemble. Renew. Energy, 109, 510–517. doi: 10.1016/j.renene.2017.02.041

[4] Guo, J., Huang, G., Wang, X., Li, Y., and Yang, L. (2018). Future changes in precipitation extremes over China projected by a regional climate model ensemble. Atmospher. Environ., 188, 142–156. doi: 10.1016/j.atmosenv.2018.06.026

[5] John, C. J. and James, T. T. (2011). Annual Energy Outlook, United States Energy Information Administration.

[6] United Nations [UN] (2017).World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. Department of Economic and Social Affairs.

[7] U.S. Energy Information Administration (2022). Energy Explained. Use of Electricity. https://www.eia.gov/energyexplained/electricity/use-of-electricity.php

[8] Zheng, W., Cheng, X., Yang, X. and Wang, Y. (2017). Trend analysis of precipitation and temperature over the upper changjiang river basin by statistical-downscaled cmip 5 climate projections. China Rural Water Hydropower, (09), 43-51.

[9] Liu, X., Tang, Q., Voisin, N. and Cui, H. (2016). Projected impacts of climate change on hydropower potential in China. Hydrol. Earth Syst. Sci. 20, 3343–3359. doi: 10.5194/hess-20-3343-2016

[10] Madueme, T.C. (2017), Electric Power Consumption Reduction in the University of Nigeria, Nsukka Power Network, Journal of Electrical and Electronics Engineering, 12(4), 11–18.

[11] Zhang, D.-L., Lin, Y., Zhao, P., Yu, X., Wang, S., Kang, H. (2013). The Beijing extreme rainfall of 21 July 2012: "Right results" but for wrong reasons. Geophys. Res. Lett. 40, 1426–1431. doi:10.1002/grl.50304.

[12] Olukanni, D. O., Adejumo, T. A. and Salami, A. W. (2016). Assessment of Jebba Hydropower Dam Operation for Improved Energy Production and Flood Management. Journal of Engineering and Applied Sciences, 11(3), 8450-8467.

[13] Salami, A.W., Raji, M.O., Sule, B.F, Abdulkareem, Y.A. andBilewu, S.O. (2010), "Impacts of Climate Change on the Water Resources of Jebba Hydropower Reservoir", Second Annual Civil Engineering Conference, University of Ilorin, Nigeria.

[14] Adegbehin, A.B.1, Iguisi, E.O., Yusuf, Y.O. Zubairu, I. andAnumonye, E.N. (2016), "Effect of Weather Parameters on Hydroelectric Power Generation in Kainji Dam". Niger State, Nigeria.

[15] Ifabiyi, I.P. (2011), Contributions of Reservoir Elements to Monthly Electricity Generation in the Jebba Hydropower Reservoir, Nigeria. Journal of Applied Sciences, 2, 251 – 263.

[16] Li W., Li j., Guo J., Bao Z., Fu L. and Hou B. (2020). The Effects of Precipitation on Hydropower Generation Capacity: A Perspective of Climate Change. Frontiers in Earth Science, 8, -13. doi:10.3389/feart.2020.00268.