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Research Article

IMPACT OF CLIMATIC PARAMETERS AND RIVER FLOW ON ELECTRICITY GENERATION AT JEBBA DAM, NIGERIA

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Abstract
This study investigates the influence of climatic parameters and river flow on electricity generation at Jebba Dam, Nigeria. Climatic factors such as rainfall, temperature, and evaporation directly affect reservoir inflow and outflow, which in turn impacts hydropower generation. Secondary data on climatic parameters, reservoir inflow and outflow, and hydropower production from Mainstream Energy Solution Limited in 2018 were analyzed using averages, with results presented in graphs and charts. The findings indicate that power generation at Jebba Dam peaked from July to December, with the highest generation occurring in November at 432.5 MWh. Reservoir inflow and outflow also increased during this period, reaching their highest values in September, with inflow and outflow recorded at 4860 m³/sec and 4858 m³/sec, respectively. Rainfall patterns showed a marked increase from May to November, with September experiencing the highest rainfall at 330.4 mm. The highest temperature of 36°C occurred in both February and November, while March recorded the highest evaporation rate of 25 m³/sec. The study highlights the significant effects of these climatic factors on reservoir flow and hydropower generation, emphasizing the importance of considering climate change in the management of hydropower resources. The findings suggest that the government must urgently address the challenges posed by climate change to ensure the sustainability of hydroelectric power generation in Nigeria.

Keywords: Climatic Parameters, River Flow, Hydropower Generation, Jebba Dam, Climate Change

Introduction

The growing global demand for electricity driven by industrialization, urbanization, and overpopulation presents significant challenges and opportunities for energy generation. With the increased need for reliable and sustainable power sources, hydropower remains a crucial component of the energy mix, especially in developing regions. Hydropower, which generates electricity through the flow of water, is highly sensitive to climatic factors. Climatic parameters such as rainfall, temperature, and evaporation have profound effects on the water flow and storage in reservoirs, which in turn impact hydropower production. These interactions between climate and hydropower generation are particularly important in regions heavily dependent on hydropower for their energy needs, such as Nigeria. In this context, understanding the relationship between climatic parameters, river flow, and electricity generation is vital for effective water resource management and ensuring sustainable power generation.

Climatic Parameters and Their Influence on Hydropower The relationship between climatic parameters and hydropower generation is well-established in hydrological studies. Rainfall, temperature, and evaporation play key roles in regulating the inflow and outflow of reservoirs. Precipitation is the primary source of water that fills reservoirs, while temperature and evaporation influence the rate at which water is lost from the system. As such, changes in these climatic factors can significantly affect the availability of water for power generation. Studies have shown that even small fluctuations in precipitation can lead to notable changes in hydropower production. For instance, a 43% increase in precipitation can result in a 39% increase in hydropower generation, highlighting the critical role of rainfall in the production of electricity from dams.

Temperature also plays a crucial role, as higher temperatures can lead to increased evaporation rates, reducing the amount of water available in reservoirs for hydropower generation. In addition, prolonged periods of drought, often exacerbated by rising global temperatures due to climate change, can severely limit the water supply to hydropower plants. Evaporation, driven by temperature, humidity, and solar radiation, is another factor that can reduce the overall efficiency of hydropower production. As temperatures rise and the rate of evaporation increases, less water remains in the reservoir, which directly impacts electricity generation capacity.

The increasing unpredictability of climatic patterns, largely due to climate change and global warming, exacerbates these challenges. Changes in rainfall patterns, rising temperatures, and altered evaporation rates can make it difficult to predict and manage hydropower generation. In regions such as sub-Saharan Africa, including Nigeria, these impacts are especially pronounced, as many countries rely heavily on hydropower to meet their growing energy demands.

Global and Regional Context of Hydropower

Globally, the demand for electricity is expected to double between 2007 and 2035, driven by population growth and increased industrial and technological development. By 2050, the world's population is projected to reach 10 billion, and by 2100, this number could surpass 11.2 billion. This rapid population growth will place even greater pressure on existing energy infrastructure, making it essential to find sustainable solutions to meet the increasing energy needs. Hydropower, with its ability to provide large-scale, renewable energy, is poised to play a key role in meeting this demand.

In countries such as the United States, electricity consumption has increased dramatically, with the total consumption rate reaching 3.93 trillion kWh, which is 13 times higher than in 1950. This demonstrates the extent to which electricity demand has grown, underscoring the need for reliable and efficient energy generation systems. Hydropower can contribute significantly to meeting this demand, particularly in regions with abundant water resources. However, hydropower generation is not without its challenges. Issues such as equipment failure, human error, and overload can cause interruptions in power supply, leading to outages. Furthermore, weather conditions can have fundamental effects on the operation of hydroelectric dams. Variations in rainfall, temperature, and other climatic conditions directly influence the efficiency and reliability of these dams.

In developing countries, particularly in Africa, the impact of climate change is expected to be especially severe. Africa is already experiencing rising temperatures and changes in precipitation patterns that threaten the stability of hydropower generation. Countries in sub-Saharan Africa are expected to be some of the hardest-hit by climate change, as they have limited capacity to adapt to its impacts. These changes can lead to reduced water availability for hydropower, further exacerbating the energy crisis in these regions. As temperatures rise and rainfall patterns become more erratic, the performance of hydroelectric dams may decline, affecting power generation and supply. Moreover, the degradation of the natural atmospheric balance caused by greenhouse gas emissions is contributing to the worsening of climatic conditions, including altered rainfall, temperature, humidity, and evaporation rates.

Climate Change and Its Impact on Hydropower in Nigeria

Nigeria, like many other African nations, faces significant challenges related to the impacts of climate change on its energy sector. As a country heavily reliant on hydropower for electricity generation, Nigeria is particularly vulnerable to the effects of changes in climatic parameters. The Jebba Dam, located in central Nigeria, is one of the country's key hydropower plants, providing a substantial portion of the national electricity supply. However, like other dams across the country, the Jebba Dam is subject to the variability of rainfall, temperature, and evaporation, all of which can influence the amount of water available for power generation.

Climate change is expected to intensify these challenges, with rising temperatures and changing precipitation patterns affecting the water supply to the dam. This is of particular concern, given the growing demand for electricity in Nigeria, driven by urbanization and industrialization. As the population continues to increase and the economy develops, the demand for reliable and sustainable power generation will only continue to grow. However, the country's ability to meet this demand is increasingly at risk due to the effects of climate change on hydropower resources.

The Jebba Dam, like many other hydropower plants in Nigeria, faces the risk of reduced water levels during dry periods, leading to lower power generation. Droughts, which are becoming more frequent and severe as a result of climate change, further exacerbate this issue. Additionally, the rising temperatures that are characteristic of climate change are likely to increase evaporation rates, further reducing the amount of water available for electricity generation. These factors make it essential to understand the relationship between climatic parameters and hydropower generation at the Jebba Dam, in order to better manage the reservoir and optimize power production.

The Need for Climate-Resilient Hydropower Management

Given the growing threat of climate change, there is an urgent need for climate-resilient management practices to ensure the continued operation of hydropower plants such as Jebba Dam. Adapting to the changing climate requires a comprehensive understanding of how climatic factors influence water flow and electricity generation. This includes analyzing the patterns of rainfall, temperature, and evaporation, and their impact on the reservoir inflow and outflow. It is also necessary to develop strategies to mitigate the adverse effects of climate change, such as the implementation of more efficient water management systems and the use of predictive modeling to forecast changes in climatic parameters.

In addition to improving the management of existing hydropower resources, it is important to invest in the development of new, climate-resilient infrastructure. This includes the construction of dams and reservoirs that are designed to withstand the impacts of climate change, such as fluctuating rainfall and temperature patterns. It also involves exploring alternative energy sources, such as solar and wind power, to complement hydropower and reduce the country's dependence on a single energy source.

As Nigeria continues to experience the effects of climate change, the importance of understanding the interactions between climatic parameters and hydropower generation cannot be overstated. This study aims to explore these interactions at the Jebba Dam, with a focus on the characterization of climatic parameters and river flow capacity on electricity generation. By examining these factors, the study seeks to contribute to the development of more effective strategies for managing hydropower resources in the face of climate change, ensuring a reliable and sustainable power supply for Nigeria's growing population.

2. Methodology

Jebba Hydroelectric Power Station is located within within latitudes 9^{o}10'N to 9^{o}55' N and longitudes 4^{o}30'E to 5^{o}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.

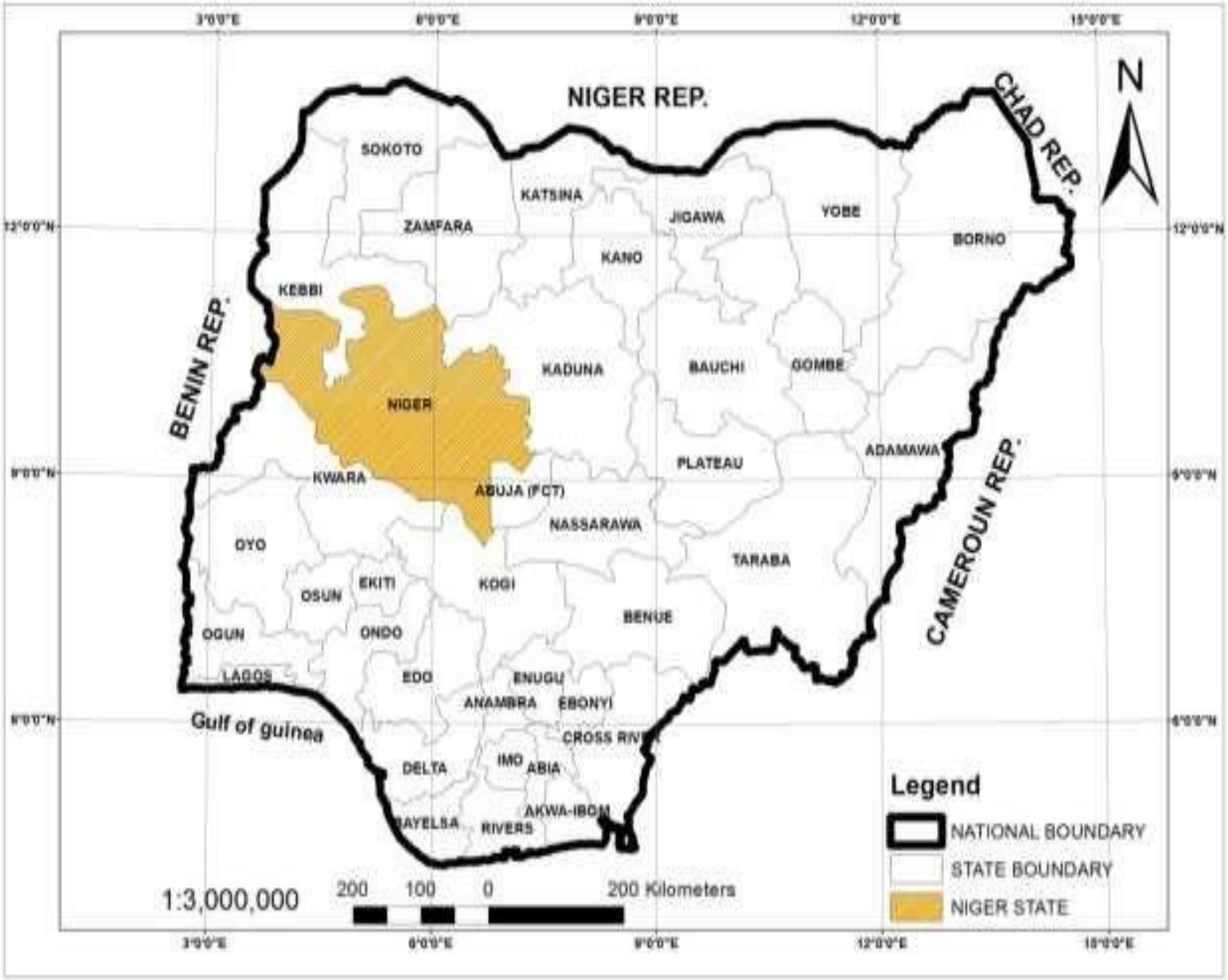
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Figure 1. Map of Niger State in Nigeria

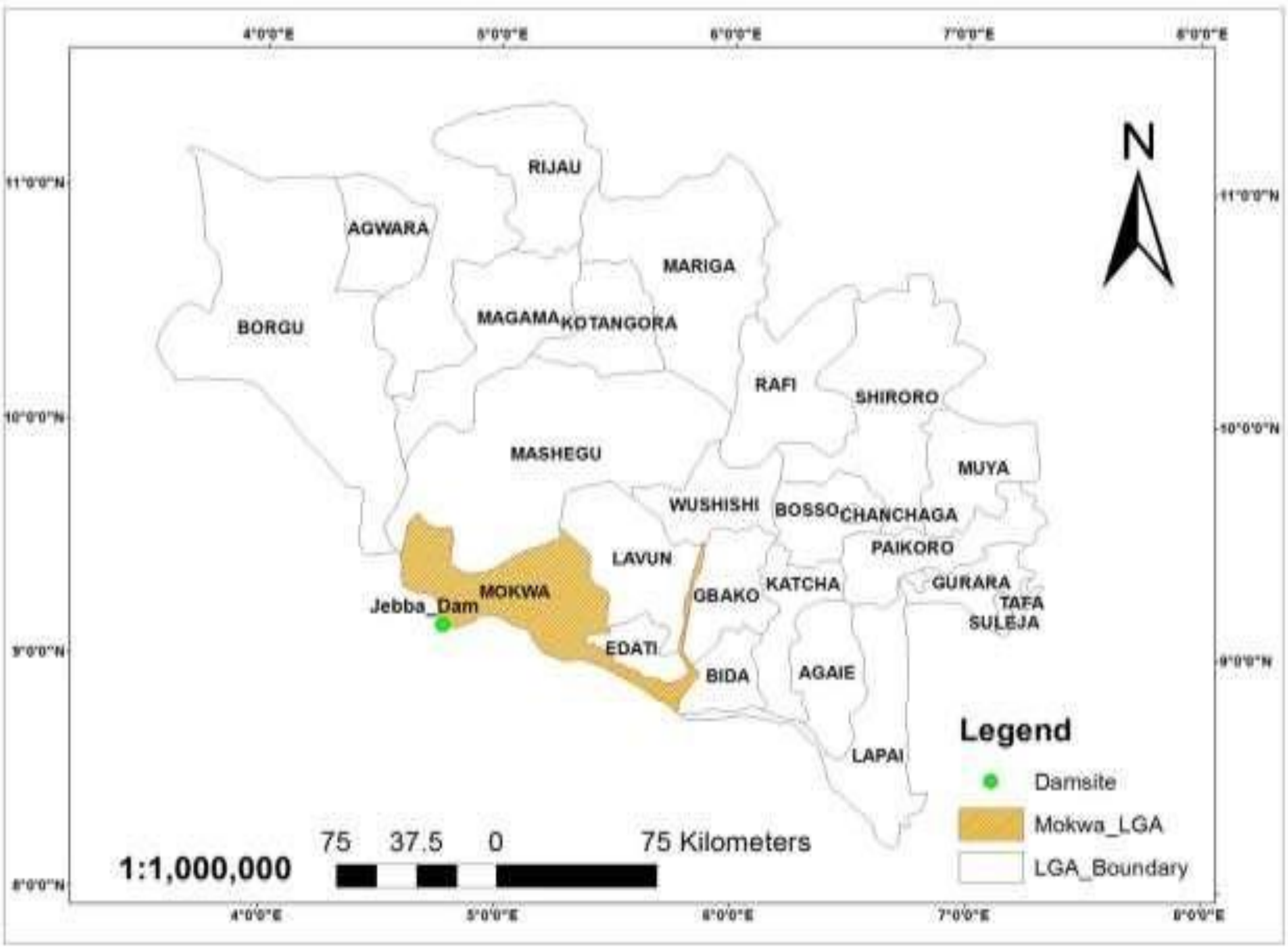

Figure 2: Location of Jebba Dam in Mokwa LGA of Niger State

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.

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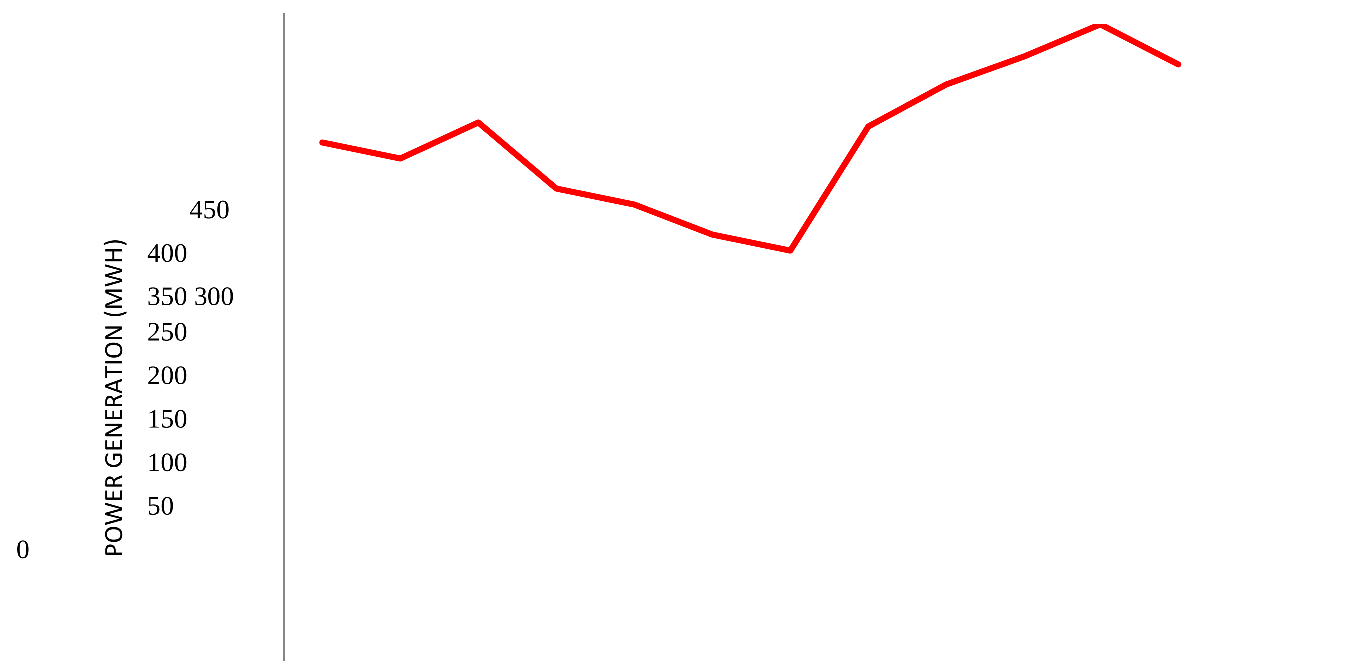
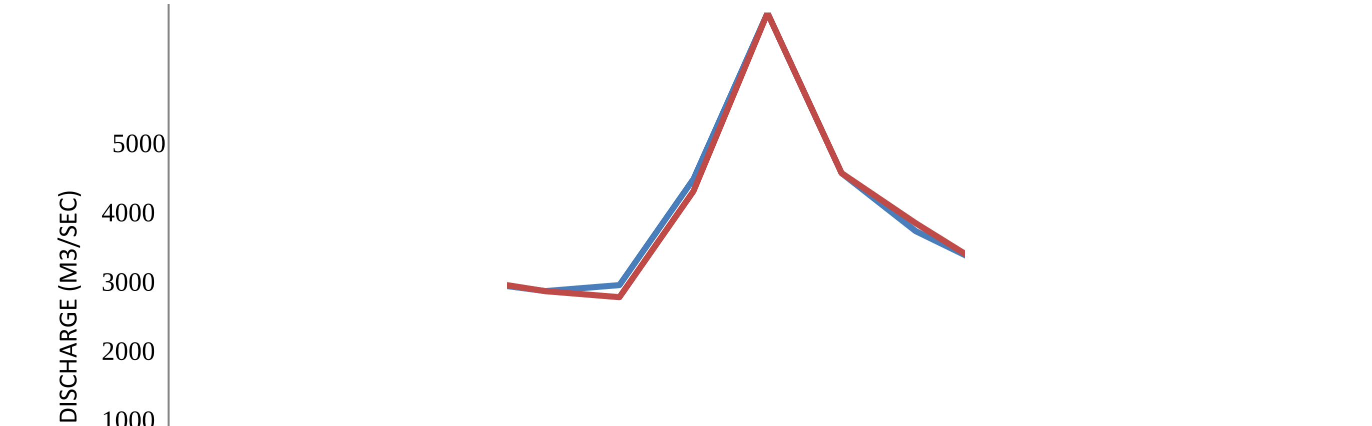
However, from January to June had low power generation with the month of June having the least power output of 185MWH indicating that dry season affected the amount of power generation in the Jebba dam.



	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.

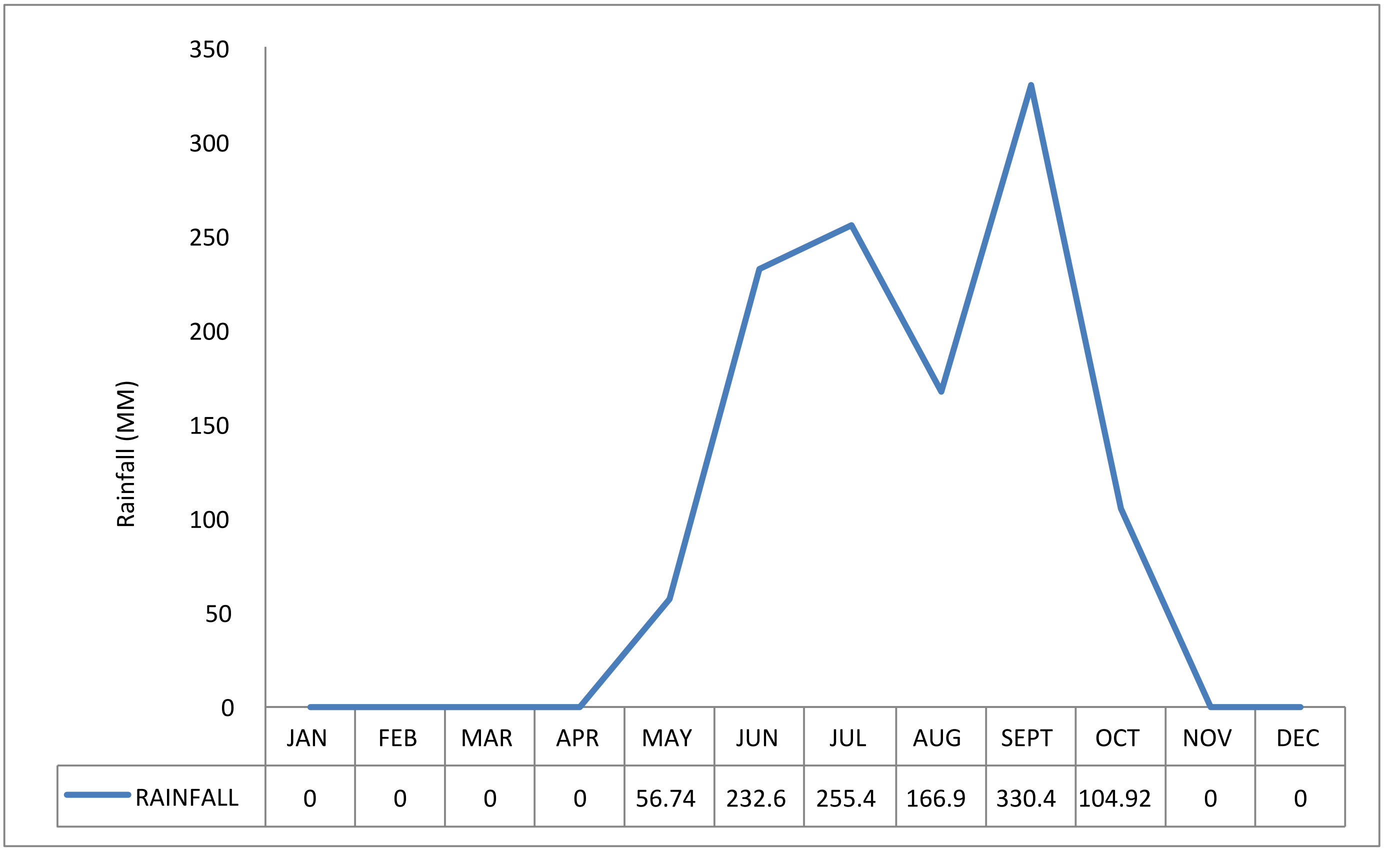


Figure 5. Rainfall Pattern from January to December (2018)

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.

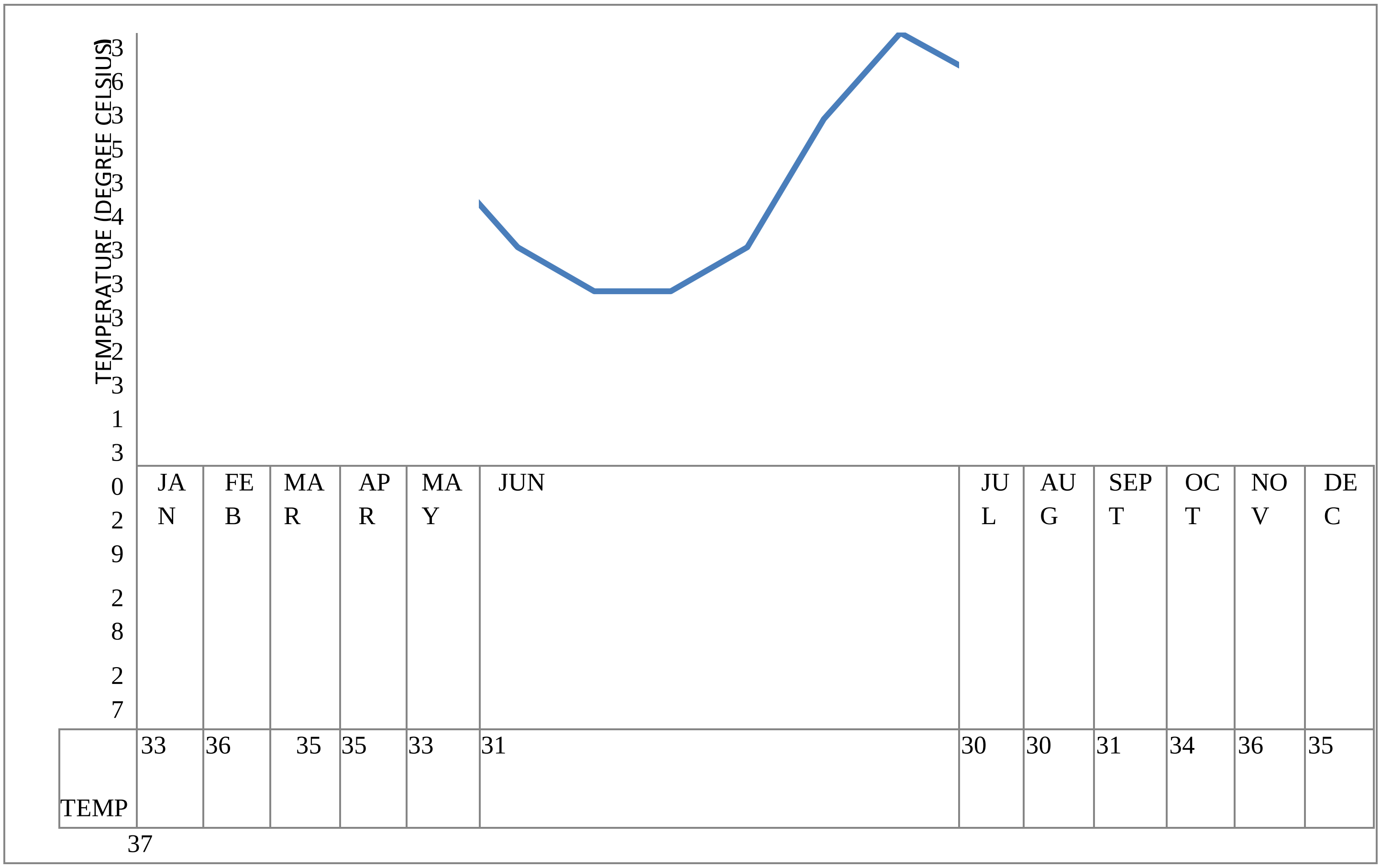
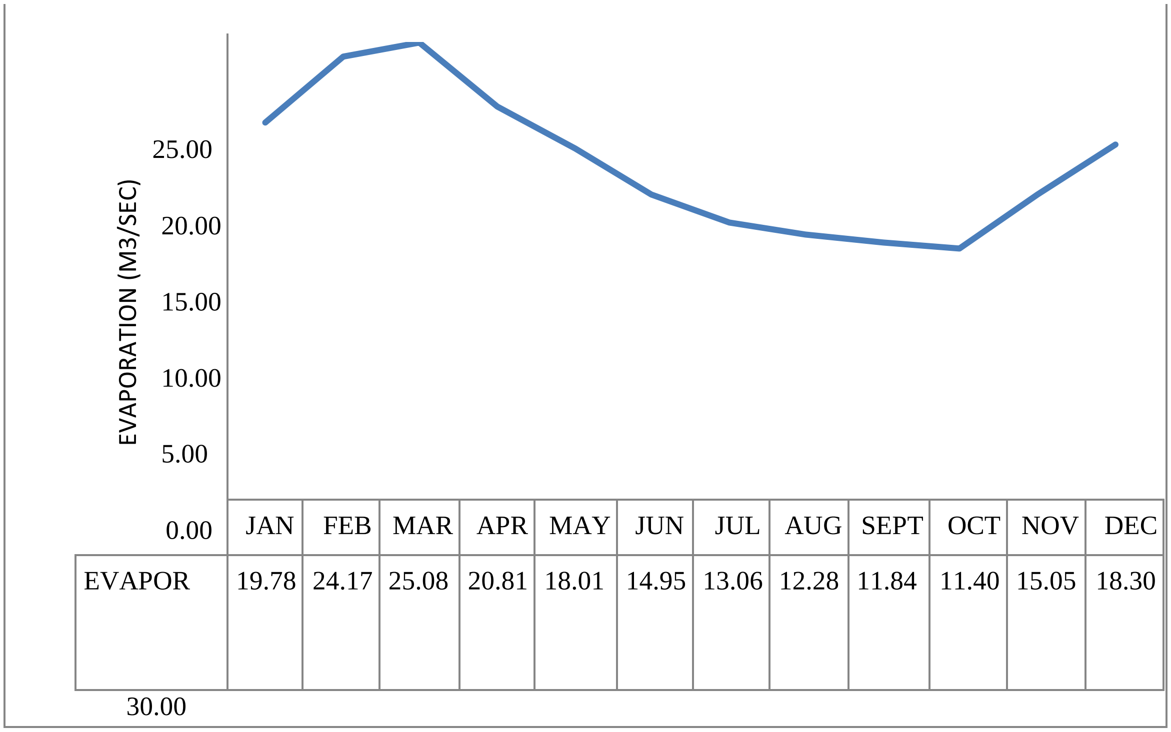


Figure 6. Temperature Pattern from January to December (2018)

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.

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