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Evaluating Changing Hydrological Patterns On Hydropower Generation Of Kainji Hydropower Station Of Nigeria

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ABSTRACT
Hydropower remains a vital component of Nigeria's energy mix, with the Kainji Hydropower Station playing a central role in electricity generation. However, the reliability of hydropower is increasingly challenged by shifting hydrological patterns driven by climate variability. This study assessed the influence of rainfall, temperature, and evaporation on power generation at the Kainji Hydropower Station over a 10-year period (2012–2022). Adopting a quantitative research design, the study relied on secondary data sourced from the Nigerian Meteorological Agency (NiMet) and the Nigerian Bureau of Statistics (NBS), covering monthly records of hydrological parameters and electricity output. Analytical methods included trend analysis, seasonal mean comparisons, Pearson's correlation, and multiple regression techniques. Results revealed a notable increase in rainfall throughout the decade, with a weak positive correlation to power generation. Interestingly, average power output was higher during the dry season (348.87 MW) than in the rainy season (317.42 MW), likely due to regulated water release and reservoir management. Temperature remained relatively stable, ranging from 27.58°C to 29.10°C, and showed a weak but statistically significant influence on power output. Evaporation peaked in the early years and declined in later years, maintaining a weak positive correlation with electricity generation.Collectively, the three hydrological parameters demonstrated a moderate positive effect on hydropower output, indicating that their combined influence is more significant than their individual impacts. The study concludes that effective forecasting and management of hydrological conditions are critical for optimizing power generation. It recommends that policymakers strengthen climate-resilient energy planning, improve water resource management practices, and integrate real-time hydrological data into dam operation strategies to enhance energy reliability amid ongoing environmental variability.
Keywords: Hydropower generation; Climate variability; Rainfall trend; Evaporation; Temperature;

INTRODUCTION

Hydropower remains a vital component of global renewable energy strategies, accounting for approximately 16% of the world's electricity supply (IEA, 2021). As a clean and renewable source, it plays a crucial role in mitigating the impacts of climate change while supporting economic development. However, the efficiency and reliability of hydropower generation are heavily dependent on consistent hydrological patterns—principally rainfall, temperature, and evaporation. These variables directly affect water availability in dam reservoirs, which in turn determines the potential for electricity generation (Ahmed et al., 2020).

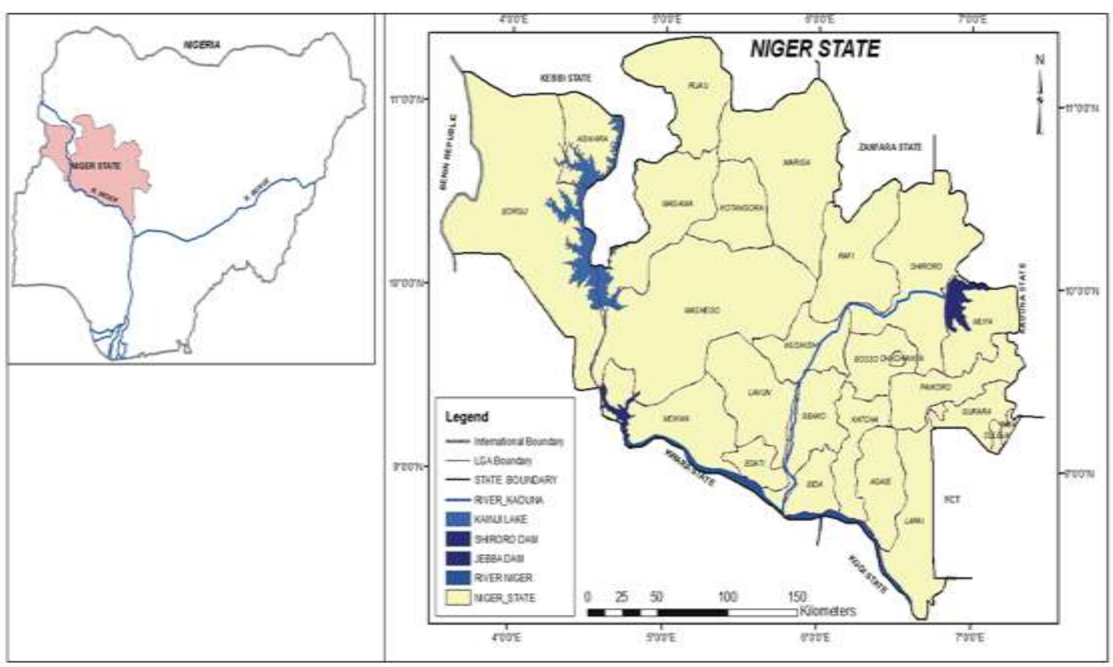
In sub-Saharan Africa, and particularly in Nigeria, hydropower is central to national energy planning. Nigeria's Kainji Hydropower Station, commissioned in 1968 and situated across the Niger River in Niger State, is one of the largest hydropower facilities in West Africa. Originally designed to generate 960 megawatts (MW) of electricity, only eight out of its twelve turbines have been installed, limiting its current generation capacity to about 760 MW (Afolayan et al., 2022). Recent decades have witnessed increasing fluctuations in reservoir inflow and seasonal water availability, often attributed to changing climatic patterns, anthropogenic activities, and inefficient reservoir management practices.

Studies such as those by Adedeji and Oyebanji (2021) and Rasiu et al. (2022) have emphasized the role of climate variability in altering the hydrological balance essential for hydropower production. However, few of these studies have focused extensively on the long-term interplay between rainfall, temperature, evaporation, and electricity generation in Nigeria. This gap in literature necessitates a thorough investigation into how changing hydrological patterns affect hydropower generation at a station as strategic as Kainji Dam.

This study assesses 10 years of data (2012–2022) to evaluate the trends in key hydrological parameters and their influence on power generation. The findings will contribute to improved water resource planning, energy policy development, and climate adaptation strategies in Nigeria and similar hydropower-dependent regions.

METHODOLOGY

3.1 Study Area



The Kainji Hydropower Station is located in New Bussa, Borgu Local Government Area, Niger State, Nigeria. Positioned on the River Niger, the dam lies approximately at latitude 9.86°N and longitude 4.62°E. It is the oldest and one of the most significant hydropower facilities in Nigeria, designed to produce a maximum of 960 MW of electricity. The dam forms part of the broader Niger River Basin, which experiences a tropical savanna climate characterized by distinct wet (April–October) and dry (November–March) seasons. The hydrological cycle in this region is sensitive to climate-induced fluctuations, making it an ideal location for this study.

3.2 Research Design

This study employed a quantitative research approach to assess the relationship between hydrological parameters and hydroelectric power generation over a 10-year period (2012–2022). The design was retrospective and correlational, focusing on historical data to determine trends and associations between variables such as rainfall, temperature, evaporation, and electricity output.

3.3 Data Collection

The research utilized **secondary data** obtained from reputable sources:

Hydrological data (monthly rainfall, temperature, and evaporation) were sourced from the Nigerian Meteorological Agency (NiMet).

Power generation data (monthly electricity output in megawatts) were obtained from the Nigerian Bureau of Statistics (NBS) and official reports from the Kainji Hydropower Station.

3.4 Data Analysis

The data were subjected to several analytical techniques: **Trend analysis** was used to identify long-term patterns in the hydrological and power generation datasets. **Descriptive statistics** (means and standard deviations) helped summarize the data over time. **Pearson's correlation** was employed to evaluate the strength and direction of relationships between hydrological variables and power generation. **Multiple regression analysis** was applied to determine the combined effect of rainfall, temperature, and evaporation on electricity output. All statistical analyses were conducted using **SPSS (Version 26)**, with significance evaluated at the **0.05 level**.

RESULTS AND DISCUSSION

The analysis of rainfall, temperature, and evaporation data from 2012 to 2022 revealed notable variations across the years. The section covers the presentation of data and discussion of findings.

Table 1: Rainfall (mm) Pattern for the Period of 2012-2022

Month	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	10.7	6.7	9.9	9.3	0.0	0.0	17.0	16.1	0.0	5.6	0.0
Mar	20.6	36.3	38.4	44.7	68.1	17.4	19.5	18.4	31.5	24.0	28.0
Apr	100.0	72.3	113.1	40.9	76.0	61.1	77.9	77.1	67.4	74.5	105.7
May	172.1	128.0	201.2	149.8	165.1	150.2	173.3	172.5	181.6	171.0	109.8
Jun	153.0	124.5	156.8	106.0	170.9	176.7	163.2	168.9	191.0	210.4	202.0
Jul	236.9	187.4	156.2	204.3	202.8	159.2	231.4	272.1	188.6	116.3	208.6
Aug	190.5	43.3	252.5	353.9	230.5	286.3	214.3	178.9	181.1	312.0	203.0
Sep	247.4	198.5	241.3	144.5	192.0	187.7	220.8	276.0	233.9	188.2	140.5
Oct	194.9	62.8	95.0	145.0	126.0	98.4	149.0	200.5	92.0	175.9	204.5
Nov	0.0	0.0	6.1	5.0	0.0	0.0	5.5	7.3	0.0	5.3	0.0
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source|: Nigeria Metrological Agency

Rainfall data from the Nigerian Meteorological Agency for the period 2012 to 2022 shows a consistent seasonal pattern, with peak rainfall typically occurring between July and September each year. August and September were the months with the highest rainfall across most years, reaching peaks like 312 mm in August 2021 and 286.3 mm in August 2017. The months of January, February, November, and December frequently recorded no rainfall, indicating a clearly defined dry season. While annual rainfall amounts varied, this pattern of concentrated wet and dry periods was consistently observed throughout the 11-year period.

Table 2: Evaporation (ml) Pattern for the Period of 2012-2022

	1	2	3	4	5	6	7	8	9	10	11
Month	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Jan	1.9	1.9	2.0	1.9	2.0	2.0	2.0	2.0	2.0	2.1	2.0
Feb	1.9	1.9	2.1	1.8	2.1	2.1	2.0	2.0	2.2	2.1	2.2
Mar	2.0	1.9	2.0	1.8	1.8	2.0	1.8	2.1	2.0	2.1	2.0
Apr	1.7	1.6	1.9	1.8	1.7	1.9	1.6	1.8	1.8	2.0	1.7
May	1.5	1.5	1.6	1.6	1.6	1.6	1.4	1.6	1.6	1.6	1.5
Jun	1.5	1.4	1.5	1.5	1.4	1.5	1.5	1.4	1.5	1.5	1.5
Jul	1.3	1.3	1.4	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.4
Aug	1.2	1.3	1.4	1.3	1.3	1.2	1.3	1.3	1.4	1.4	1.3
Sep	1.3	1.3	1.4	1.4	1.4	1.3	1.4	1.4	1.3	1.4	1.4
Oct	1.4	1.9	1.5	1.5	1.5	1.5	1.6	1.4	1.5	1.5	1.6
Nov	1.7	1.9	1.9	1.8	1.8	1.9	1.8	1.8	1.9	1.7	2.0
Dec	2.0	1.9	2.0	2.0	1.9	1.9	1.9	2.0	2.0	2.0	2.0

Source: Nigeria Metrological Agency Survey 2024

Evaporation data from the Nigerian Meteorological Agency between 2012 and 2022 shows a seasonal pattern, with higher evaporation rates typically recorded during the dry months of January to March and December, peaking at 2.2 ml in February 2020 and 2022. Conversely, lower evaporation rates were consistently recorded during the wet months of July and August, with values often between 1.2 and 1.4 ml. August frequently had the lowest evaporation, as seen in 2012, 2016, 2017, and 2018. This pattern reflects the climatic cycle of the region, with higher temperatures and drier air in the early and late parts of the year contributing to increased evaporation.

Table 3: Mean of Temperature ($O^{c)}$ for the Period of 2012-2022

Month	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Jan	27.8	28.6	26.9	26.7	27.1	29.3	26.4	28.1	26.7	28.9	27.2
Feb	31.5	30.9	29.2	31.3	30.9	30.9	31.2	29.6	29.3	30.3	30.1
Mar	32.6	32.3	30.4	31.3	31.7	32.9	31.2	32.2	32.2	31.5	32.2
Apr	30.8	29.6	29.7	31.2	30.6	31.3	30.2	31.5	30.4	31.0	29.1
May	28.5	28.3	29.0	29.9	29.9	29.3	28.2	29.6	29.2	28.7	27.9
Jun	27.1	27.6	28.2	28.9	28.2	28.4	28.1	28.1	28.1	27.2	26.9
Jul	26.8	26.8	27.3	27.4	27.6	27.2	27.3	27.7	27.3	26.5	26.9
Aug	26.5	26.6	26.8	27.3	27.4	26.7	26.9	27.2	27.6	26.9	26.0
Sep	27.0	26.8	26.8	27.5	27.5	27.3	26.7	27.2	26.7	27.7	26.6
Oct	27.5	28.8	27.9	28.3	28.5	28.7	28.1	27.4	28.0	28.3	27.2
Nov	29.1	26.2	28.6	28.5	29.7	29.2	28.7	28.5	29.3	29.1	28.8
Dec	27.5	25.3	27.2	30.5	28.0	28.0	26.3	26.9	29.0	27.3	26.8
Mean	28.56	28.15	28.10	29.23	23.93	29.10	28.28	28.67	28.65	28.62	27.98

Source: Nigeria Metrological Agency Survey 2024

Temperature data from 2012 to 2022 revealed a consistent seasonal trend, with March typically recording the highest temperatures each year, peaking at 32.6°C in 2012 and 32.2°C in 2019, 2020, and 2022. The lowest temperatures were mostly observed in the wet months, particularly August, September, and December, with August 2022 recording the lowest value of 26.0°C. On average, temperatures ranged between 26.0°C and 32.6°C, indicating moderate variation over the years. These patterns reflect the climatic cycle in the region, where dry season months are hotter, while wet season months experience cooler temperatures.

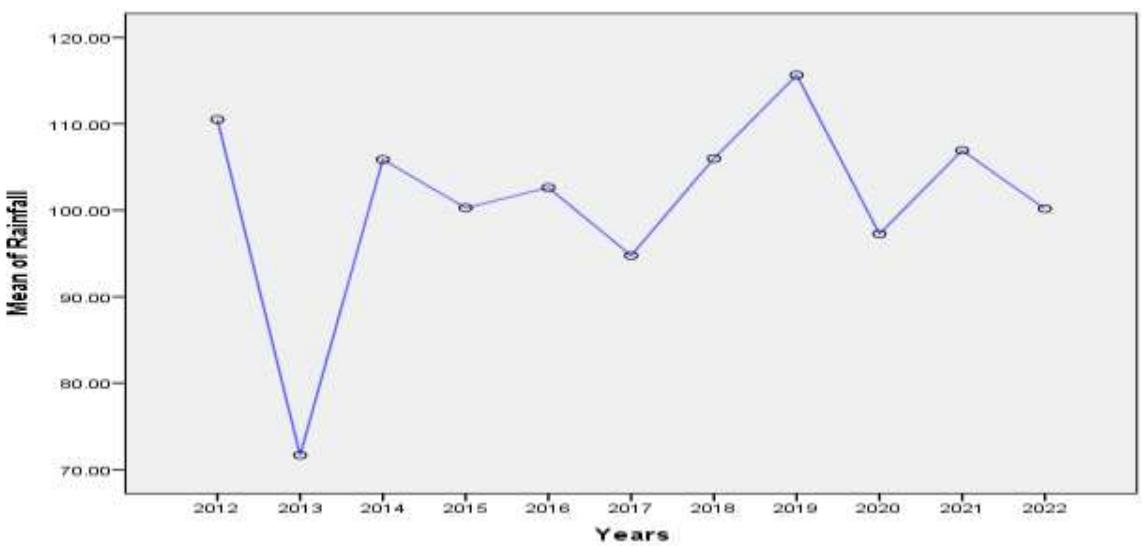
Table 4: Mean of Power Generated the Period of 2012-2022

Month	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Jan	3,459	3,538	3,623	3,550	4,106	3,100	822	11,911	12,375	10,654	11,814
Feb	3,542	3,645	3,733	3,475	4,045	3,741	756	10,728	11,981	11,89	9,109
Mar	3,653	3,753	3,844	3,378.	3,472	3,832	779	11,949	12,819	9,414	12,098
Apr	3,461	3,564	3,655	3,160	3,244	3,574	656	9,175	8,949	8,005	12,218
May	3,574	3,683	3,784	2,543	2,638	3,643	732	9,109	9,064	7,602	9,212
Jun	3,661	3,794	3,914	3,432	2,206	3,525	615	7,394	8,834	8,407	7,878
Jul	3,482	3,609	3,739	3,828	2,841	3,405	637	6,869	8,545	7,953	11,949
Aug	3,594	3,725	3,859	3,989	3,262	3,397	1,010	8,968	9,212	7,375	9,175
Sep	3,674	3,849	3,984	3,993	3,518	3,484	727	10,559	7,878	15,933	8,407
Oct	3,514	3,691	3,824	3,888	3,510	944	1,217	12,098	11,131	12,621	7,953
Nov	3,623	3,813	3,953	4,115	2,765	892	1,155	12,218	11,814	12,537	11,814
Dec	3,694	3,866	4,024	3,898	2,685	829	1,156	12,552	10,448	12,704	10,448
Mean	3578	3711	3828	3604	3191	2869	855	10294	10254	9533	10173

Source: Nigerian Bureau of Statistics 2024

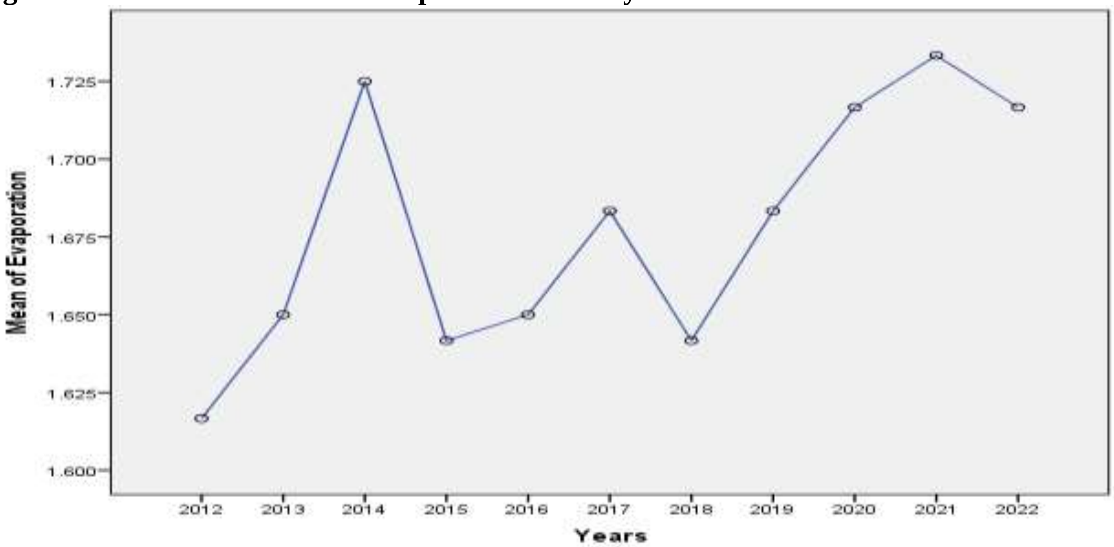
Power generation at Kainji Hydropower Station from 2012 to 2022 showed noticeable fluctuations. In the early years (2012–2014), generation ranged between 3,459 MW and 3,866 MW, with peaks typically occurring in December. A significant drop occurred in 2018, with January recording only 615 MW, though output rose to 1,156 MW by December. From 2019 onwards, there was a marked increase in generation capacity. The highest generation was recorded in 2021, peaking at 15,933 MW, while 2022 recorded a range between 7,878 MW and 12,218 MW. Overall, the data reflects a progressive rise in power generation capacity post-2018, suggesting improvements in dam operations or water resource availability in recent years.

Fig 1:Trend of Rainfall, Evaporation and Temperature Pattern in the Study in the Period of 2012-2022.



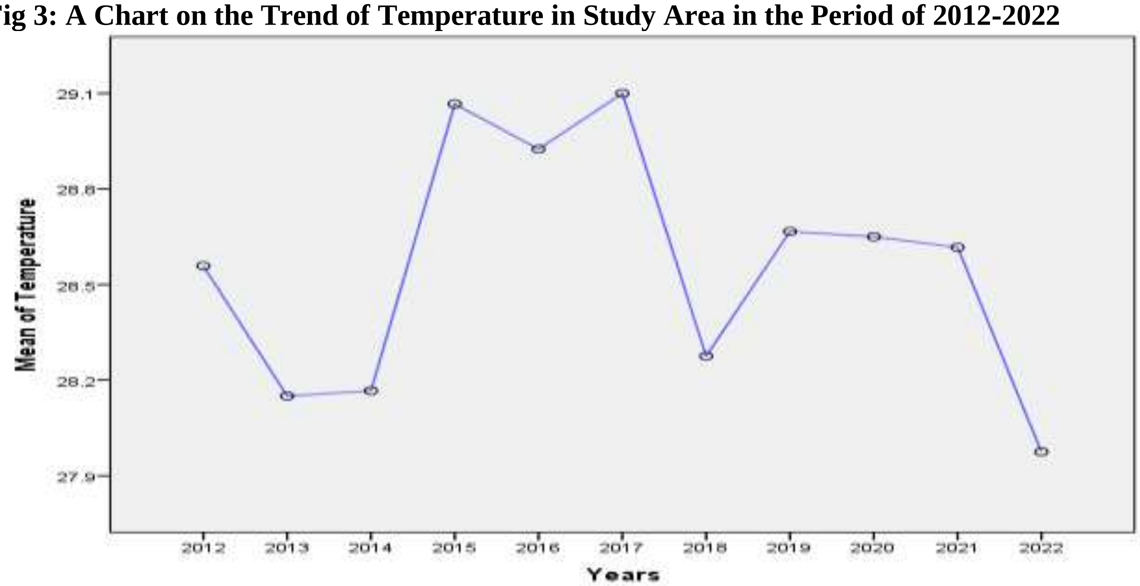
The chart above shows the trend of rainfall in study area in the period of 2012 to 2022. The trend shows there have been fluctuations in the period as shown above. In 2012, the mean of rainfall was 110.5mm. In 2013, there was a sharp decline in the amount of rainfall. The rainfall dropped to 71.7mm. The amount of rainfall rose in 2014 to 105.9mm and continued to fluctuate. In 2019 there was a peak rainfall of 115.6mm which as followed with a sharp drop to 97.2 mm in 2020. There was an increase in the amount of rainfall in 2021 and a slight drop to 101.3mm in 2022. The findings of the study is harmony with Ayodele (2016) whose study shows that rainfall in the study area has been fluctuating and the pattern shows gradual increase over the years. His study further agrees that the study area does not seem to have a major shortage in amount of rainfall.

Fig 2: A Chart on the Trend of Evaporation in Study Area in the Period of 2012-2022



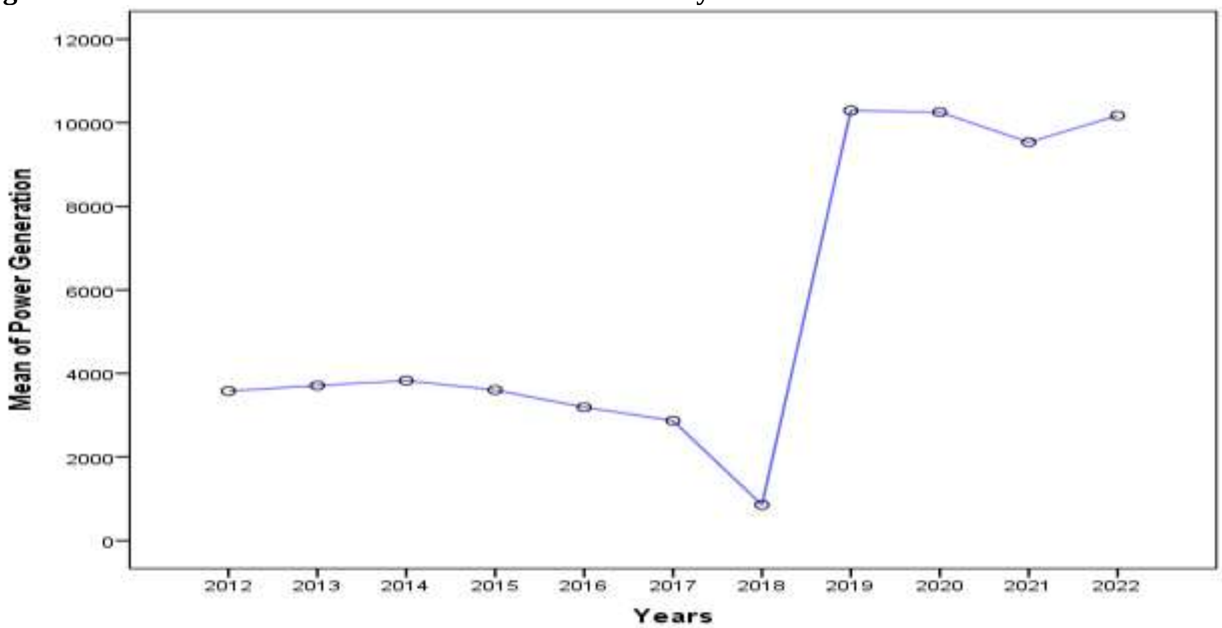
The findings of the study as presented in Figure 2 indicates an increase in the amount evaporation in the study area. However, 2012, 2015 and 2018 recorded a drop the amount of evaporation. There was a steady increase in the amount of evaporation with the peak in 2021. The findings of the study agree with Cole, *et al* (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

Fig 3: A Chart on the Trend of Temperature in Study Area in the Period of 2012-2022



The chart above shows the trend of temperature in the study area in the period between 2012 and 2022. As shown in the figure 3 above, the temperature in the study area have been fluctuating. The temperature in 2012 was 28.56 O^c and dropped to 28.15 O^c and 28.10 O^c in the years 2013 and 2014 respectively. Between 2014 and 2017 witnessed a tremendous increase in the temperature of the region. The temperature dropped to 28.28 O^c in 2018 and remained almost constant between 2019 and 2021. The was a sharp decline in the temperature of the study area in 2022 with a temperature of 28.56 O^c. The findings of the study agree with Adegbehin *et al* (2016) who attributed the increase in temperature in the study area on the effect of climate change. They further noted that 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 equipment required for electricity generation.

Fig 4: A Chart on the Trend of Power Generation in Study Area in the Period of 2012-2022



The chart above shows that there have been a gradual decline in the amount of power generated in the period of 2012 to 2017. There was a remarkable drop in power generation in 2018 with a total of 855MW. The year 2019 witnessed an upsurge in amount of power generated with a mean of 10294MW. Although there have slight fluctuations between 2019 and 2022 in the amounted of power generated. The findings of the study agree with Adeoye and Oladimeji (2020) who maintained that in 2013, the total installed capacity was 6,953MW while available capacity was 4,598MW. The actual average generation was 3,800MW. The World Bank noted that Nigeria had a total installed capacity of 8,457MW in 2014 with generation from hydroelectric sources reported at 17.59% of the total installed capacity. In early September 2016, the peak power generation was 4,285.90 MW by the Nigerian Electricity System Operator.

Mean of Rainfall, Evaporation, Temperature and Amount of Power Generated Data for the period 2012-2022

Table 5: Mean of Rainfall (mm) Pattern for the Period of 2012-2022

Month	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	10.7	6.7	9.9	9.3	0.0	0.0	17.0	16.1	0.0	5.6	0.0
Mar	20.6	36.3	38.4	44.7	68.1	17.4	19.5	18.4	31.5	24.0	28.0
Apr	100.0	72.3	113.1	40.9	76.0	61.1	77.9	77.1	67.4	74.5	105.7
May	172.1	128.0	201.2	149.8	165.1	150.2	173.3	172.5	181.6	171.0	109.8
Jun	153.0	124.5	156.8	106.0	170.9	176.7	163.2	168.9	191.0	210.4	202.0
Jul	236.9	187.4	156.2	204.3	202.8	159.2	231.4	272.1	188.6	116.3	208.6
Aug	190.5	43.3	252.5	353.9	230.5	286.3	214.3	178.9	181.1	312.0	203.0
Sep	247.4	198.5	241.3	144.5	192.0	187.7	220.8	276.0	233.9	188.2	140.5
Oct	194.9	62.8	95.0	145.0	126.0	98.4	149.0	200.5	92.0	175.9	204.5
Nov	0.0	0.0	6.1	5.0	0.0	0.0	5.5	7.3	0.0	5.3	0.0
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	110.5	71.6	125	77.2	102.6	94.8	106	97.3	106.9	100.2	101.1

Source|: Nigeria Metrological Agency

Table 5 above shows the mean of rainfall for the period of 2012-2023. The table reveals that in the 2012 the mean of rainfall was 110.5mm, for 2013 the mean of rainfall was 71.6mm, in the 2014 there was increase in the mean of rainfall with a record of 125mm, 2015 had a mean 77.2, the mean of rainfall in

2016 was 102.6mm, in 2017 the mean of rainfall was 94.8mm, in the 2018 the mean obtained was 106mm, in 2019 the mean of rainfall was 106.9mm, in 2021 the mean obtained was 100.2 and finally in 2022 the mean obtained was 101.1mm.

Table 6: Mean of Temperature ($O^{c)}$ for the Period of 2012-2022

Month	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Jan	27.8	28.6	26.9	26.7	27.1	29.3	26.4	28.1	26.7	28.9	27.2
Feb	31.5	30.9	29.2	31.3	30.9	30.9	31.2	29.6	29.3	30.3	30.1
Mar	32.6	32.3	30.4	31.3	31.7	32.9	31.2	32.2	32.2	31.5	32.2
Apr	30.8	29.6	29.7	31.2	30.6	31.3	30.2	31.5	30.4	31.0	29.1
May	28.5	28.3	29.0	29.9	29.9	29.3	28.2	29.6	29.2	28.7	27.9
Jun	27.1	27.6	28.2	28.9	28.2	28.4	28.1	28.1	28.1	27.2	26.9
Jul	26.8	26.8	27.3	27.4	27.6	27.2	27.3	27.7	27.3	26.5	26.9
Aug	26.5	26.6	26.8	27.3	27.4	26.7	26.9	27.2	27.6	26.9	26.0
Sep	27.0	26.8	26.8	27.5	27.5	27.3	26.7	27.2	26.7	27.7	26.6
Oct	27.5	28.8	27.9	28.3	28.5	28.7	28.1	27.4	28.0	28.3	27.2
Nov	29.1	26.2	28.6	28.5	29.7	29.2	28.7	28.5	29.3	29.1	28.8
Dec	27.5	25.3	27.2	30.5	28.0	28.0	26.3	26.9	29.0	27.3	26.8
Mean	28.56	28.15	28.10	29.23	23.93	29.10	28.28	28.67	28.65	28.62	27.98

Source: Nigeria Metrological Agency Survey 2024

The data with regards to the mean of temperature was presented in Table 6. The table reveals that in the 2012 the mean of temperature was 28.56 O^C, for 2013 the mean of temperature was 28.15 O^C, in the 2014 there was a slight decrease in the mean of temperature with a record of 28.10 O^C. In 2015, a mean of 23.95 O^C, the mean of temperature in 2016 was 23.93 OC, in 2017 the mean of 29.10 O^C, was obtained, in the 2018 the mean obtained was 28.28 O^C, in 2019 the mean of temperature was 28.67 O^C, 2020 recorded a mean of 28.65 O^C, in 2021 the mean obtained was 28.62 O^C and finally in 2022 the mean obtained was 27.98 O^C.

Table 7: Mean of Power Generated the Period of 2012-2022

Month	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Jan	3,459	3,538	3,623	3,550	4,106	3,100	822	11,911	12,375	10,654	11,814
Feb	3,542	3,645	3,733	3,475	4,045	3,741	756	10,728	11,981	11,89	9,109
Mar	3,653	3,753	3,844	3,378.	3,472	3,832	779	11,949	12,819	9,414	12,098
Apr	3,461	3,564	3,655	3,160	3,244	3,574	656	9,175	8,949	8,005	12,218
May	3,574	3,683	3,784	2,543	2,638	3,643	732	9,109	9,064	7,602	9,212
Jun	3,661	3,794	3,914	3,432	2,206	3,525	615	7,394	8,834	8,407	7,878
Jul	3,482	3,609	3,739	3,828	2,841	3,405	637	6,869	8,545	7,953	11,949
Aug	3,594	3,725	3,859	3,989	3,262	3,397	1,010	8,968	9,212	7,375	9,175
Sep	3,674	3,849	3,984	3,993	3,518	3,484	727	10,559	7,878	15,933	8,407
Oct	3,514	3,691	3,824	3,888	3,510	944	1,217	12,098	11,131	12,621	7,953
Nov	3,623	3,813	3,953	4,115	2,765	892	1,155	12,218	11,814	12,537	11,814
Dec	3,694	3,866	4,024	3,898	2,685	829	1,156	12,552	10,448	12,704	10,448
Mean	3578	3711	3828	3604	3191	2869	855	10294	10254	9533	10173

Table 7 shows the mean of power generated in the period of 2012 to 2022. The table revealed that in 2012 the mean power generated was 3578MW, in 2014 the mean power generated was 3711 MW, 3828 MW was the mean of power generated in 2015, in 2016 the mean of 3191 MW was generated, 2017 had a mean power generation of 2869. 2018 witnessed a power generated with a total mean of 855 MW. 2019 was marked by remarkable increase in power generation a mean of 10,294MW was produced in the said year with slight drop in 2020 which recorded a mean of 10254MW. In 2021 a total of 9533 MW was generated and finally in 2022 a mean of 10173 MW was generated.

Relationship between Hydrology and Power Generation for the Period in the Period 2012-2022.

Table 8: Pearson Product Moment Correlation between Rainfall and Power Generation for the Period in the Period 2012-2022.

Variables		Rainfall	Power Generation
Rainfall	Pearson Correlatvion	1	.248
	Sig. (2-tailed)		.462
	N	11	11
Power Generation	Pearson Correlation	.248	1
	Sig. (2-tailed)	.462	
	N	11	11

Table 8 above shows the relationship between Rainfall and Power Generation for the Period in the Period 2012-2022. Based on the findings of the table the correlation coefficient value (r) is .25. This suggest that there is a very weak positive relationship between the variables in the study area. This implies that increase in rainfall leads to an increase in the amount power generated. The correlation coefficient value (r) of .25 further suggest that the relationship is not significant. The findings of the study contradict Adegbehin (2016) whose study shows a positive significant relationship between rainfall and power generated in the period of 1985 and 2014. The difference in their findings could be attributed other non-climatic factors mitigating power production in Nigeria. These factors as identified by Adeoye and Oladimeji (2020) includes but is not limited to inadequacy in generation availability, insufficient and delayed maintenance of facilities, obsolete facilities, inadequacy in communication equipment and staff morale.

Table 9: Pearson Product Moment Correlation between Evaporation and Power Generation for the Period in the Period 2012-2022.

Variables		Rainfall	Power Generation
Power generation	Pearson Correlation	1	.658*
	Sig. (2-tailed)		.028
	N	11	11
Evaporation	Pearson Correlation	.658*	1
	Sig. (2-tailed)	.028	
	N	11	11

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

The relationship between evaporation and power generation in the period 2012-2022 was presented in Table 9 above. The study reveals that the correlation coefficient (r) between evaporation and power generation is .66. This value indicates a moderate positive relationship. Thus an increase in evaporation results to an increase in power generation. The findings of the study disagree with Aliyu *et al* (2024) whose study revealed that the annual trend of evaporation showed a significant trend with -0.81 as the rate of change per year. The difference could be attributed to the different dams used for the study.

Table 10: Pearson Product Moment Correlation between Temperature and Power Generation for the Period in the Period 2012-2022.

Variables		Rainfall	Power Generation
Power generation	Pearson Correlation	1	-.143
	Sig. (2-tailed)		.675
	N	11	11
Evaporation	Pearson Correlation	-.143	1
	Sig. (2-tailed)	.675	
	N	11	11

The relationship between temperature and power generation in the period 2012-2022 was presented in Table 10 above. The study reveals that the correlation coefficient (r) between evaporation and power generation is -.14. This value indicates very weak negative relationship between the two variables. Thus an increase in evaporation results to and decrease in power generation. The correlation coefficient of -.14 suggests that the relationship is not significant. The findings of the study is harmony with Adegbehin (2016) this implies that there is no significant relationship between the amount of power generated and temperature at 0.05 level of significance. This means that temperature does not really affect power generation in the study area.

CONCLUSION

This study critically examined the relationship between changing hydrological patterns—specifically rainfall, temperature, and evaporation—and hydropower generation at the Kainji Hydropower Station over a 10-year period (2012–2022). The findings highlighted that while each hydrological variable showed varying degrees of fluctuation, they all maintained a weak to moderate positive relationship with power generation.

Rainfall trends revealed an overall increase, with a corresponding rise in power output, especially after 2013. Interestingly, more power was generated in the dry season than in the rainy season, indicating that water release strategies and reservoir management practices significantly influence generation patterns. Temperature, although fluctuating mildly over the study period, showed a weak but consistent positive effect on power output. Similarly, while evaporation levels declined in recent years, it too showed a weak positive relationship with hydropower generation.

Collectively, these variables had a combined moderate positive correlation with electricity production, suggesting that the interaction between climate variables and power generation is complex but significant. The study reinforces the importance of understanding localized climate dynamics in hydropower planning and operations.

As hydropower remains a cornerstone of Nigeria's renewable energy strategy, the study recommends proactive policies focused on improving climate monitoring, optimizing reservoir management, and integrating climate resilience into national energy planning. These steps are essential to sustaining and enhancing hydropower output in the face of growing environmental variability and energy demands.

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