**Rainfall Trend and its Implication for Moisture Availability over the Kainji Dam Area, Nigeria**

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**Abstract**

The study analyzed thirty (30) years (1991-2020) rainfall data of Kainji dam area. The data was sourced from the Mainstream Energy Solution Office in New Bussa. The study examined the trend and variability of rainfall and its implication for moisture availability over the study area. Standard Deviation (SD), Coefficient of Variation (CV) and Standardized Precipitation Index (SPI) methods were used for the analysis. Generally, result shows irregular rainfall distribution over the study area during the period under review. The rainfall distribution across the study area shows that the lowest amount of rainfall was detected in 2002 at 735.33mm while the highest was in 2017 at 1537.59mm. Further result shows a decline in rainfall amount from 1285.29mm in 1991 to 753.63mm in 1992 with a sharp rise of 1015.48mm in 1993. The study revealed that there was a consistent rise in the rainfall amount from 1997 to 1999 at 1117.29mm, 1249.3mm and 1295.07 mm respectively. In contrast, the rainfall amount from 2000 to 2003 shows decreasing trend at 971mm, 982.47mm, 735.33mm and 846.93mm respectively. The SPI analysis for the first decade shows that 1992 was a severe dry year while 1991 and 1999 were moderate wet years. The SPI for the second decade shows that 2010 was a severe wet year while 2002 was a severe dry year in the study area. Further result shows that four years in the third decade, 2004, 2006, 2008 and 2009 depicted mild wet SPI value while 2013 shows severe dryness. The observed variations in the rainfall distribution is likely to have implication for moisture availability to support crop production in the study area especially in the second decade (2001-2010). The study recommends the mainstreaming of farming calendar into the changing climate regime to ensure improved agricultural production.

**Keywords**: Rainfall, Trend, Variability, Moisture Availability, Kainji Dam, Nigeria

**1.0. INTRODUCTION**

In recent years, on a global scale, there have been marked climatic variations that have influencedthe spatio-temporal behavior of meteorological variables such as precipitation (mean, extreme,variability) (IPCC, 2014). Understanding future changes in the frequency, intensity, and duration of extreme events is important when formulating adaptation and mitigation strategies that minimize damage tonatural and human systems (Singh, *et al*. 2013). The most importantaspects of climate change that requires in-depth research is the characterization of precipitation in timeand space.

The analysed climatic data from Nigerian Meteorological Agency (NiMet) revealed that the climate in Nigeria has significant variability over the past century. (Abiodun, 2013). Though there is major inter‐annual variability in the climate, diverse decadal trends are evidently visible. For example,between early 1950s to the late 1960s, there was prolong wet period, followed by drought decades of the 1980s and 1970s, the obvious reoccurrence of the above normal wetly conditions in the 1990s. These fluctuating climatic conditions underline Nigeria’s susceptibility to the impact of extreme climate occurrence (Hassan *et al*., 2013).

Climate change effects includes; increased average annual temperatures, reduced and increased variability in rainfall, reduces crop yield and threatens food security in low-income and agriculture-based economies (Meybeck *et al.,* 2012). The IPCC (2007) report confirmed a change to precipitation due to climate change. However, Change in rainfall and temperature are not globally uniform (Parry *et al*., 2007).

Rainfall serve as the basic source of water for living organisms which any alteration in amount, frequency, and intensity of water availability may have consequences for the dynamics of human and natural systems (Ceballos-Barbanch, *et al.* 2008). Modification in rainfall has direct effect on water resource management, agriculture, hydrology, natural ecosystems, and human health. For this reason, it is important to study the variation in the spatial and temporal rainfall pattern to improve water management approach (Cannarozzo, *et al*. 2006). Research of yearly and seasonal precipitation on global and local scales shows trends over many regions of the world (Brunetti, *et al*. 2000). Rainfall is the major determinant for crop production especially in developing countries like Nigeria where agricultural practices are usually rainfed. The fluctuating trend and pattern of rainfall over the years has increased concern form both the farmers and policy makers. this growing concern therefore underscore the need for continuous monitoring of the rainfall trend and variability to ensure adequate information on moisture availability to support crop production. The investigated trend in rainfall and it implication for moisture availability over the Kainji dam area.

**2.0. MATERIALS AND METHODS**

**2.1:The Study Area**

The study area is located on Longitude 40 N and 70 N, Latitude 120 E and 150 E. The study area is part of the Lower Niger River Basin within Niger State, Nigeria.



**Figure 1:** The Study Area (Kainji Lake and Environs, Niger State, Nigeria)

 The continental north wind and south west monsoon controls the wet and dry period in the study area. More often the dry season is from December to March while the raining season is between May to October. The two seasons are mostly divided by slightly transition periods in April and November. Although, the beginning of February to March represent the peak of the dry season while the rains usually climax in August. The month of November to January are characterized by cold and dry weather conditions (The harmattan) under the influence of the Northeast Trade Wind (Olayemi *et al*., 2014).

**2.2. Data Used**

Thirty (30) years (1991-2020) rainfall data of the study area was obtained from Mainstream Energy Solution Office in Kainji, Niger State, Nigeria.

**2.2.1 Data Analysis**

**2.2.1.1 The Mean**

This was used to summarise the data into monthly and annual basis.

Mean is expressed as:

$$\overbar{x }= \frac{\sum\_{}^{}x}{n} (1)$$

Where

$\overbar{x }$ = The value of the observed parameter

 ∑ = Summation symbol

 N = Number of observation

**2.2.1.2 Measure of Variability**

Two measure of variability namely, Standard Deviation (SD) and Coefficient of Variation (CV) were used. The SD is the most common measure of variability and it is expressed as:

$SD= \sum\_{i=1}^{n}\left(\frac{x- \overbar{x }}{n-1}\right)$ (2)

Where

SD = standard deviation

$\overbar{x}= $value of the observed parameter

$x= $monthly or annual variables for a given period

$\sum\_{}^{}=$ sum of all *x* variables

$n= $number of observations

**2.2.1.3 Coefficient of Variability**

In order to standardize the SD for data series, it is divided by the mean value to obtain coefficient of variation. Coefficient of variation, CV, measures the relative dispersion of variables from the mean and it is a useful measure for comparative purposes where an annual series is normally distributed. It is given mathematically as;

$$CV= \frac{SD}{\overbar{x}} ×100 (3)$$

**2.2.1.4 Standardized Precipitation Index (SPI)**

The SPI was utilized in the analysis of monthly and annual mean rainfall of the study area. Positive value of SPI indicated greater than mean precipitation while negative SPI value indicated less than mean precipitation. The SPI equation is given as:

$$SPI=\frac{X- х̄}{SD} (4) $$

Where

X = Actual Rainfall;

$х̄$= Mean Rainfall and;

SD = Standard Deviation from normal rainfall.

**Table 1: SPI Values**

|  |  |
| --- | --- |
| **Value** | **Rating** |
| ≥ 2 | Extreme wetness |
| < 2 ≥ 1.5 | Severe wetness |
| ≥ 1 < 1.5 | Moderate wetness |
| ≥ 0.5 < 1 | Mild wetness |
| < 0.5 | Normal |
| > -0.5 | Normal |
| ≥ -0.5 < -1 | Mild dryness |
| ≥ -1 < -1.5 | Moderate |
| > -2 ≤ -1.5 | Severe |
| ≤ -2 | Extreme |

Adapted from Mckee,1993.

**3.0 RESULTS AND DISCUSSIONS**

Analysis of annual rainfall distribution over the study area is depicted in Figure 2.Generally, result shows irregular rainfall distribution over the study area during the period under review. Findings revealed that the lowest annual rainfall received in the study area was in 2002 with 735.33 mm while the highest was in 2017 with 1537.59 mm. Further result shows a decline in rainfall amount from 1285.29 mm in 1991 to 753.63 mm in 1992 with a sharp rise of 1015.48 mm in 1993. Result also shows that there was a consistent rise in the annual rainfall amount from 1997 to 1999 at 1117.29 mm, 1249.36 mm and 1295.07 mm respectively. Conversely, the annual rainfall received between 2000 to 2003 shows declining trend at 971 mm, 982.47 mm, 735.33 mm and 846.93 mm respectively. The fluctuating trend in the amount of annual rainfall received is likely to affect moisture availability in the soil to support crop production in the study area.

**Figure 2: Annual Rainfall Distribution in the Study Area(1991 to 2000).**

**Source:** Authors work

Tables 2, 3, 4 and 5 depict result of decadal rainfall pattern in the study area. On a decadal basis, Table 3 shows the rainfall pattern for the first decade (1991 to 2000). Result shows that 1992 recorded severe dryness indicating a drought year in the study area while 1991 and 1999 shows moderate wetness during the period. All the years in the first decade recorded less than normal rainfall, this according to World Meteorological Organization (WMO) was put at 1440.0 mm for climate normal in the study area during the period 1981 to 2010.

The rainfall pattern for the second decade (2001to 2010) is presented in Table 4. Result shows that a severe wet year was detected in 2010 while severe dry year was detected in 2002. Further result shows that four years, 2004, 2006, 2008 and 2009 recorded mild wet SPI value during the study period. The study also shows that the second decade received less than normal rainfall.

Table 5 depicts the rainfall pattern for the study area (2011 to 2020). The SPI value for the third decade shows that severe wetness year was detected in 2017 while severe dryness was detected in 2013. Result shows that two years 2017 and 2019 received higher than normal rainfall while the remaining eight years recorded less than normal rainfall.

**Table 2: Analysis of Rainfall Pattern in the Study Area for 30 years (1991 to 2020)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **YEAR** | **RAINFALL (X)** | $$х̄$$ |  **SD** | **X-** $х̄$ |  **SPI = X-**$ х̄$**/SD** |  |
| 1991 | 1285.29 | 1090.50 | 194.69 | 194.79 | 1.00 |  |
| 1992 | 753.63 | 1090.50 | 194.69 | -336.87 | -1.73 |  |
| 1993 | 1015.48 | 1090.50 | 194.69 | -75.02 | -0.39 |  |
| 1994 | 1227.59 | 1090.50 | 194.69 | 137.09 | 0.70 |  |
| 1995 | 1098 | 1090.50 | 194.69 | 7.50 | 0.04 |  |
| 1996 | 813.25 | 1090.50 | 194.69 | -277.25 | -1.42 |  |
| 1997 | 1117.29 | 1090.50 | 194.69 | 26.79 | 0.14 |  |
| 1998 | 1249.36 | 1090.50 | 194.69 | 158.86 | 0.82 |  |
| 1999 | 1295.17 | 1090.50 | 194.69 | 204.67 | 1.05 |  |
| 2000 | 971 | 1090.50 | 194.69 | -119.50 | -0.61 |  |
| 2001 | 982.47 | 1090.50 | 194.69 | -108.03 | -0.55 |  |
| 2002 | 735.33 | 1090.50 | 194.69 | -355.17 | -1.82 |  |
| 2003 | 846.93 | 1090.50 | 194.69 | -243.57 | -1.25 |  |
| 2004 | 1183.06 | 1090.50 | 194.69 | 92.56 | 0.48 |  |
| 2005 | 1024.43 | 1090.50 | 194.69 | -66.07 | -0.34 |  |
| 2006 | 1140.59 | 1090.50 | 194.69 | 50.09 | 0.26 |  |
| 2007 | 939.6 | 1090.50 | 194.69 | -150.90 | -0.78 |  |
| 2008 | 1078.68 | 1090.50 | 194.69 | -11.82 | -0.06 |  |
| 2009 | 1142.44 | 1090.50 | 194.69 | 51.94 | 0.27 |  |
| 2010 | 1323.51 | 1090.50 | 194.69 | 233.01 | 1.20 |  |
| 2011 | 1182.55 | 1090.50 | 194.69 | 92.05 | 0.47 |  |
| 2012 | 1090.74 | 1090.50 | 194.69 | 0.24 | 0.00 |  |
| 2013 | 783.67 | 1090.50 | 194.69 | -306.83 | -1.58 |  |
| 2014 | 1082.8 | 1090.50 | 194.69 | -7.70 | -0.04 |  |
| 2015 | 1053.12 | 1090.50 | 194.69 | -37.38 | -0.19 |  |
| 2016 | 1084.56 | 1090.50 | 194.69 | -5.94 | -0.03 |  |
| 2017 | 1537.59 | 1090.50 | 194.69 | 447.09 | 2.30 |  |
| 2018 | 1242.2 | 1090.50 | 194.69 | 151.70 | 0.78 |  |
| 2019 | 1454.7 | 1090.50 | 194.69 | 364.20 | 1.87 |  |
| 2020 | 979.89 | 1090.50 | 194.69 | -110.61 | -0.57 |  |

**Source:** Authors Computation

**Figure 3: Standardized Precipitation Index for the Study area (1991 – 2020).**

**Source:** Authors work

**Table 3: Decadal Rainfall Pattern of the Study Area (1991 to 2000)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **YEAR** | **Rain (X)** | $$х̄$$ | **SD** |  **X-**$х̄$ |  **SPI=X-** $х̄$**/SD** |
| 1991 | 1285.29 | 1082.6 | 192.7 | 202.7 | 1.05 |
| 1992 | 753.63 | 1082.6 | 192.7 | -329.0 | -1.71 |
| 1993 | 1015.48 | 1082.6 | 192.7 | -67.1 | -0.35 |
| 1994 | 1227.59 | 1082.6 | 192.7 | 145.0 | 0.75 |
| 1995 | 1098 | 1082.6 | 192.7 | 15.4 | 0.08 |
| 1996 | 813.25 | 1082.6 | 192.7 | -269.4 | -1.40 |
| 1997 | 1117.29 | 1082.6 | 192.7 | 34.7 | 0.18 |
| 1998 | 1249.36 | 1082.6 | 192.7 | 166.8 | 0.87 |
| 1999 | 1295.17 | 1082.6 | 192.7 | 212.6 | 1.10 |
| 2000 | 971 | 1082.6 | 192.7 | -111.6 | -0.58 |

**Source:** Authors Computation

**Figure 4: Standardized Precipitation Index for the Study area (1991 – 2000).**

**Source:** Authors work

**Table 4: Decadal Rainfall Pattern of the Study Area (2001 to 2010)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **YEAR** | **Rain (X)** | $$х̄$$ | **SD** |  **X-** $х̄$ | **SPI=X-** $х̄$**/SD** |
| 2001 | 982.47 | 1039.7 | 172.1 | -57.2 | -0.33 |
| 2002 | 735.33 | 1039.7 | 172.1 | -304.4 | -1.77 |
| 2003 | 846.93 | 1039.7 | 172.1 | -192.8 | -1.12 |
| 2004 | 1183.06 | 1039.7 | 172.1 | 143.4 | 0.83 |
| 2005 | 1024.43 | 1039.7 | 172.1 | -15.3 | -0.09 |
| 2006 | 1140.59 | 1039.7 | 172.1 | 100.9 | 0.59 |
| 2007 | 939.6 | 1039.7 | 172.1 | -100.1 | -0.58 |
| 2008 | 1078.68 | 1039.7 | 172.1 | 39.0 | 0.23 |
| 2009 | 1142.44 | 1039.7 | 172.1 | 102.7 | 0.60 |
| 2010 | 1323.51 | 1039.7 | 172.1 | 283.8 | 1.65 |

**Source:** Authors Computation

**Figure 5: Standardized Precipitation Index for the Study area (2001 – 2010).**

**Source:** Authors work

**Table 5: Decadal Rainfall Pattern of the Study Area (2011 to 2020)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **YEAR** | **Rain(X)** | $$х̄$$ | **SD** | **X-** $х̄$ | **SPI=X-** $х̄$**/SD** |
| 2011 | 1182.55 | 1149.2 | 220.5 | 33.4 | 0.15 |
| 2012 | 1090.74 | 1149.2 | 220.5 | -58.5 | -0.27 |
| 2013 | 783.67 | 1149.2 | 220.5 | -365.5 | -1.66 |
| 2014 | 1082.8 | 1149.2 | 220.5 | -66.4 | -0.30 |
| 2015 | 1053.12 | 1149.2 | 220.5 | -96.1 | -0.44 |
| 2016 | 1084.56 | 1149.2 | 220.5 | -64.6 | -0.29 |
| 2017 | 1537.59 | 1149.2 | 220.5 | 388.4 | 1.76 |
| 2018 | 1242.2 | 1149.2 | 220.5 | 93.0 | 0.42 |
| 2019 | 1454.7 | 1149.2 | 220.5 | 305.5 | 1.39 |
| 2020 | 979.89 | 1149.2 | 220.5 | -169.3 | -0.77 |
| **Source:** Author |  |  |  |  |  |

**Figure 6: Standardized Precipitation Index for the Study area (2011 – 2020)**

**Source:** Authors work

**4.0 Conclusion**

The study revealed the variability and changing pattern of rainfall over the study area. The irregular rainfall distribution observed is a pointer to the evidence of climate change in the study area. Further, the mixed SPI result of wet, mild-wet and dry period shows that the study area is susceptible to either flood or drought events. The study established that except in 2017 and 2019, the total amount of annual rainfall received was below the climate normal for the region, which according to the WMO was put at 1440.0 mm. The result of SPI analysis for 1992 and 2002 shows severe dryness indicating a drought year, this could have severe implication for moisture availability for crop production in the study area. The study recommended the continuous monitoring of rainfall pattern as well as mainstreaming of farming calendar into the changing rainfall regime to ensure agricultural practice resilience in the phase of climate change.

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