Analysis of Rainfall Trends and Patterns in Kainji Lake Basin, Nigeria

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ABSTRACT

Rainfall in Nigeria is highly dynamic and variable on a temporal and spatial scale. This has taken a more pronounced dimension due to climate change. In this paper, Standard Precipitation Index (SPI) and Coefficient of Variability statistical tools were employed to analyse rainfall trends and patterns in Kainji Lake Basin between 1991 and 2020. Daily rainfall data of 30 years was used for the study. The daily rainfall data was subjected to several analyses. The result obtained indicated that there is a downward trend in the rainfall amount received in Kainji Lake Basinover the last 30 years. Also, a gradual decadal decline in rainfall was observed using the SPI to compare the three decades under review. Recommendation to build more weather observatories which is a major challenge in sub-Saharan Africa for sufficient climatic data representation especially in the study area as data from one synoptic station was not sufficient for the study was proffered. Mitigation and adaptation strategies especially for meteorological drought should be considered with a view to reducing the effects of climate change

1. INTRODUCTION.

Climate change has been a major discourse for many researchers with particular interest in the impact of the phenomenon. One major concern of climate change is to study and identify documented changes in the climatic system [Razie, 2008]. Rainfall serve as the basis of fluids for living organisms which any alteration in amount, frequency, and intensity of fluid availability may have important consequences for the dynamics of human and natural systems [Ludwig *et al*, 2007]. Modification in rainfall has direct effect on water resource 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 [Marinela and Irina 2012]. Research of yearly and seasonal precipitation on global and local scales shows trends over many regions of the world [Hernandez,2012]. Global rise in temperature as observed in the last few decades has certainly impacted on the world climate giving rise to increase in precipitation especially in certain regions of the world [Hernandez 2012 and IPCC,2014]
There have been regional trends in floods and droughts across the world. For example, average precipitation amount has been recorded in some regions of the world such as in the Northern America with larger increases and decreases in some areas leading to extremities experienced in those areas such as flooding and drought [Kunkel et al., 2008)]. Reasons for this are attributed to

increase in temperature which is reducing ice volumes and surface extents on lands, lakes and seas.

Additionally, some publications project drought as increasing over much of the southern and central U.S. [Wu and Lorenzo, 2017, Gleason et al. (2008)]. Similarly, observed precipitation has increased in southern America [(Dufek and Ambrizzi, 2008;] while negative trends in annual precipitation have been observed over Chile and parts of the western coast of the continent [Marengo et al., 2009]. These variations are suggestive of latitudinal changes in monsoon features. Essentially, the largest negative trends since 1901 in annual precipitation are observed over western Africa and the Sahel, although there were downward trends in many other parts of Africa, and in south Asia. Studies show that changes in global precipitation patterns is as a result of factors such as changes in radioactive forcing from combined anthropogenic, volcanic and solar sources which have played a part to observe trends in mean precipitation. For instance, an observed pattern of continued aridity throughout North Africa south of the Sahara was noted by [Nichalson and Saleto,2000]. This pattern is most persistent in the western region of the continent. They noted that the driest period was in the 1980s with some recovery occurring during the 1990s, particularly in the easternmost sectors where rainfall in some years was near or just above the long term mean. Although [Nichalson and Saleto, 2000] argued that Southern Africa was relatively moist in the 1950s and 1970s, [Hulme et 1996] found significant decreases in precipitation being observed since the late 1970s. The pattern of rainfall in Nigeria is seasonal with double maximal in the south and single peak in the north [Chindo and Nyilong, 2005]. Stated that rainfall was generally decreasing across Nigeria particularly in the north. Although he observed a slight increase in the rainfall amount received in the coastal areas, he discovered a significant decrease in the duration of rainy days especially in the north.

Then he implied, must have altered the vegetation pattern of the country. In his view, the changing pattern of rainfall might have increased the rate of erosion/desertification, soil erosion, coastal flooding, drought and other extremities in the country.

2. STUDY AREA

Kainji Lake Basin (Figure 1) lies between Latitude 9°29' and Latitude 10°29'N and between Longitude 4°21' and Longitude 4°51'E. The humidity is related to the movement of the ITD. Highest values are recorded during the rainy season (about 80 percent). Lowest values occur in January (approx. 30 percent). The mean annual solar radiation is 500 cal/cm^2 /day. Length of rainy days ranges between 150 -200 in the Basin (Juddy *et al*, 2013).

The area is characterized by of a single maximum rainfall period like other parts of the north. Rainfall starts about 4th of May and end about 20th October in the area giving a duration of 178days planting season. The mean annual rainfall is 1010mm. There is extreme concentration of rainfall in two to three months of July, August and September in Kainji Lake Area. In fact these three months account for about 60% of rainfall in the region. Fishing is a major occupation of the people in the basin, apart from cultivation of crops. Aquaculture is another emerging business where 2 trailer loads of smoked fish lives New Bussa town per week to the Southern part of Nigeria (Nwabeze, 2016)

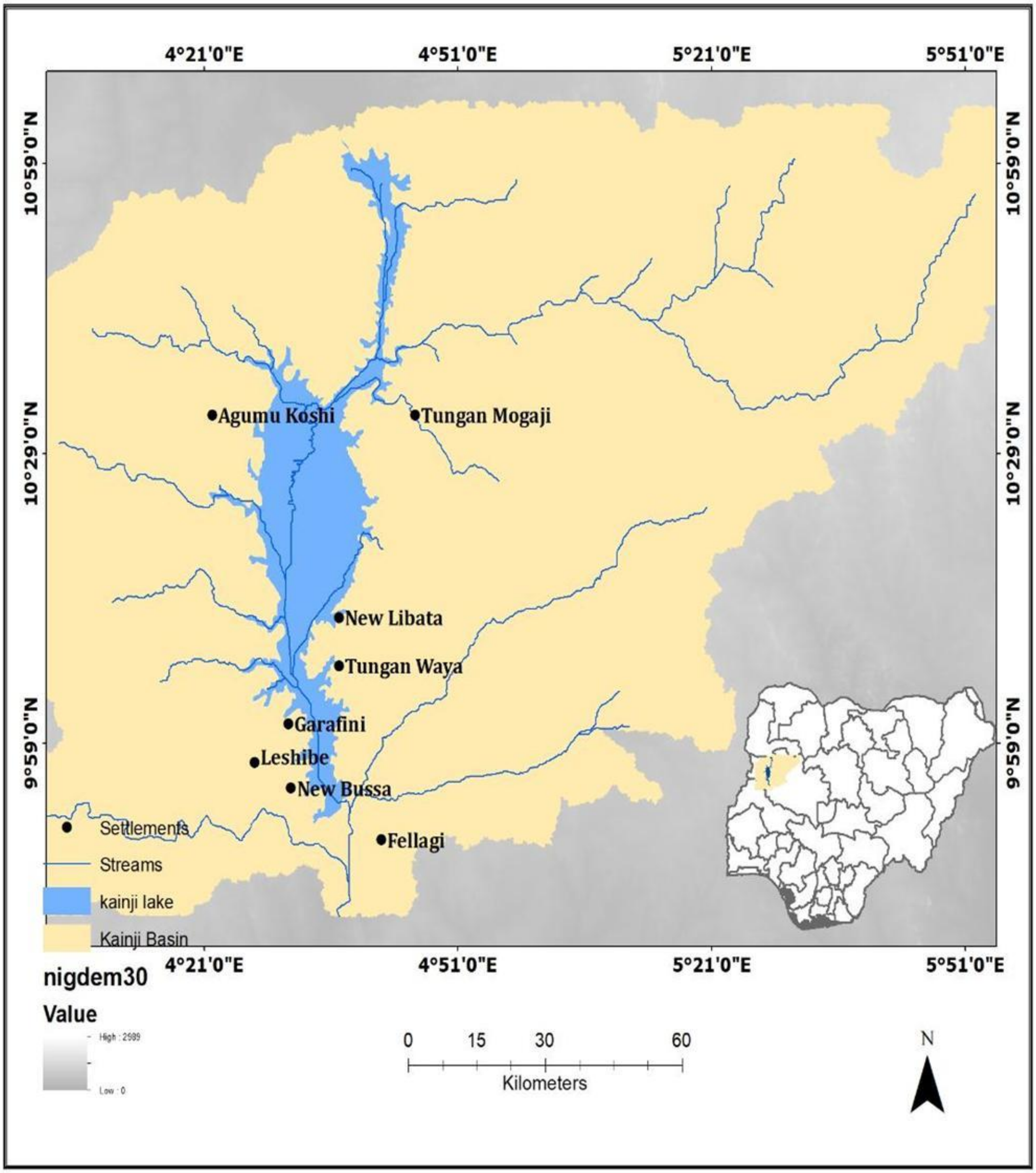

Fig. 1. Map of Kainji Lake Basin

3. METHODOLOGY

3.1 Sources and Types of Data

3.2 Standardized Precipitation Index (SPI)

The SPI was used to analyze the daily, monthly and annual mean rainfall of the study area. Rainfall trends for three (3) decades were also determined. Positive SPI values indicated greater than mean precipitation while negative values indicated less than mean precipitation.
Formula for SPI is given as **x – x bar /SD**
Where
X = Actual Rainfall
X bar = Mean Rainfall
SD = Standard Deviation from the 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

Source: Mckee (2003)

3.3 Coefficient of Variability Adopted from SPI

The Coefficient of Variability (CV) is a measure of dispersion from the normal. The CV was used to determine the temporal pattern of rainfall over the period of study

CV = x – x bar x 100 /SD

Where X = Actual Rainfall
X bar = Mean Rainfall and;
SD = Standard Deviation from the normal rainfall

4. RESULTS AND DISCUSSION

4.1 Rainfall Trends and Patterns

The rainfall for the 30 years was analysed and presented in Table 2. The Table shows a decline in rainfall from 1285.29mm in 1991 to 753.63 mm in 1992 and rising trend of 1015.48 mm and 1227.59 mm in 1993 and 1994 respectively. Similarly, a sharp downward trend of 813.25 mm of rainfall was observed in 1996 with a very sharp increase to in 1998 through 1999 with rainfall of

1049.36 mm and 1295.17 mm respectively. Also from the table, another noticeable downward trend beginning in 2000 through to 2003 but more pronounced in 2002 with rainfall value of 735.33mm. Furthermore, 2010 recorded 1323.51 mm of rainfall dropping to 783.65mm in 2013 but with an upward trend of 1537.04mm in 2017. This cyclic nature of rainfall received in Kainji is observed to be prevalent throughout the period of study.

Fig. 2 shows a gradual downward trend of rainfall especially against the World Meteorological Organization (WMO) Climate Normal of 1440.0 mm from 1981 to 2010 for the study area. The Figure shows consistent fluctuations in the rainfall amount received in the last 30 years. It is important to point out that half of the study period experienced drought while the other half period experienced floods. There was a severe cyclical and decadal dryness indicating meteorological drought in Kainji Lake Area in 1992, 2002 and 2013 with a record of -332.26, -350.50 and-302.22 2002 This implies that Kainji is gradually getting drier and highly variable in daily, monthly and annual precipitation received.

Table 2. Analysis of rainfall pattern of Kainji for 30 years

Year	Rain (X)	Mean	X- Mean	SD	SPI= X-Mean/SD
1991	1285.29	1085.89	199.4	36.41	5.48
1992	753.63	1085.89	-332.26	60.77	-5.47
1993	1015.48	1085.89	-70.41	12.85	-5.48
1994	1227.59	1085.89	146.7	25.87	5.48
1995	1098	1085.89	12.11	4.88	2.48
1996	813.25	1085.89	-272.64	7.21	-5.48
1997	1117.29	1085.89	31.4	5.73	5.48
1998	1249.36	1085.89	163.47	29.85	5.48
1999	1295.17	1085.89	209.28	38.21	5.48
2000	971	1085.89	-114.89	20.98	-5.48
2001	982.47	1085.89	-103.42	18.88	-5.48
2002	735.33	1085.89	-350.56	64	-5.48
2003	846.93	1085.89	-238.96	43.63	-5.48
2004	1183.06	1085.89	97.17	17.74	5.48
2005	1024.43	1085.89	-61.46	11.22	-5.48
2006	1140.59	1085.89	54.7	9.99	5.48
2007	939.6	1085.89	-146.29	26.71	-5.48
2008	1078.68	1085.89	-7.21	1.32	-5.48
2009	1142.44	1085.89	56.55	10.32	5.48
2010	1323.51	1085.89	237.62	43.38	5.48
2011	1182.55	1085.89	96.66	17.65	5.48

2012	1090.74	1085.89	4.85	0.89	5.45
2013	783. 67	1085.89	-302.22	55.18	-5.48
2014	1082.8	1085.89	-3.09	0.56	5.52
2015	1053.12	1085.89	-32.77	6.09	-5.43
2016	1121.46	1085.89	35.57	6.49	5.48
2017	1537.59	1085.89	451.7	82.47	5.48
2018	1243.04	1085. 89	157.15	28.69	5.48
2019	1205.84	1085.89	119.95	21.9	5.48
2020	1053.12	1085.89	-33.09	6.04	-5.48

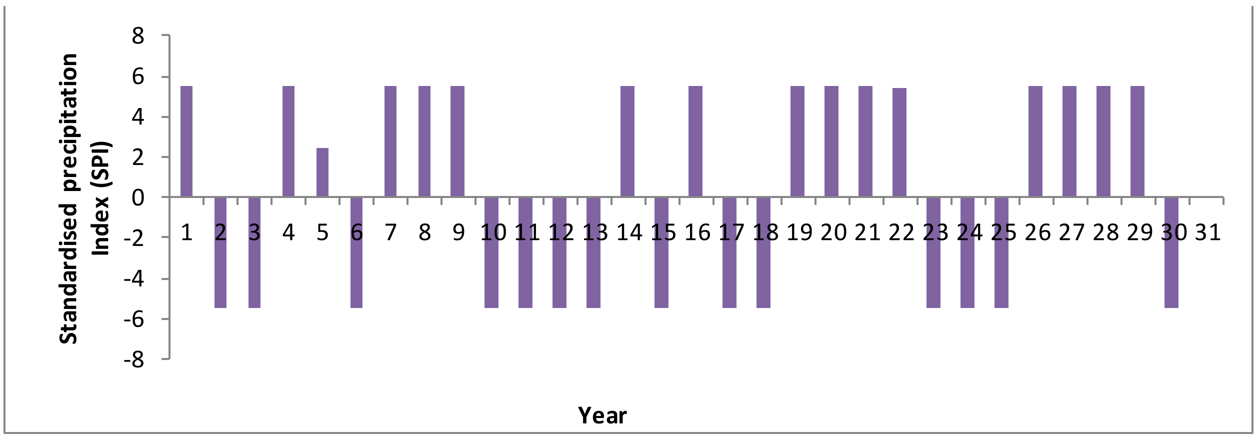

Fig. 2. Standard precipitation index for Kainji between 1991 and 2020

4.2 Decadal Rainfall Patterns

Table 3 shows that the study area received less above than normal rainfall for 4years and normal for 6 years indicating wetter years than drier. The table shows 1992 and 1996 as the driest years in the decade under review. Although there was a rise in rainfall from 1993 through to 1994 however, the following year 1995 experienced a decline in rainfall. Moderate dryness was experienced twice in 1992 and 1996 while some other years had mild and normal dryness. It is important to point out therefore that the decadal rainfall trend recorded moderate and mild drought; this also reflected in year 2000 which experienced moderate dryness and some other years with mild dryness respectively.

Table 4 shows represents the 2rd decade and the study area received less than normal rainfall for 5years and above normal for 5 years, this indicating moderate rainfall. The table shows 2002 and 2007 as the driest years in the decade under review. Although, there was rise in the rainfall amount in 2004 and 2006, the following year 2007 experienced a decline in rainfall but progressively experienced a rise in rainfall from 2008 through 2010. Moderate dryness was experienced three times in 2002, 2003 and 2007 while some other years had mild and normal dryness. The table also shows that in this decade some years experienced moderate rainfall, while some years received mild and normal rainfall.

Table 5 represents the 3rd decade and the study area received less than normal rainfall for 6years and above normal for 4years, this indicating severe dryness in the basin. The driest year was recorded in 2013 and the wettest year was in 2017. From the table, it can be seen that this last decade received less rainfall than the previous two decades 1991-2000 and 2000-2010. Although there was decline in rainfall in 2013, the following years experienced a rise in rainfall in the following year.

Table 3. Yearly rainfall Kainji Lake Basin from 1991-2000

Year	Rain (X)	Mean	SD	X-Mean	SPI= X-Mean/SD
1991	1285.29	1090.71	199.4	36.41	5.41
1992	753.63	1090.71	-337.16	61.76	-5.48
1993	1015.48	1090.71	-75.31	13.75	- 5.48
1994	1227.59	1090.71	136.8	24.98	5.48
1995	1098	1090.71	7.21	1.73	-4.17
1996	813.25	1090.71	-272.64	7.21	5.48
1997	1117.29	1090.71	26.5	4.84	4.48
1998	1249.36	1090.71	158.57	29.85	5.48
1999	1295.17	1090.71	204.38	37.31	5.48
2000	971	1090.71	-37.99	6.94	-5.47

Table 4. Yearly rainfall of Kainji Lake Basin from 2001-2010

Year	Rain (X)	Mean	SD	X-Mean	SPI= X-Mean/SD
2001	982.47	1039.7	-57.23	10.45	-5.48
2002	735.33	1039.7	-304.37	55.57	-5.48
2003	846.93	1039.7	-192.77	35.19	-5.48
2004	1183.06	1039.7	143.36	26.17	5.48
2005	1024.43	1039.7	-15.27	2.79	-5.47
2006	1140.59	1039.7	100.89	18.42	5.48
2007	939.6	1039.7	-1001.1	18.28	-5.48
2008	1078.68	1039.7	38.98	7.12	-5.47
2009	1142.44	1039.7	102.74	18.76	5.48
2010	1323.51	1039.7	283.81	51.82	5.48

Table 5. Yearly rainfall of Kainji Lake B andasin from 2011-2020

Year	Rain (X)	Mean	SD	X-Mean	SPI= X-Mean/SD

2011	1182.55	1135.36	47.19	8.62	5.47
2012	1090.74	1135.36	-44.62	8.14	-5.48
2013	783. 67	1135.36	-351.62	64.2	-5.48
2014	1082.8	1135.36	-52.56	9.6	-5.48
2015	1053.12	1135.36	-82.56	15.07	-5.48
2016	1121.46	1135.36	-13.9	2.54	-5.47
2017	1537.59	1135.36	409.23	73.44	5.48
2018	1243.04	1135.36	107.68	19.66	5.48
2019	1205.84	1135.36	70.84	12.93	5.48
2020	1053.12	1135.36	-82.56	15.07	-5.48

5. SUMMARY OF THE FINDINGS

The summary of the major findings of this work in line with the objectives of the study are:

i. Kainji Lake Area is experiencing a cyclic pattern of rainfall but gradual downward trend for the last 30 years with the persistent decline from 2001 with the exception of 1999.2010 and 2016; indicative of drier years over the last 10 years which was very pronounced in 2013.
ii. The study shows high rainfall variability throughout the years under review prevailing mostly in the last decade.

6. CONCLUSION

From the study, climate variability and climate change seem to have taken the centre stage in Kainji Lake Basin with gradual but consistent decrease in rainfall recorded in the last three decades and sharply represented in the immediate past decade. The fluctuations observed in the pattern of dry and wet period might also be linked to the El-nino and La-nina effects, by the intensity of precipitation and drought experienced during the years under review.

The need for more synoptic stations is necessary for sufficient climatic data representation of the study area considering the spatial variations of weather,. In addition, active collaborations at different levels especially to equip the existing manual weather stations and also to build automatic weather stations for wide spatial representation of weather data.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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