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Analysis of Rainfall Trends and Patterns in Abuja, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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 Abuja between 1986 and 2016. Daily rainfall data of 31 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 Abuja over the last 31 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.

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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 [1]. 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 [2]. 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 [1]. Research of yearly and seasonal precipitation on global and local scales shows trends over many regions of the world [3].

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 [4 and 5]. 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 [6]. 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. [7,8,9]. Similarly, observed precipitation has increased in southern America [10] while negative trends in annual precipitation have been observed over Chile and parts of the western coast of the continent [10]. 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 in observed trends in mean precipitation. For instance, an observed pattern of continued aridity throughout North Africa south of the Sahara was noted by [11]. 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 [11] argued that Southern Africa was relatively moist in the 1950s and 1970s, [12] 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 [13]. 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. The type of Precipitation that is prevalent in Abuja like elsewhere in the tropics consists almost entirely of rainfall, [14] as it is the most variable element of tropical climate.

According to [14], Abuja exemplifies a transitional character as between the zone of double rainfall maximum to the south and of a single maximum to the north. This coupled with its locational advantage to the windward of the Jos Plateau are some of the factors responsible for the variation in rainfall amounts received in year. Rainfall starts at about 20th of March on the southern boundary of territory to about 10th of April at the northern limits. Rainfall cessation dates range from 20th October in the north to about 18th November in the south, giving a duration of between 190-240 days. The mean annual total rain emphasizes the unusual situation in territory resulting from its location to the windward side of the Jos Plateau. This gives rise to a general increase in rainfall total as we move from south to the north rather than the more usual decrease in this direction. Annual rainfall viability coefficient ranges from 85% - 117% while on monthly basis the values are between 20% and 280%. There is extreme concentration of rainfall in two to three months of

July, August and September in Abuja. In fact these three months account for about 60% of rainfall in the region. This is more pronounced in the northern areas of the territory [15].

2. STUDY AREA

The study area, Abuja lies at the centre of Nigeria between coordinates of latitude 8°25' and 9°25' north of the equator and longitude 6°45'and 7°45' east of Greenwich. The territory covers an area of 8,000 square km. It is bordered to the north by Kaduna State, to the east by Nasarawa State, to the south west by Kogi State and to the west by Niger State. The climate of the study area is the hot and humid tropical type. It is such that its major segments have systems that are transitional from those of the southern and northern parts of the country. Thus, relative humidity is not as high as in the southern part and temperatures are not as high as in the far north either [15]. The most important quantitative indicator in this area is the annual total which differs from year to year and place to place widely. Other rainfall characteristics, such as its seasonal and diurnal distribution, intensity, duration and frequency of rain-days also show important differences in both place and time within Abuja. Since other climatic elements are much more uniform in the tropics, rainfall has been greatly used to mark boundaries of climatic regions in the tropics of which includes Abuja [14,16]. Rainfall is an essential environmental factor to agriculture in Abuja since the sector largely depend on rainfall in this region.

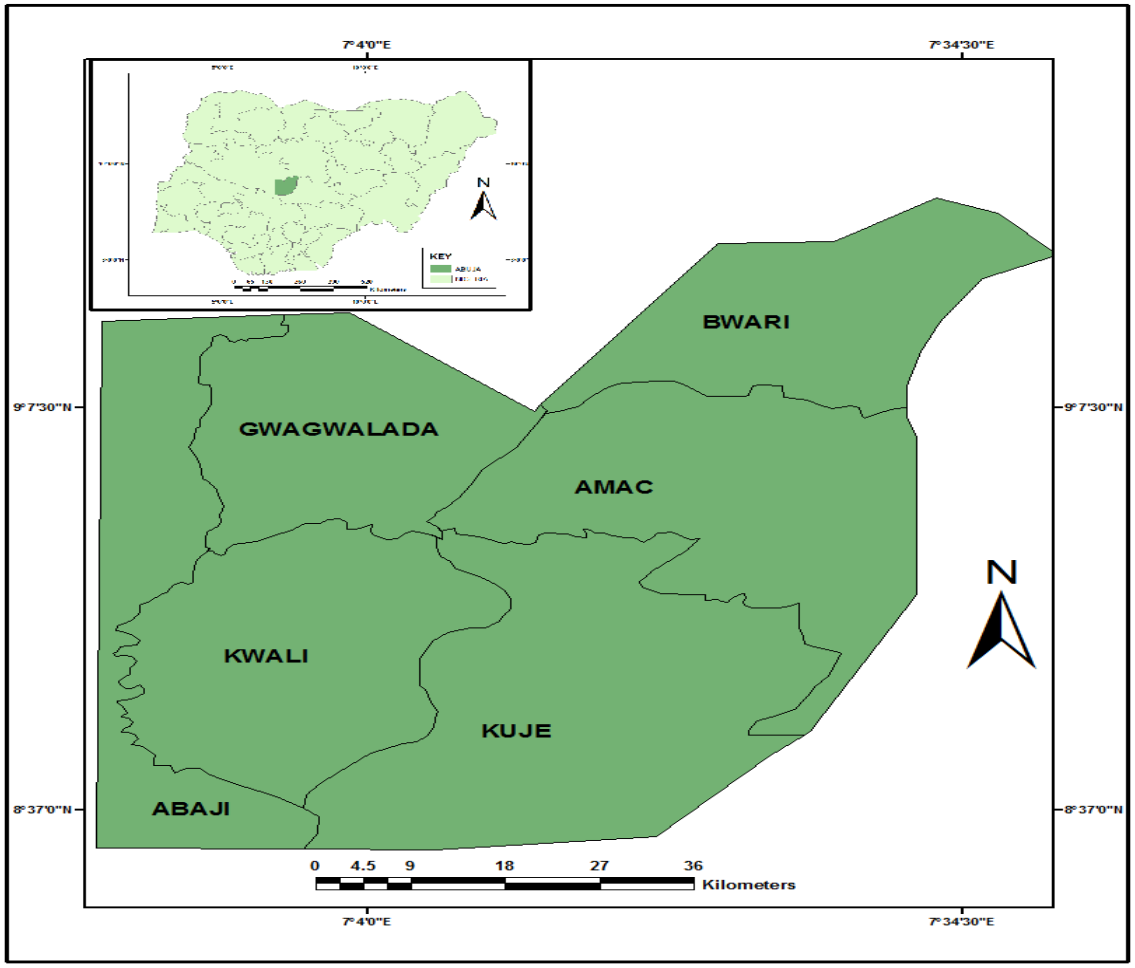

Fig. 1. Map of Abuja showing the six area councils
Source: National Space Research Development Agency (NARSDA), Abuja 2015

3. DATABASE AND METHODS

3.1 Sources and Types of Data

Thirty one (31) years daily rainfall data (*ISO 90001:2015 certified*) of Abuja from 1986 to 2016 was collected from the Headquarters of the Nigerian Meteorological Agency (NIMET) for the purpose of the study. Monthly and Annual average rainfall amount was calculated for the period of study.

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 $\frac{x - \bar{x}}{SD}$

Where x = Actual Rainfall;
$\bar{x}$ = 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

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.

$$CV = \frac{x - \bar{x} * 100}{SD}$$

Where X = Actual Rainfall;
$\bar{x}$ = Mean Rainfall and;
SD = Standard Deviation from normal rainfall.

4. RESULTS AND DISCUSSION

4.1 Rainfall Trends and Patterns

The rainfall for the 31 years was analysed and presented in Table 2. The Table shows a decline in rainfall from 1558 mm in 1986 to 1227 mm in 1989 and rising trend of 1552 mm and 1651 mm in 1993 and 1994 respectively. Similarly, a downward trend of 1198mm of rainfall was observed in 2000 with a very sharp increase to 1941.6 mm of rainfall in 2002. Also from the table, another noticeable downward trend began in 2006 through to 2008 with 1311.6 mm and 1174.7 mm respectively. Furthermore, 2010 recorded 1682.2 mm of rainfall dropping to 1099.9mm in 2013 but with an upward trend of 1586mm in 2016. This cyclic nature of rainfall received in Abuja is observed to be prevalent throughout the period of study especially against the World Meteorological Organization (WMO) Climate Normal of 1440.0 mm from 1981 to 2010 for the study area.

Fig. 2 shows a gradual downward trend of rainfall in Abuja for the period under study. The Figure shows consistent fluctuations in the rainfall amount received in the last 31years with the exception of 2013 and 2014 which showed severe dryness indicating meteorological drought in Abuja. This implies that Abuja is gradually getting drier and highly variable in daily, monthly and annual precipitation received.

4.2 Decadal Rainfall Patterns

Table 3 shows that the study area received less than normal rainfall for six years and above normal for four years indicating drier years than wetter. The Table shows 1988 and 1989 as the driest years in the decade under review. Although there was a rise in rainfall from 1990 through to 1994 however, the following year 1995 experienced a decline in rainfall. Moderate dryness was experienced twice in 1988 and 1989 while some other years had mild and normal dryness.

It is worthy to note 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 as in Table 4.

Table 2. Analysis of rainfall pattern of Abuja for 31 years

Year	Rain (x)	$\bar{x}$	SD	$X-\bar{x}$	SPI = $X-\bar{x}/SD$
1986	1558.6	1424.3	185.4351	134.3	0.72
1987	1391.7	1424.3	185.4351	-32.6	-0.18
1988	1240.7	1424.3	185.4351	-183.6	-0.99
1989	1227.2	1424.3	185.4351	-197.1	-1.06
1990	1438.3	1424.3	185.4351	14.0	0.08
1991	1499.6	1424.3	185.4351	75.3	0.41
1992	1377	1424.3	185.4351	-47.3	-0.26
1993	1522.7	1424.3	185.4351	98.4	0.53
1994	1651.5	1424.3	185.4351	227.2	1.23
1995	1310.9	1424.3	185.4351	-113.4	-0.61
1996	1401.6	1424.3	185.4351	-22.7	-0.12
1997	1336.3	1424.3	185.4351	-88.0	-0.47
1998	1455.1	1424.3	185.4351	30.8	0.17
1999	1667.9	1424.3	185.4351	243.6	1.31
2000	1198.3	1424.3	185.4351	-226.0	-1.22
2001	1383	1424.3	185.4351	-41.3	-0.22
2002	1941.6	1424.3	185.4351	517.3	2.79
2003	1428.3	1424.3	185.4351	4.0	0.02
2004	1541.2	1424.3	185.4351	116.9	0.63
2005	1471.8	1424.3	185.4351	47.5	0.26
2006	1311.6	1424.3	185.4351	-112.7	-0.61
2007	1388.9	1424.3	185.4351	-35.4	-0.19
2008	1174.7	1424.3	185.4351	-249.6	-1.35
2009	1444.6	1424.3	185.4351	20.3	0.11
2010	1682.2	1424.3	185.4351	257.9	1.39
2011	1212.4	1424.3	185.4351	-211.9	-1.14
2012	1638.1	1424.3	185.4351	213.8	1.15
2013	1099.9	1424.3	185.4351	-324.4	-1.75
2014	1128.9	1424.3	185.4351	-295.4	-1.59
2015	1443.3	1424.3	185.4351	19.0	0.10
2016	1586	1424.3	185.4351	161.7	0.87

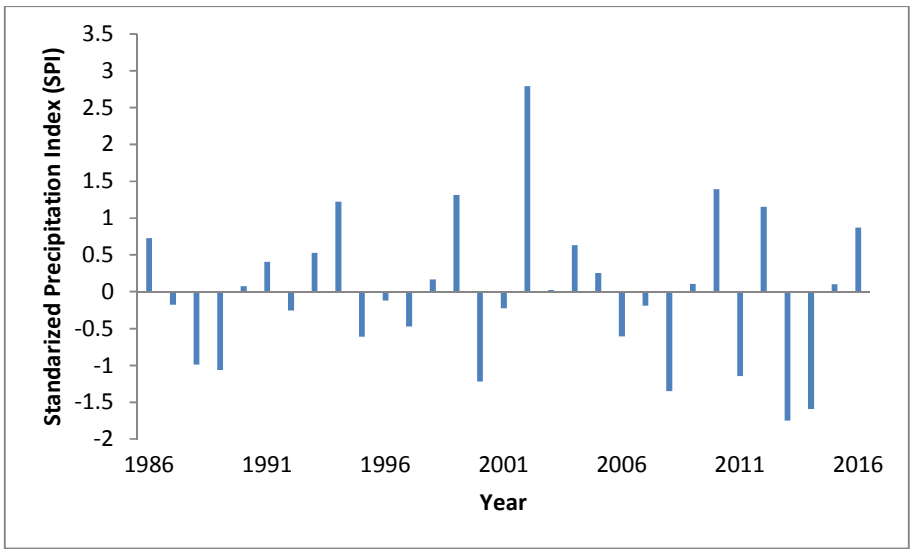

Fig. 2. Standard precipitation index for Abuja between 1986 and 2016

Table 3. Yearly rainfall of Abuja from 1987 to 1996

Year	Rain (X)	Mean	SD	X-Mean	SPI= X-Mean/SD
1987	1391.7	1406.1	130.4248	-14.4	-0.11
1988	1240.7	1406.1	130.4248	-165.4	-1.27
1989	1227.2	1406.1	130.4248	-178.9	-1.37
1990	1438.3	1406.1	130.4248	32.2	0.25
1991	1499.6	1406.1	130.4248	93.5	0.72
1992	1377	1406.1	130.4248	-29.1	-0.22
1993	1522.7	1406.1	130.4248	116.6	0.89
1994	1651.5	1406.1	130.4248	245.4	1.88
1995	1310.9	1406.1	130.4248	-95.2	-0.73
1996	1401.6	1406.1	130.4248	-4.5	-0.03

Table 4. Yearly rainfall of Abuja from 1997 to 2006

Year	Rain (X)	Mean	SD	X-Mean	SPI= X-Mean/SD
1997	1336.3	1473.5	208.9225	-137.2	-0.66
1998	1455.1	1473.5	208.9225	-18.4	-0.09
1999	1667.9	1473.5	208.9225	194.4	0.93
2000	1198.3	1473.5	208.9225	-275.2	-1.32
2001	1383	1473.5	208.9225	-90.5	-0.43
2002	1941.6	1473.5	208.9225	468.1	2.24
2003	1428.3	1473.5	208.9225	-45.2	-0.22
2004	1541.2	1473.5	208.9225	67.7	0.32
2005	1471.8	1473.5	208.9225	-1.7	-0.01
2006	1311.6	1473.5	208.9225	-161.9	-0.77

5. SUMMARY OF THE FINDINGS

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

i. Abuja is experiencing a cyclic pattern of rainfall but gradual and steady downward trend for the last 30 years especially with the persistent decline from 2006 with the exception of 2010, 2012 and 2016; indicative of drier years over the last 10 years which was very pronounced in 2013 and 2014.

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 Abuja 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.

Taking into account the spatial variations of weather, the need for more synoptic stations is paramount for sufficient climatic data representation of the study area. In addition, active collaborations at different levels especially to build more automatic weather stations to complement existing weather observatories is required for wide spatial representation of weather data.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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