Medicon Agriculture & Environmental Sciences
Volume 4 Issue 4 April 2023
Research Article

Analysis of Annual and monthly rainfall variation in Benue State

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Received: March 20, 2023; **Published:** March 31, 2023

Abstract

This study looked at monthly rainfall variations in Benue State to see what trends and patterns there were during the rainy season in Makurdi, Otukpo, Gboko, Zaki-Biam, Igumale, Vandeikya, Katsina-Ala, and Bopo stations. The month of December had the least amount of rainfall, followed by January and February at all of the stations. Except at Makurdi station, where the highest rainfall amount was obtained in August, September was the month with the highest rainfall quantity. The maximum monthly rainfall was reported at Vandeikya and Igumale stations in the south, while the lowest monthly rainfall was recorded at Makurdi and Bopo stations in the north. From 1984 to 2017, total rainfall at all stations ranged from 672.11mm in 1999 at Bopo station to 3454.66mm in 2000 at Vandeikya station. The significance level of 0.05 in the analysis of variance (ANOVA) used to evaluate the variation in yearly rainfall amount across all stations indicated that F7,264=13.51, indicating that there is a substantial variation in rainfall amount across all stations in Benue State. Using the Mann-Kendal and Sen Slope, the rainfall trend and pattern in Benue State from 1984 to 2017 shows both increase and downward trends in yearly rainfall across all stations. From 1985 to 1989, yearly rainfall trends were on the rise. Makurdi Station's rainfall ranges from 1290mm to 1584mm (294mm); Otukpo Station's rainfall ranges from 1233mm to 1479mm (246mm); Gboko Station's rainfall ranges from 1413mm to 1675mm (262mm); Zakibiam Station's rainfall ranges from 1411mm to 1717mm (306mm); Igumale Station's rainfall ranges from 1307mm to 1665mm (358mm); Vandeikya Station's rainfall ranges from 1815mm to 2135mm (320mm); and Bopo Station's rainfall ranges from 1506mm to 1629mm (123mm). Only Katsina-Ala station recorded a negative trend from 1833mm to 1624mm (-320mm). The rainfall variation in Benue state is mostly on an upward trend, which can be utilised for aggressive forestation and reforestation in areas where deforestation is a concern, particularly in the state's southern and north-eastern regions. In the guinea savannah zone of the country, where Benue state is located, there is a need for continual cultivation of roots, tubers, and cereals, which are the most suited crops.

Keywords: Monthly Rainfall; Trends; Variation; Mann Kendal Test

Introduction

Changes in rainfall driven by changing surface and air temperatures may replenish or discharge a region's surface and groundwater levels, determining its agricultural output (Stocker 2014 1; Pachauri et al. 2014 2; Trenberth 2008 3; Dore 2005 4; Amekudzi et al. 2015 5). Reduced rainfall, particularly in dry locations, limits the amount of water available for agriculture and salts water bodies (Mkuhlani et al. 2019 6). Rainfed agriculture provides over 60% of staple foods to over 80% to 90% of rural areas in Africa and around the world (FAO 2005 7; Wani et al 2009 8; Rockstroom et al 2003 9). Reduced rainfall and changing weather patterns in the Mediterranean region have impacted both subterranean and surface water storage capabilities, resulting in a present water stress problem in the region (Bocci and Smanis, 2019 10). Within the next 50 years, rainfall in Southern Africa will decrease by 10% to 20%. (IPCC 2014 11; Niang et al. 2014 12).

As a result, due to rainfall variability, the manifestation of soil fertility decline, the incidence of crop disease, and the production of indigenous crops would grow (Kashaigili et al 2014 13; Kyei-Mensah 2017 14; Olesan et al 2011 15; Kurukulasuriya and Rosenthal 2013 16). In the Worobong Ecological Area in Fanteakwa District, Ghana, a study on the impacts of rainfall variability on crop production by Kyei-Mensah et al (2019 17) found a coefficient of variation of 5.7% in the minor season, with a total rainfall decline of 267.16mm. Because of its tropic's location, Nigeria's atmosphere is characterized by high relative humidity, temperature, and rainfall variability (Oguntoyinbo, 1983 18; Nieuwolt, 1977 19). As a result, rainfall in Nigeria decreases with increasing latitude, from 400mm per year in the Sahel region of Lake Chad in the northeast to 2710mm per year in the Delta Niger region of Nigeria (e.g., Port Harcourt, Calabar) (Akinbile, et al., 2019 20). Oyinbo et al. (2014 21) found a rainfall coefficient of variation of 78.4 percent and an index of agricultural output CV of 51.4 percent in a study that looked at the causal association between variations in rainfall and agricultural production in Nigeria from 1970 to 2008. Rainy season varies across Nigeria, with a minimum of 9 months in the south and 4 months in the north (Obarein and Amanambu 2019 22), necessitating an analysis of monthly rainfall variance to unravel rainfall trends in Nigeria and forecast possible consequences on agricultural production. The most applied of which is the Mann Kendall and Sen slope which is currently been used in the monitoring of rainfall trends in the Himalayan Mountain Catchment of Bagmati River in Nepal (Tuladhar et al. 2019 23).

Materials and Methods

Study Area

Benue State is located in northern Nigeria, between the Savannah Belt and the Rain Forest, and has a unique climate, pedology, and vegetation. It is located between the latitudes of 6^0 25'N and 8^0 8' N, and the longitudes of $7^0$47'E and 10^0 0' E, with a landmass of 34,059km^2 and a predicted population of 7,097,863 in 2020 (NPC; 2006 24). It is politically divided into 23 local council districts, including Makurdi the state capital. It shares boundary with Nasarawa State to the north, Taraba State to the east, Cross River State and the Republic of Cameroun to the south and south east, and Kogi and Enugu States to the west and south west of Nigeria. It has an ethnically homogeneous Tiv, diverse Idoma, Igede, Etulo, Jukun, and immigrant Ibo, Hausa, Yoruba, and other Nigerians in the state. The dry season begins in November with a harmattan and ends in March with heat, whereas the wet season begins in April with high humidity and precipitation and finishes in October. Due to East-West line squalls signaling the start of the planting season, light rains are also typical in January, February, and March. Annual rainfall in the area ranges from 1200mm to 1500mm, with typical maximum and minimum diurnal temperatures of 35°C and 21°C during the rainy season and 37°C and 16°C during the dry season, relative humidity of 74.88% and 6.2 hours of daily sunlight. The landscape is defined by oxisols and ultisols tropical ferruginous soil in the North, lateritic and forest vegetation cover in Oju, Obi, Ogbadibo, Oturpo and Vandekiya areas in the South, entisols, inceptisols with young soils on hill slopes and recent alluvium and Eutrophic Brown earth and volcanic parent materials in Gbajimba, deep gullies in Ogbadibo an extension of the eastern Nigerian, metasedimentary deep gully system and other gully sites in Makurdi North Bank area, Tse Mker and Gbem in Vandeikya, and Gbajimba town. In Kwande LGA, streambank erosion in Gboko town and incised streams on sloppy ground coterminous with the Anwase, Kyogen, and Abande ranges are unique environmental landscapes and challenges. The Benue River and its tributaries, which originate in the Cameroonian mountains and meet the Niger River at Lokoja, drain the state (Tyubee, 2006 25; Adamgbe and Ujo, 2012 26).

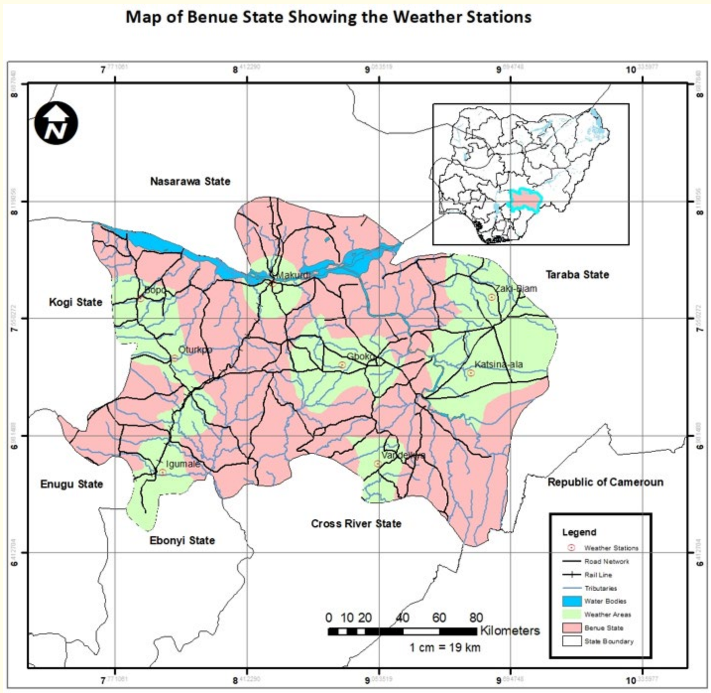


Figure 1: Study Area.

Methods

Coefficient of Variation

According to Sharma and Kumar, (2019) CV is:

$$CV = \frac{s}{\bar{x}} * 100\%$$

Where CV is the Coefficient of variation, S is the standard deviation and x̄ mean of rainfall, a higher value of CV indicates higher spatial variability, and vice versa.

Mann-Kendall Trend Test

The Mann-Kendall test is a non-parametric statistical test used to test for the presence of an increasing or a decreasing trend in the considered time series (Mann, 1945, 27 Kendall, 1975 28). Mann-Kendalll test statistic was done using R Language. Studies that have employed the Mann-Kendall test for the detection of trends in hydrological time series data are (Wilks, 1995 29; Serrano et al., 1999 30; Brunetti et al., 2000a 31; 2000b; Onoz and Bayazit, 2003 32; Patra et al., 2012 33) and it has proven to be more efficient for detecting a trend in a skewed data distribution (Lonobardi and Villani, 2009 34).

The computations assume that the data are independent and are identically distributed.

The mathematical equation for calculating Mann-Kendall statistics is given as;

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\left(x_j - x_k\right)$$

Where n is the number of data, x is the data point at times j and k (k>j), and the sign function is given as:

$$sgn(x_j = x_k) = \quad 0 \quad if \quad x_j - x_k = 0$$

Where S = Mann-Kendall test statistic, Sgn = an indication function, xj and xk are the annual values in years j and k, j > k, respectively. A positive S value indicates an increasing trend while a negative S indicates a decreasing trend in the data series.

In a situation where there are ties (i.e., equal values in the x values), the variance of S is estimated and given by:

Var (S) = [n (n-1) (2n+5)]-∑mi=1 ti(ti-1) (2ti+5)]

Where m = number of tied groups in the data set and ti is the number of data points in the ith tied group.

For a time, series such as this with n longer than 10 (n > 10), S approximates a standard normal distribution, ZMK. ZMK is computed to test the presence of a statistically significant trend. The Z test statistics are given as;

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} if S > 0 \\ if S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} if S < 0 \end{cases}$$

A positive value of Z indicates an increasing trend while a negative value indicates a decreasing trend.

The Julian days defined as the particular day of the year in which a date fall was used. For example, the 28th day of February marks the 59th day of the year from January 1st.

Theil-Sen's Slope

Theil-Sen's Slope was used to estimate the slope of an existing trend that is, the change in rainfall (mm) per year. It is used where the trend is assumed to be linear. It is insensitive to outliers and has been called the most popular nonparametric techniques for estimating a linear trend. The trend magnitude is computed;

$$B = \text{Median} \left(\frac{Xj-Xi}{Tj-Ti} \right)$$

Where xj and xi = values at times tj and ti respectively.

Exponential Population Projections

$$Nt = P_0 \, e^{rt}$$

Where; Nt = number of people at a future time, P = number of people at the beginning time.
E = base of the natural logarithms at 2.71828, r = rate of increase divided by 100 and.
t = time involved.

Discussion

Variation in Monthly Rainfall in Benue State

As indicated in Table 1, 2 and Figure 2, the month of December had the least amount of rainfall, followed by January and February for all of the stations. Except at Makurdi, where the maximum rainfall amount was obtained in August, September was the month with the highest rainfall quantity in all of the stations. In comparison to the other stations, Vandeikya and Igumale stations in the south had the most rainfall in all months, while Makurdi and Bopo stations in the north received the least. With more than 51mm of rainfall, the months of April through October are the most beneficial months for agricultural activity in Benue state, however March also reported a larger quantity for Gboko, Vandeikya and Katsina-Ala stations. This is consistent with the findings of Tyubee, (2006) 24 and Adamgbe and Ujoh (2012) 25 who observed that April to October marked the period of the rainy season in Benue state.

Months	*Makurdi*	*Otukpo*	*Gboko*	*Zakibiam*	*Igumale*	*Vandeikya*	*Bopo*	*Kataina-Ala*
Jan	2.97	5.09	4.51	3.23	4.74	6.93	4.03	4.51
Feb	7.93	13.20	11.77	7.21	12.28	18.53	10.93	11.77
Mar	32.22	48.29	51.18	35.30	49.23	78.84	36.14	51.18
Apr	106.47	116.31	127.84	115.59	120.78	171.31	101.99	127.84
May	160.92	157.94	182.12	181.32	168.04	228.47	152.32	182.12
Jun	188.15	184.04	208.68	212.32	193.65	262.67	180.13	208.68
Jul	201.23	201.56	210.99	217.93	202.44	262.07	215.52	210.99
Aug	231.22	220.87	234.23	249.61	226.23	274.48	231.75	234.23
Sep	229.85	228.78	249.16	256.65	235.41	301.93	234.07	249.16
Oct	155.38	173.06	201.24	179.35	185.21	279.36	148.65	201.24
Nov	22.06	37.47	40.38	24.09	38.52	65.30	22.33	40.38
Dec	2.23	4.18	3.85	2.49	3.76	6.19	3.78	3.85
Maximum	231.22	228.78	249.16	256.65	235.41	301.93	234.07	249.16
Minimum	2.23	4.18	3.85	2.49	3.76	6.19	3.78	3.85

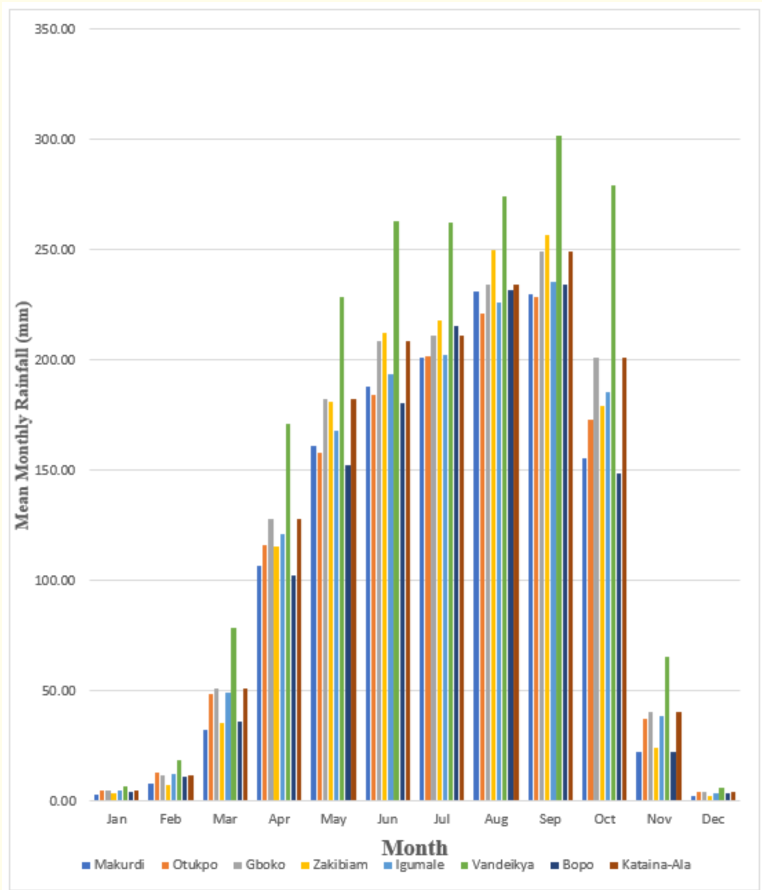
Source: Author's Computation (2019).

Table 1: Mean Monthly Rainfall (mm) from 1984 to 2017.

Month	*Makurdi*	*Otukpo*	*Gboko*	*Zakibiam*	*Igumale*	*Vandeikya*	*Bopo*	*Katsina-Ala*
Jan	144.04	144.39	157.64	151.49	157.27	151.99	125.61	157.64
Feb	130.30	121.49	118.10	117.25	120.23	119.79	118.82	118.10
Mar	73.25	56.71	61.87	85.15	58.26	57.32	72.51	61.87
Apr	43.72	50.15	48.18	40.27	50.00	52.71	44.19	48.18
May	31.31	26.16	27.28	28.57	27.22	25.74	30.41	27.28
Jun	51.60	50.66	50.20	46.05	51.70	51.11	48.85	50.20
Jul	42.48	41.47	41.83	33.75	42.56	45.38	39.80	41.83
Aug	36.85	36.54	33.28	27.72	35.23	31.95	39.71	33.28
Sep	29.59	28.03	26.70	22.10	27.41	27.96	29.54	26.70
Oct	34.39	31.24	30.01	31.11	30.05	30.57	37.62	30.01
Nov	87.37	77.12	78.07	81.52	78.84	75.38	76.11	78.07
Dec	202.52	171.70	184.01	206.24	178.57	178.21	180.68	184.01
Maximum	202.52	171.70	184.01	206.24	178.57	178.21	180.68	184.01
Minimum	29.59	26.16	26.70	22.10	27.22	25.74	29.54	26.70

Source: Author's Computation (2019).

Table 2: Monthly Coefficient of Variation Values (%) from 1984 to 2017.



Source: Author's Computation (2019).

Figure 2: Mean Monthly Rainfall for the selected station from 1984-2017.

In most of the stations, the coefficient of variation suggested a minimum value for September, as seen in Table 3. Except for the Makurdi station, where the maximum amount of rainfall was obtained in August as previously stated, this month (September) had the highest amount of rainfall in all of the stations. The month with the most rainfall has the lowest CV, and the reverse is true. Exceptional occurrences exist in some stations, where the month of May had the lowest CV despite receiving the least amount of rainfall. This was seen at the stations of Otukpo, Igumale, and Vandeikya. As a result, rainfall amounts in May are more evenly distributed and less unpredictable at the sites studied. Still, despite the fact that Vandeikya station had the most rainfall throughout the course of the time, its CV was not the lowest as expected; rather, the Zakibiam station, which received the least rainfall, had the lowest CV of all the stations. This also indicates that the rainfall is less variable in Zakibiam than the Vandeikya station with the highest rainfall amount.

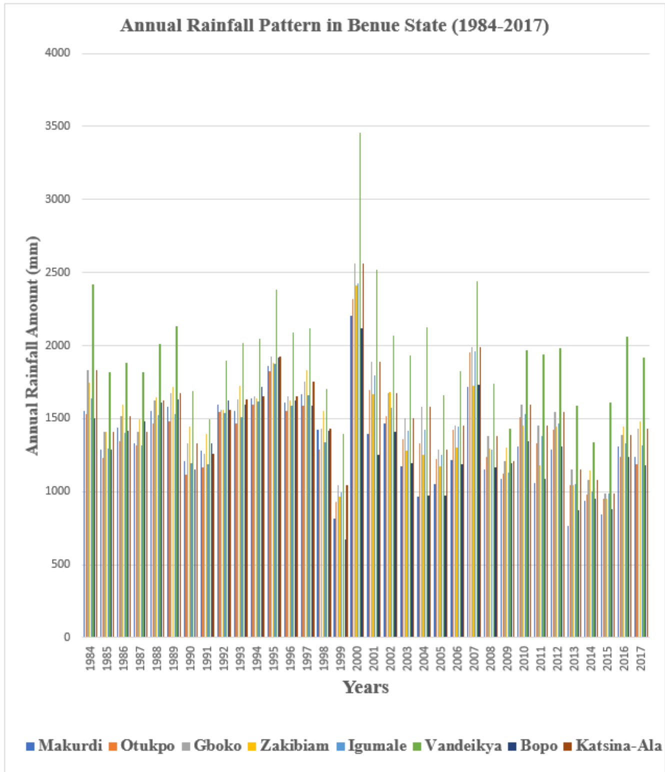
Characteristics of the Annual Rainfall Pattern (1984 to 2017)

The rainfall quantity in all the stations from 1984 to 2017 is displayed in Figure 3 to 7. It ranges from a minimum of 672.11mm in 1999 at Bopo station to a maximum of 3454.66mm in 2000 at Vandeikya station. The Vandeikya station still has the largest rainfall amount (1956.09mm), while Makurdi, Otukpo, and Bopo have the lowest (1340.63mm, 1390.78mm and 1341.60mm) respectively. In the year 2000, the Makurdi station received the highest annual rainfall quantity of 2205.53mm, while the lowest number for the same station was 764.16mm in 2013. Following the same pattern, the greatest rainfall at Otukpo station was 2320.37mm in 2000, with a minimum of 926.66mm (in 1999). The greatest rainfall at Gboko station was 2559.39mm in 2000, while the minimum was 990.33mm (in 2015). The maximum rainfall at Zakibiam station was 2414mm in 2000, while the minimum was 947.81mm (in 2015). In 2000, the greatest rainfall at Igumale station (figure 4.5a) was 2424.89mm, while the minimum was 984.3mm (in 2015). In 2000, the greatest rainfall at Vandeikya station was 3454.7mm, while the lowest was 1338.7mm (2014). The maximum rainfall for Bopo station was 2115.75mm in 2000, while the minimum was 677.11mm in 1999, while the greatest rainfall for Katsina-Ala station was 2559.39mm in 2000, while the minimum was 990.33mm in 1999 (in 2015). All of the stations have modest inter-annual variation in annual rainfall amounts, with Bopo and Makurdi having the highest coefficients of variation of 23.50 and 23.31, respectively, and Gboko having the lowest CV. This means that rainfall is more reliable at stations with lower CV values and less reliable in stations with fewer CV values.

Variable	Mean	SD.	Variance	CV	Minimum	Median	Maximum
Makurdi	1340.6	312.5	97626.2	23.31	764.2	1309.8	2205.5
Otukpo	1390.8	287.6	82705.6	20.68	926.7	1352.3	2320.4
Gboko	1526.0	304.3	92572.4	19.94	990.3	1509.2	2559.4
Zakibiam	1485.1	292.2	85401.8	19.68	947.8	1469.1	2414.6
Igumale	1440.3	295.0	87003.9	20.48	984.3	1423.5	2424.9
Vandeikya	1956.1	394.3	155465.7	20.16	1338.7	1935.6	3454.7
Bopo	1341.6	315.3	99423.0	23.50	672.1	1320.0	2115.8
Katsina-Ala	1525.95	304.3	95572.4	19.94	991.3	1509.2	2459.5

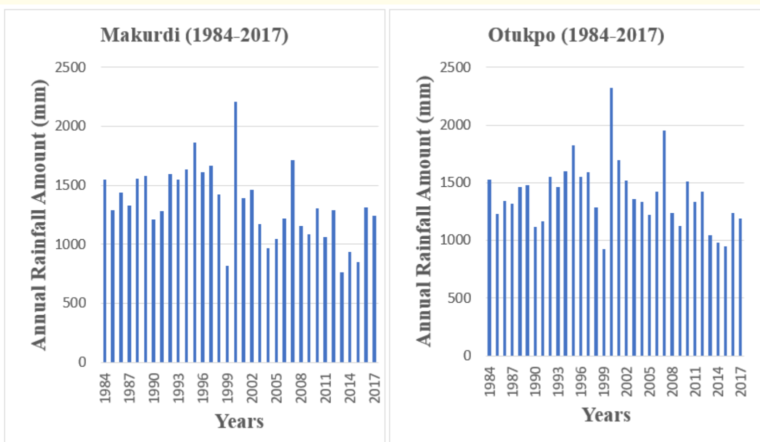
Source: Author's Computation (2019).

Table 3: Descriptive Statistics of the Annual Rainfall Pattern.



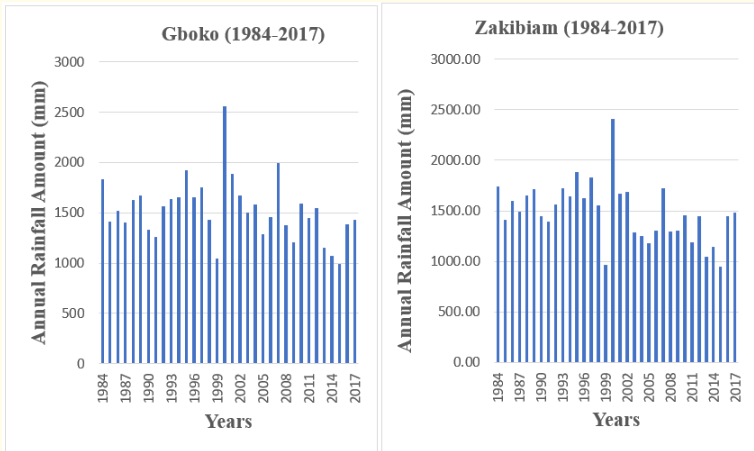
Source: Author's Computation (2019).

Figure 3: Annual Rainfall for all the Stations in Benue State.



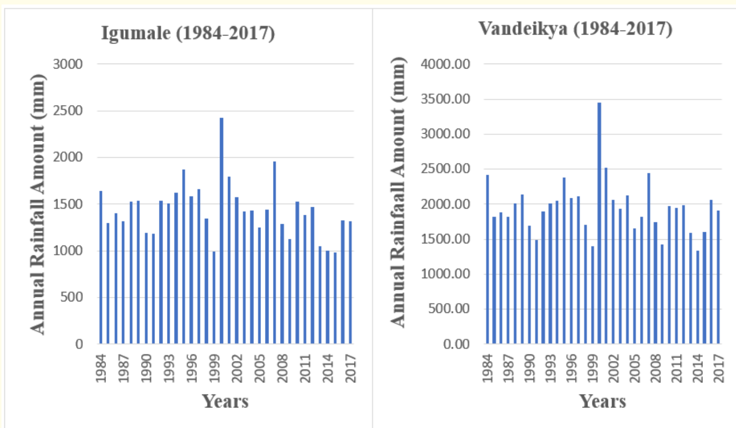
Source: Author's Computation (2019).

Figure 4a and b: Annual Rainfall Amount of Makurdi and Otukpo Stations.



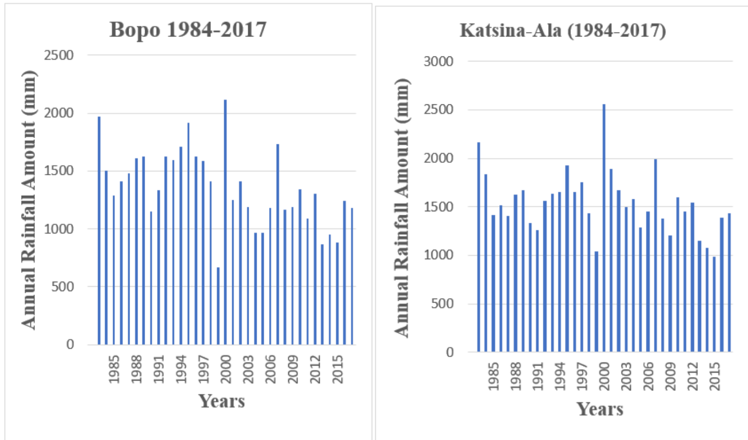
Source: Author's Computation (2019).

Figure 5a and b: Annual Rainfall Amount of Gboko and Zakibiam Stations.



Source: Author's Computation (2019).

Figure 6a and b: Annual Rainfall Amount of Igumale and Vandeikya Stations.



Source: Author's Computation (2019).

Figure 7a and b: Annual Rainfall Amount of Bopo and Katsina-Ala Stations.

Mean Annual Rainfall Across Stations

The significant difference in yearly rainfall amounts among the selected stations was tested using the analysis of variance (ANOVA) indicated in Table 4. The mean difference in yearly rainfall values over the research area was highly significant, with a significance threshold of 0.05 at f7,264=13.51. As a result, the alternative hypothesis (Hi) that there is a significant difference in mean annual rainfall across the identified rainfall stations in Benue State during a thirty-four-year period is accepted. As a result, the observed significant value validates the spatial variation among the stations.

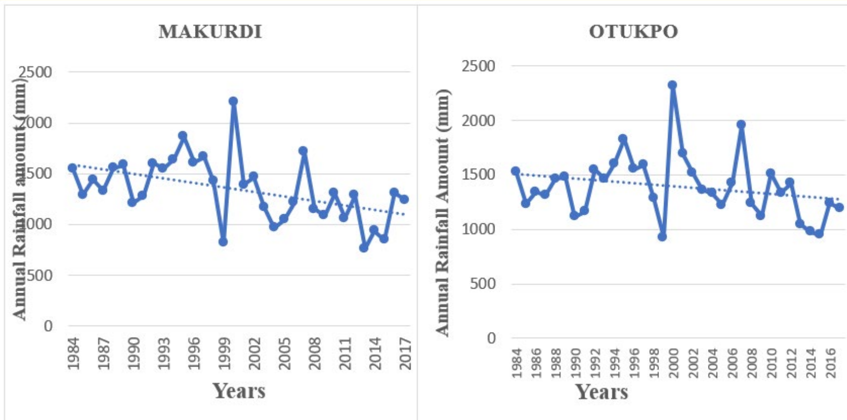
Source	*Sum of Squares*	*Mean of Squares*	*DF*	*F*	*P*
Between groups	9369210	1338459	7	13.51	0.000
Within groups	26161446	99096	264		
Total	35530656		271		

Source: Author's Analysis (2019).

Table 4: ANOVA Result of Annual Rainfall Variation Across Stations.

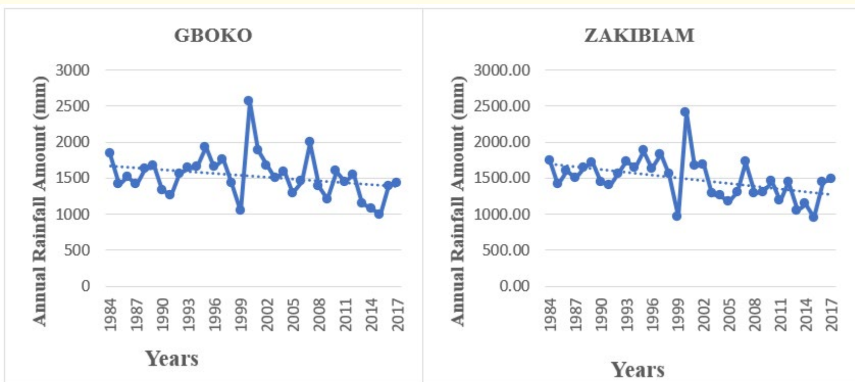
Annual Rainfall Trends and Patterns

From 1984 to 2017, a trend analysis of monthly and annual rainfall events in Benue state was conducted at eight different weather stations: Makurdi, Otukpo, Gboko, Zakibiam, Igumale, Bopo, Vandeikya, and Katsina-Ala, using descriptive statistics, Mann-Kendall test statistics, and Sen's slope estimator, as shown in figures 8 to 11 and Table 5. Benue State's rainfall trend and pattern from 1984 to 2017 showed a non-linear trend with numerous swings in annual rainfall. Annual rainfall increased from 1985 to 1989, ranging from 1290mm to 1584mm (294mm) in Makurdi Station, 1233mm to 1479mm (246mm) in Otukpo Station, 1413mm to 1675mm (262mm) in Gboko Station, 1411mm to 1717mm (306mm) in Zakibiam Station, 1411mm to 1717mm (306mm), Igumale, 1307mm to 1665mm (358mm); Vandeikya, 1815mm to 2135mm ((320mm); Bopo, 1506mm to 1629mm (123mm) while only Katsina-Ala station recorded a downward trend from 1833mm to 1624mm (209mm). From 1989 to 1991, all of the stations experienced a downward trend, with Makurdi station receiving 1584mm to 1280mm (304mm); Otukpo station 1477mm to 1164mm (313mm); Gboko station 1675mm to 1265mm (410mm); Zakibiam station 1717mm to 1396mm (321mm); Vandeikya station 2135mm to 1492mm (643mm); Igumale station 1665mm to 1175mm (490mm); and 1675mm to 1261mm (414mm) for Katsina-Ala station.



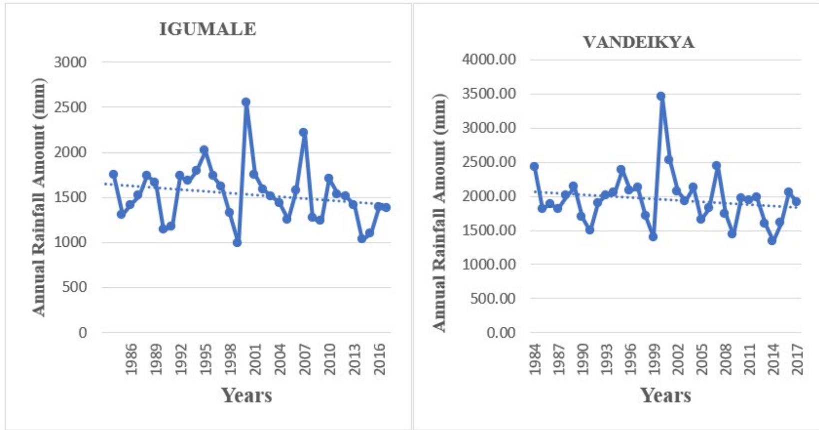
Source: Author's Computation (2019).

Figure 8a and b: Annual Rainfall Trend for Makurdi and Otukpo Stations (1984-2017).



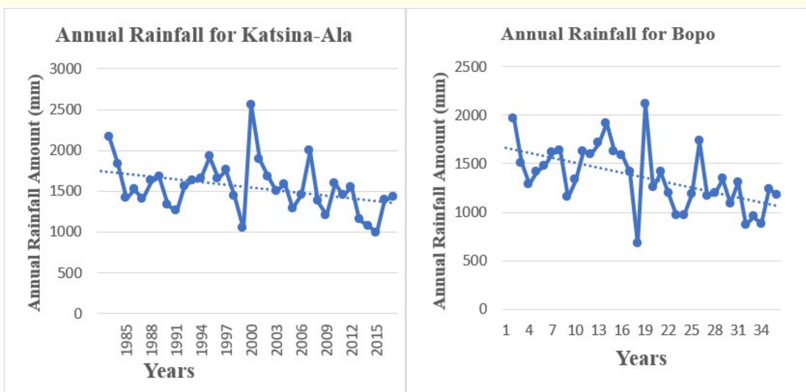
Source: Author's Computation (2019).

Figure 9a and b: Annual Rainfall Trend for Gboko and Zakibiam Stations (1984-2017).



Source: Author's Computation (2019).

Figure 10a and b: Annual Rainfall Trend for Igumale and Vandeikya Stations (1984-2017).



Source: Author's Computation (2019).

Figure 11a and b: Annual Rainfall Trend for Katsina-Ala and Bopo Station (1984-2017).

From 1992 to 1997, nearly all of the stations experienced an upward trend, with Makurdi station receiving 1280mm to 1666mm (386mm); Otukpo station receiving 1164mm to 1590mm (426mm); Gboko station receiving 1261mm to 1755mm (494mm); Zakibiam station receiving 1396mm to 1833mm (437mm); Vandeikya station receiving 1492mm to 2119mm (627mm); Igumale station receiving 1175mm to 1616 (441mm); Katsina-Ala station, 1261mm to 1755mm (494mm) and 1332mm to 1588mm (256mm) for Bopo station. This was followed by a general declining trend for all stations between 1998 and 1999, with a dramatic surge in the year 2000, which was the highest for all stations across the period. The yearly rainfall in Makurdi is 2205mm, 2320mm in Otukpo station, 2559mm in Gboko station, 2415mm in Zakibiam, 3455mm in Vandeikya, 2552mm in Igumale, and 2559mm in Katsina. This indicates a possible increase or higher agricultural output for the year and possible flooding events and rising peaks of the watershed regions in the state. Between 2001 and 2005, Makurdi station received 1392mm to 1047mm (345mm); Otukpo station received 1693mm to 1223mm (470mm); Gboko station received 1890mm to 1288mm (602mm); Igumale station received 2522mm to 1656mm (866mm);

Katsina-Ala station received 1889mm to 1991mm (102mm); and Bopo station received 1251mm to 970mm (281mm). After a general increase in yearly rainfall for all stations in 2008, the rest of the study period saw a constant falling trend from 2009 to 2017, with the exception of the years 2010 to 2012, when higher or rising trends were seen.

Mann-Kendall Trend Test and Sen's Slope Estimate of the Annual Rainfall

The Mann-Kendall trend was used to test the nature and significance of the trend in annual rainfall in all the stations and the trend magnitude was done using Sen's slope estimator. The results revealed a downward trend pattern in the annual rainfall for all the stations. However, the downward trend is only significant for three stations: Makurdi, Zakibiam and Bopo at 0.05 level of significance since the Z value is less than 0.05 for these stations while it is not significant for the rest stations for their respective P-values are greater than 0.05. Thus, the null hypothesis for Makurdi, Zakibiam and Bopo which states that there is no significant trend in the annual rainfall is rejected at 0.05 of Z>1.96. There is a significant downward trend in the annual rainfall pattern at the Makurdi, Zakibiam and Bopo while the downward trend in the annual rainfall pattern for the rest of the stations is not significant. The Sen's slope confirmed the nature of the trend as it shows a downward trend for all the stations. Vandeikya station recorded the highest value of the downward trend followed by Makurdi and Bopo stations respectively while Igumale station recorded the least value throughout the study. The trend shows a high degree of fluctuations over the period.

Station	*Z*	*P-Value*	*Mann-Kendall*	*Sen's Slope*	*Nature of Trend*
Makurdi	-2.5795	0.0099*	-175	-13.89263	Downward
Otukpo	-1.69	0.09103	-115	-8.031304	Downward
Gboko	-1.8975	0.05776	-129	-8.699286	Downward
Zakibiam	-2.6091	0.0091*	-177	-7.709286	Downward
Igumale	-1.6603	0.09685	-113	-5.45	Downward
Vandeikya	-0.9488	0.3427	-65	-14.9575	Downward
Bopo	-2.9945	0.0028*	-203	-12.40125	Downward
Katsina-Ala	-1.7975	0.05786	-138	-9.679286	Downward

*Significant at the 0.05 significance level.

Source: Author's analysis (2019).

Table 5: Mann-Kendall Trend Test and Sen's Slope on Annual Rainfall Pattern.

The downward trend in annual rainfall in Benue State seen in this study is similar with Ismail and Oke, (2012) 34; Odjugo (2010) 35 and Itiowe et al., (2012) 36 findings on the annual rainfall pattern in Nigeria. Odjugo (2010) 35, for example, found that the rainfall pattern in Nigeria between 1901 and 2005 indicated an overall drop of 81mm during a 105-year period. Itiowe et al. (2019) 36 used the Standard Precipitation Index (SPI) and Coefficient of Variability statistical tools to analyze rainfall trends and patterns in Abuja from 1986 to 2016 using daily rainfall data spanning 31 years, and found a downward trend in the amount of rain received in Abuja over the last 31 years. In addition, Ismail and Oke (2012) 34 used non-parametric Mann-Whitney and Sen's estimators and found a substantial decrease trend in yearly total and mean rainfalls at Birnin Kebbi over the last three decades (30years).

Conclusion

December had the least amount of rainfall, followed by January and February for all stations, while September had the most rainfall across all stations except Makurdi, where the most rainfall was recorded in August. Throughout the investigation, Benue state had roughly 6-7 months of effective rainfall. The Vandeikya station in the state's south had the most yearly rainfall, while the Bopo station in the state's north western corner had the least. The mean yearly rainfall amount differed significantly amongst the locations. This means that staples such as maize, millets, beans, and soya beans may be farmed and harvested twice or three times during a wet season. The state's wealth of roots and tubers such as cassava, yam, cocoyam, and potatoes are undeniable, as the state's precipitation levels are ideal for the continued production and sustainability of roots and tubers. The rainfall variation in Benue state is mostly on an upward trend, which can be utilised for aggressive forestation and reforestation in areas where deforestation is a concern, particularly in the state's southern and north-eastern regions. In the guinea savannah zone of the country, where Benue state is located, continuous cultivation of roots, tubers, and cereals, which are the most appropriate crops, is necessary.

Acknowledgements

AE and PNA designed and provided the concepts for the paper and edited the manuscripts while AOA and CPO contributed and assisted in the organization and presentation of the paper. All authors read and approved the manuscripts.

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