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Time Series Analysis for Annual Precipitation in North Central Nigeria

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Abstract:- Precipitation holds immense significance for both the environment and its inhabitants, particularly in the context of agricultural activities, which rely heavily on the availability of rainfall. Accurate estimations of future precipitation levels at specific locations are therefore essential for informed environmental and agricultural decision-making. In this study, time series analysis was employed to assess precipitation patterns in North Central Nigeria. Monthly rainfall data spanning a forty-year period (1981-2020) from four stations in specific North Central Nigerian locations was sourced from the Nigerian Meteorological Agency. Various statistical measurements were applied, including mean, median, maximum, minimum, standard deviation, variance, skewness, kurtosis, and coefficient of variation. The analysis of rainfall variations across the research region revealed that Jos recorded the highest mean annual rainfall amount, totaling 1211.2mm, while Makurdi reported the lowest, with 520.2mm, which also exhibited the lowest rainfall variability, with a coefficient of variation of 12%. The year 2001 witnessed the highest mean annual rainfall, reaching 14662.3mm, while the lowest was recorded in 1983, at 645.7mm. Notably, Minna displayed the highest coefficient of variation value, standing at 38% during the study period. Consequently, the findings indicate an increasing trend in rainfall over the research duration.

Keywords:- *Precipitation, Time Series, North Central and Nigeria.*

I. INTRODUCTION

Precipitation plays a vital role in various scientific studies, particularly in understanding the impact of climate change on water resources, as highlighted by Harpold et al. (2017). It is a fundamental variable used in hydrological modeling, as emphasized by Tripathi et al. (2004), to estimate water availability in different water bodies. Sectors such as agriculture and forestry heavily rely on precipitation data for planning purposes (Gaaloul et al., 2020). However, the importance of precipitation extends beyond these domains, impacting climate studies, water management, and even daily human activities, as noted by Vörösmarty et al. (2000).

Climate change has had substantial effects on ecosystems worldwide, as evidenced by numerous studies (Celik, 2020; Mooney, 2009; Parmesan, 2006). While some regions in Europe, America, and Central Africa have experienced an increase in precipitation trends, others, particularly in South Asia and Africa, have witnessed a decline (Dore, 2005). These fluctuations in precipitation patterns are closely linked to the broader impacts of climate change, resulting in destructive events like floods and storms, posing threats to lives and properties (Handmer, 2009). Hence, predicting precipitation becomes essential for various environmental, agricultural, and human-related activities. When studying long-term rainfall behavior, frequency analysis is a common approach, focusing mainly on extreme values (Faridzad et al., 2018; Li et al., 2019). However, researchers have employed various methods to study precipitation worldwide (Rahman and Islam, 2019). Data availability poses a challenge, making it difficult to obtain historical data for analysis, particularly in many countries. Consequently, accurately determining seasonal or decadal trends becomes a formidable task for researchers. Recent attention has shifted towards changes in precipitation and the identification of extreme values (Salviano et al., 2016). Yet, less emphasis has been placed on time series models and their potential to identify trends and predict future precipitation values. Some researchers, such as Donders et al. (2006) and Mustapha et al. (2018), have examined rainfall characteristics and variations but have not explored the application of robust time series methods for predicting rainfall in North Central Nigeria. The ability to identify precipitation trends and predict future values holds significant importance for both industrial and individual purposes. Therefore, this research aims to bridge existing gaps in the literature and contribute to the utilization of time series analysis for precipitation in North Central Nigeria. The study delves into monthly precipitation characteristics and trends, with a focus on forecasting based on data spanning from 1981 to 2020 from four North Central Nigerian states.

II. STUDY AREA

The research area is North Central Nigeria, it comprises of the seven states situated physically in the center belt region of the country, ranging from the west, near the confluence of the River Niger and the River Benue. The region itself is rich in natural land features, and boasts some of Nigeria's most fascinating scenery. The study focuses on four states, which are, Niger, Plateau Makurdi and Kwara State (Figure 1.).

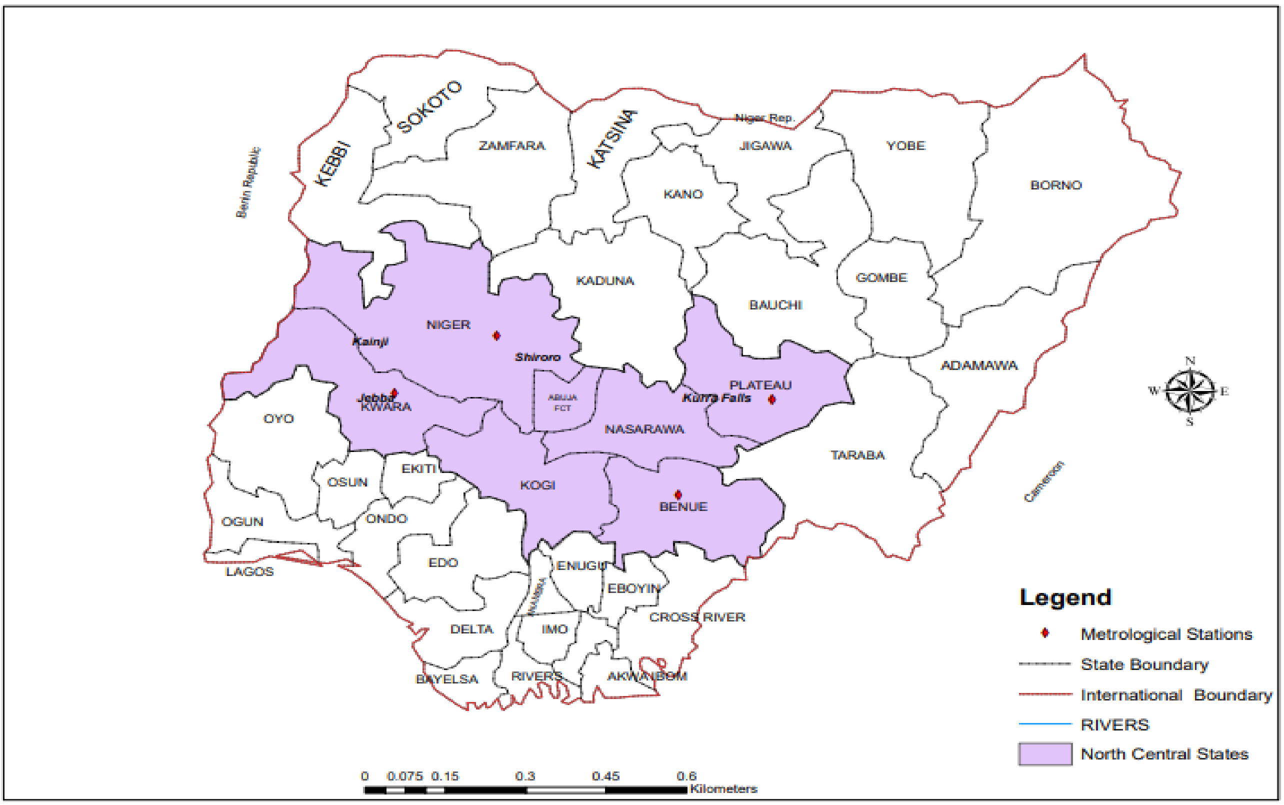

Fig 1 Location of Selected States in North Central Nigeria

III. MATERIALS AND METHODS

A. Materials

In this study, we utilized monthly rainfall data (measured in millimeters) obtained from the Nigerian Meteorological Agency. The data encompassed a 40-year period, spanning from 1981 to 2020, and was sourced from four synoptic stations situated in the northern central regions of Nigeria. To ensure the completeness and accuracy of our dataset, we conducted interpolation and averaging procedures to address any missing data points. The stations included in our analysis were Minna, Jos, Makurdi, and Ilorin.

B. Method

In our analysis, we employed two statistical software packages: Microsoft Excel and the Statistical Package for Social Sciences (SPSS). These tools allowed us to conduct a comprehensive statistical examination of the data. We applied various statistical measures to gain insights into the dataset, including measures of central tendency such as mean, mean deviation, and median. Additionally, we explored measures of data dispersion, such as range, variance, and standard deviation. Furthermore, we assessed the relationship within the data using the coefficient of variance, providing a comprehensive understanding of its characteristics.

$$\text{Mean} = \frac{\sum_{i=1}^{n} xi}{n} \quad (1)$$

$$\text{Variance} = \frac{\Sigma(x-x)^2}{n-1} \quad (2)$$

$$\text{Coefficient of Variation (CV)} = \frac{SD}{\bar{X}} \; X\ 100 \quad (3)$$

$$\text{where: SD is standard deviation} = \sqrt{\frac{\Sigma(x-x)^2}{n-1}} \quad (4)$$

IV. RESULTS AND DISCUSSION

A. Statistics of Rainfall Summaries in the Study Area by Stations

Table 1 presents the results of our comprehensive statistical analysis summarizing rainfall data for various stations over the 1981-2020 period. Notably, Jos recorded the highest mean annual rainfall total during this period, with a sum of 1263.2mm. Minna and Ilorin closely followed with 1206.5mm and 1198.1mm, respectively, reflecting substantial precipitation levels. In contrast, Makurdi reported the lowest annual rainfall, amounting to only 419.0mm. The table underscores the significant variations in precipitation across the North Central states, highlighting Jos as the region with the highest monthly rainfall over the 40-year duration. Additionally, the table reveals instances where all stations experienced months without any recorded precipitation. The relatively low standard deviation suggests that precipitation measurements are relatively close to their respective means. Furthermore, the skewness values indicate a slight positive skew in the data for each station, but this skewness does not significantly impact the overall normalcy of the data due to its relatively small magnitude.

Table 1 Statistics Summaries of Mean Annual Rainfall by State From 1981-2020

STATE	No. of YEARS	SUM	MEAN	MEDIAN	MIN	MAX	RANGE	VAR	SD	KUR	SKE	C.V%
ILORIN	40	62442.0	1113.5	1144.1	213.1	1407.7	1194.6	40493.5	201.2	8.8	-2.2	40
JOS	40	59077.9	1263.2	1246.6	814.7	1646.2	831.5	23948.4	154.8	1.8	-0.3	34
MINNA	40	53225.2	1206.5	1215.3	823.4	1582.9	759.5	28180.4	167.9	0.4	-0.3	31
MAKURDI	40	50751.3	994.1	978.4	584.0	1566.2	982.2	32220.4	179.5	3.3	1.1	22

The skewness values provided valuable insights into the rainfall distribution patterns across the stations. Specifically, Makurdi exhibited negative skewness, suggesting a tendency toward below-average rainfall distribution. In contrast, the other stations displayed positive skewness, indicating a trend of above-average rainfall distribution. The coefficient of variance further illustrated the variability in rainfall within the studied period. Jos station had the highest rainfall variability, with a 38% variation over the years, followed by Ilorin and Minna, both with values of 29% and 30%, respectively. Makurdi recorded the lowest variation among the stations, with a coefficient of variance of 12%. The time series plots in Figures 2 to 5 depicted the precipitation patterns across all stations, revealing a comparable trend in both high and low-altitude areas over the years. These plots also indicated a positively skewed distribution, suggesting a propensity for above-average rainfall distribution. Additionally, the kurtosis values showed negative values, implying flatter peak distributions compared to the normal distribution. However, in some years, the kurtosis values were even more negative, indicating flatter peak distributions relative to the average during those specific years of consideration.

B. Rainfall Distribution Trend

➢ *Mean Annual Rainfall Distribution*

The mean annual rainfall distribution across the research area varied from 660mm to 1298mm over the 40-year study period. Throughout this period, there were noticeable fluctuations, both upward and downward. Notably, there were significant upward trends in mean annual rainfall observed in Minna (as depicted in Figure 2), Jos (as shown in Figure 3), and Ilorin (illustrated in Figure 4). Conversely, there was a declining trend in mean annual rainfall in Makurdi, with a subsequent steady increase beginning around 1999, as illustrated in Figure 5. These fluctuations in mean annual rainfall emphasize the dynamic nature of precipitation patterns in the study area over the four decades of analysis.

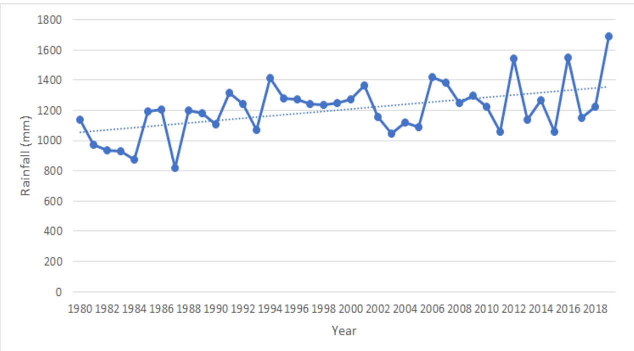

Fig 2 Mean Annual Rainfall of Minna

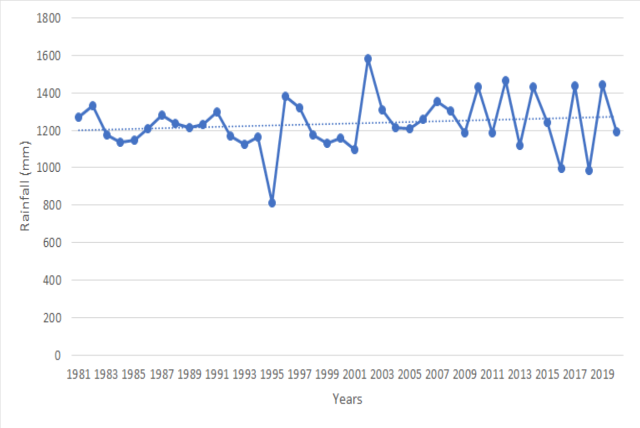

Fig 3 Mean Annual Rainfall of Jos

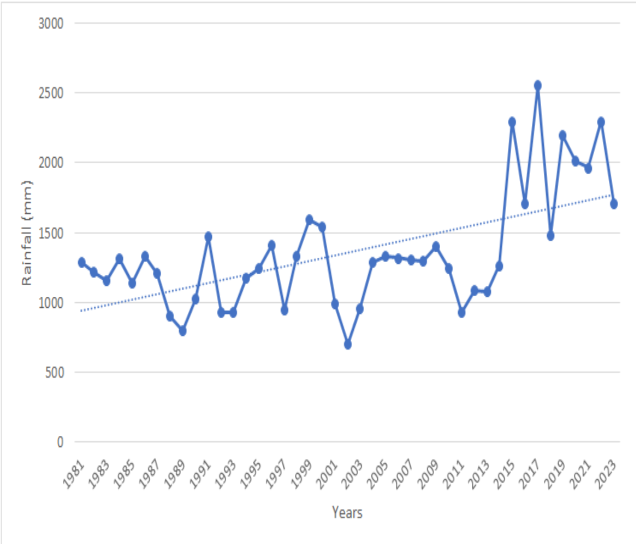

Fig 4 Mean Annual Rainfall of Ilorin

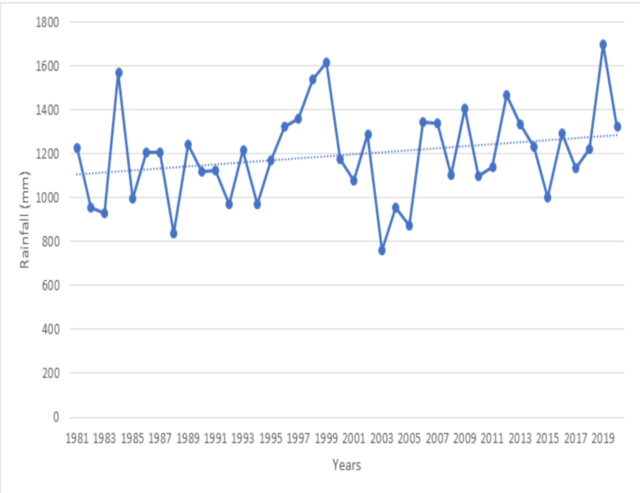

Fig 5 Mean Annual Rainfall of Makurdi

V. CONCLUSIONS

This study offers valuable insights into the diverse patterns and variations in rainfall across the study area. The data highlights that Makurdi consistently had the lowest mean annual rainfall throughout the years, while Jos recorded the highest mean annual rainfall, with a relatively low coefficient of variation at 13%. In contrast, Ilorin exhibited the highest rainfall variation of 40%, followed by Minna with 34%. Notably, the study area experienced an overall increase in rainfall over time. Further research endeavors should delve into a more comprehensive analysis, considering both rainfall and temperature data based on the climatic zones within the northern region. This approach would provide a more holistic understanding of climate dynamics and trends in the area.

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