International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 264-270 www.ijaem.net ISSN: 2395-5252

Climatological Assessment of Rainfall Deviations for Sustainable Water Resources Management in the Anambra-Imo River Basin, Nigeria

Nwabugwu Ikenna Chukwudi

Date of Submission: 01-08-2025 Date of Acceptance: 10-08-2025

ABSTRACT
This study analyzes annual rainfall variability in the Anambra-Imo River Basin, southeastern Nigeria, over a 30-year period (1990–2019), using baseline deviation and moving average techniques to assess hydrological patterns. A climatological baseline of 2407.76 mm was derived as the long-term Average Annual Rainfall (AAR), serving as a benchmark for evaluating inter-annual rainfall deviations. Annual totals were classified as either "Excess Rainfall" (positive deviation) or "Insufficient Rainfall" (negative deviation). To highlight long-term trends and reduce inter-annual fluctuations, a 5-year centered moving average was applied. Results reveal significant inter-annual variability, with years of both pronounced excess and significant deficit, indicating climatic volatility in the basin. The study provides critical insights for regional water resource management, agricultural planning, and climate adaptation strategies, emphasizing the importance of localized climate data in river basin management.

Keywords: Rainfall variability, Anambra-Imo River Basin, baseline deviation, 5-year moving average, water resources management, climate adaptation, southeastern Nigeria.

I. INTRODUCTION

Rainfall variability remains one of the most pressing hydrological and environmental challenges in sub-Saharan Africa, particularly within river basin regions where agriculture, water supply, and energy production rely heavily on predictable precipitation patterns. In Nigeria, approximately 70% of rural livelihoods depend on rain-fed agriculture, making rainfall fluctuations a significant concern for food security, water resource planning, and sustainable development.

Recent climatic irregularities, such as delayed onset of rainfall, shortened rainy seasons, and intensified rainfall events, have disrupted agricultural calendars, increased flood risk, and challenged regional adaptation strategies. In southeastern Nigeria, the Anambra-Imo River Basin represents a hydrologically sensitive area that supports agriculture, domestic water supply, and infrastructure development across several densely populated communities. However, increased rainfall variability, limited drainage infrastructure, urban encroachment, and inadequate watershed management exacerbate the region's vulnerability.

While previous national-scale studies have highlighted rising trends of extreme weather events across Nigeria, localized rainfall analyses within specific basins like the Anambra-Imo remain scarce. Inconsistencies in rainfall records across the basin, largely due to fragmented monitoring systems, further limit effective climate impact assessment.

Although global institutions recommend the application of statistical techniques like baseline deviation analysis and moving averages in climate studies, such approaches remain underutilized in Nigeria's river basins.

Therefore, this study aims to fill this critical gap by statistically analyzing 30 years of rainfall data in the Anambra-Imo River Basin. By applying baseline deviation classification and 5-year moving averages, the study identifies hydrological trends and inter-annual variability to support adaptive management strategies for water resources and agriculture in southeastern Nigeria.

II. MATERIALS AND METHODS

This study utilized a quantitative approach based on long-term rainfall records for the

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 264-270 www.ijaem.net ISSN: 2395-5252

Anambra-Imo River Basin between 1990 and 2019. Annual rainfall data were obtained from the Nigerian Meteorological Agency (NIMET) and validated with existing hydrological reports from the Federal Ministry of Water Resources. The analysis was performed in three phases:

1. Baseline Deviation Analysis:

The Average Annual Rainfall (AAR) of 2407.763 mm was computed as the climatological mean over the 30-year period. Each year's rainfall was compared against this baseline to determine deviation. Positive deviations were classified as "Excess Rainfall," while negative deviations were labeled "Insufficient Rainfall."

2. 5-Year Moving Average Computation:

A 5-year centered moving average was applied to the annual rainfall series to smooth short-term fluctuations and highlight decadal trends. This method reduces inter-annual noise and aids in identifying prolonged wet or dry periods.

3. Tabular and Graphical Representation:

Results were presented in tabular form with columns for annual rainfall, deviation from baseline, classification, and moving average. A bar chart and line graph were also developed to visualize rainfall deviations and trends.

III. RESULTS AND DISCUSSION

3.1 Overview of Annual Rainfall Variability (1990–2019)

The rainfall data for the Anambra-Imo River Basin covering a period of 30 years (1990–2019) was obtained from the Nigerian Meteorological Agency (NiMET), Lagos. The dataset was analyzed to evaluate key hydrological indicators, including Annual Rainfall (mm), Average Annual Rainfall (AAR), Deviation from AAR, Squared Deviation, Standard Deviation, Classification, and the 5-Year Moving Average.

These metrics provide a comprehensive understanding of the rainfall variability and long-term trends within the basin, which are crucial for water resource planning and climate adaptation strategies. The result of the analysis is presented in Table 1 below.

The analysis of 30 years of rainfall data from the Anambra-Imo River Basin revealed notable fluctuations in annual precipitation. The mean annual rainfall during the study period was approximately 2407.76 mm, which was adopted as the baseline Average Annual Rainfall (AAR). The standard deviation of annual rainfall was estimated to be around 305 mm, indicating moderate inter-annual variability.

These variations align with observed rainfall inconsistencies in Nigeria's southern basins. Such irregularities can disrupt agricultural scheduling, affect reservoir recharge, and increase the risk of flood or drought conditions.

Table 1: Total Annual Rainfall and Deviation Analysis in Anambra -Imo River Basin 1990 to 2019

Year	Annual Rainfall (mm)	Deviation from (Mean AAR) (mm)	(Deviation)² (mm²)	Classification	5-Year Moving Avg (mm)
1990	2861.3	453.54	205,698.53	Excess Rainfall	
1991	2667.4	259.64	67,412.93	Excess Rainfall	
1992	2494.1	86.34	7,454.60	Excess Rainfall	2586.36
1993	2282.8	-124.96	15,615.00	Insufficient Rainfall	2538.56
1994	2626.2	218.44	47,716.03	Excess Rainfall	2566.18
1995	2622.3	214.54	46,027.41	Excess Rainfall	2645.64
1996	2805.5	397.74	158,197.11	Excess Rainfall	2528.1
1997	2891.4	483.64	233,907.65	Excess Rainfall	2519.94
1998	1695.1	-712.66	507,884.28	Insufficient Rainfall	2462.92
1999	2585.4	177.64	31,555.97	Excess Rainfall	2362.68
2000	2337.2	-70.56	4,979.91	Insufficient Rainfall	2255.14
2001	2304.3	-103.46	10,705.97	Insufficient	2441.68

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 264-270 www.ijaem.net ISSN: 2395-5252

				Rainfall	
2002	2353.7	-54.06	2,923.03	Insufficient Rainfall	2277.06
2003	2627.8	220.04	48,417.60	Excess Rainfall	2260.94
2004	1762.3	-645.46	416,616.71	Insufficient Rainfall	2279.5
2005	2256.6	-151.16	22,838.35	Insufficient Rainfall	2281.08
2006	2397.1	-10.66	113.63	Insufficient Rainfall	2305.16
2007	2361.6	-46.16	2,130.39	Insufficient Rainfall	2551.86
2008	2748.2	340.44	115,899.39	Excess Rainfall	2529.72
2009	2995.8	588.04	345,797.06	Excess Rainfall	2521.8
2010	2145.9	-261.86	68,572.66	Insufficient Rainfall	2508.7
2011	2357.5	-50.26	2,526.02	Insufficient Rainfall	2399.74
2012	2296.1	-111.66	12,470.36	Insufficient Rainfall	2198.56
2013	2203.4	-204.36	41,761.01	Insufficient Rainfall	2120.12
2014	1989.9	-417.86	174,612.38	Insufficient Rainfall	2123.56
2015	1753.7	-654.06	427,794.48	Insufficient Rainfall	2167.56
2016	2374.7	-33.06	1,093.00	Insufficient Rainfall	2234.1
2017	2516.1	108.34	11,738.56	Excess Rainfall	2312.8
2018	2536.1	128.34	16,470.36	Excess Rainfall	
2019	2383.4	-24.36	593.41	Insufficient Rainfall	
Total			2,689,790.8		

Discussion Resultsin Table 1:

i. Table 1 presents a detailed summary of annual rainfall in the Anambra-Imo River Basin from 1990 to 2019, benchmarked against the long-term Average Annual Rainfall (AAR) of 2407.76 mm.

ii. The table includes annual rainfall, deviation from the AAR, squared deviations (used for calculating variance and standard deviation), and the classification of each year as either "Excess Rainfall" or "Insufficient Rainfall" based on whether the deviation is positive or negative.

iii. The rainfall data reveals significant inter-annual variability, with values ranging from a low of 1695.1 mm in 1998 (−712.66 mm deviation) to a high of 2995.8 mm in 2009 (+588.04 mm deviation). This wide range emphasizes the climatic volatility of the region, which has been widely observed in similar regional climate patterns.

iv. Of the 30 years analyzed: 17 years were classified as Excess Rainfall, including 1990, 1997, 2009, and 2018. 13 years were classified as Insufficient Rainfall, including 1998, 2004, and 2015 — all of which may have posed serious drought risks.Significant excess years (1997, 2009) likely linked to flood risks.

v. The squared deviations offer insight into the level of dispersion around the mean. Years such as 1998 and 2015 had the highest squared deviations (507,884.28 mm^2 and 427,794.48 mm^2 respectively), indicating they contributed most to the calculated standard deviation of 304.51 mm.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 264-270 www.ijaem.net ISSN: 2395-5252

vi. These deviations suggest non-random climatic shifts, possibly linked to regional climate drivers like ENSO (El Niño–Southern Oscillation), land use changes, and other environmental disturbances.
vii. High-rainfall years, as shown in the table, could increase the risk of flooding and erosion, while successive low-rainfall years, such as 2013 to 2015, could negatively impact crop yields, reservoir levels, and water supply security.
viii. This classification system provides a practical tool for water resource managers, planners, and policymakers, enabling them to prepare for water surpluses or deficits based on historical rainfall trends.
ix. The use of this method supports the implementation of climate-informed strategies in multi-purpose river basin management, including irrigation scheduling, dam operations, erosion control, and emergency response planning.

3.2 Deviation from Baseline and Classification

This figure shows the annual deviations of observed rainfall values from the long-term Average Annual Rainfall (AAR) of 2407.763 mm. Positive values represent years of excess rainfall, while negative values represent years of insufficient rainfall. The visualization helps identify years with significant hydrological anomalies, supporting the classification and trend analysis discussed in the subsequent section.

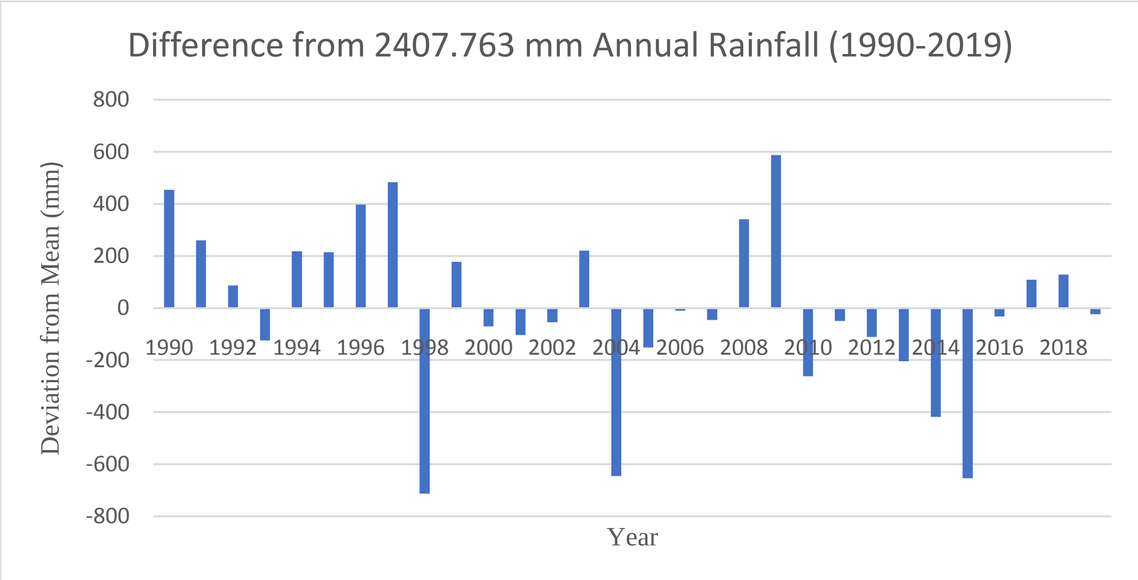

Figure 1. Rainfall Deviation from Baseline (AAR) (1990 – 2019)

Discussion of Results in Figure 1: Rainfall Deviation from AAR (1990–2019)

1. Figure 1 displays annual deviations from the long-term Average Annual Rainfall (AAR) of 2407.763 mm in the Anambra-Imo River Basin. Positive deviations indicate Excess Rainfall years, while negative deviations denote Insufficient Rainfall years.
2. Each year's rainfall was compared against this baseline. The analysis classified:
i. 17 years as Excess Rainfall
ii. 13 years as Insufficient Rainfall
3. Significant positive deviations were observed in:
i. 1990 (+453.54 mm)
ii. 1997 (+483.64 mm)
iii. 2009 (+588.04 mm), which was the highest positive deviation and a likely flood-prone year.
4. Severe negative deviations occurred in:
i. 1998 (−712.66 mm)
ii. 2004 (−645.46 mm)
iii. 2015 (−654.06 mm), making these years notably dry and potentially drought-affected.
5. The alternation between excess and deficit years shows a highly volatile rainfall pattern, reflecting irregular hydrological behavior likely influenced by regional climate variability.
6. This pattern of variability is consistent with the findings of Olaniran and Sumner [11], who

identified irregular rainfall onset and cessation dates across Nigeria.

7. Figure 1 also provides a practical visual tool for basin managers to pinpoint critical years that may require strategic interventions such as:
   i. Flood risk control in excess years
   ii. Water conservation and irrigation planning in deficit years
8. The classification of rainfall into "Excess" and "Insufficient" categories, as shown in the figure, offers a strategic guide for resource planning. It highlights the need for preparedness across sectors like agriculture, hydropower, water supply, and infrastructure.
9. This variability reinforces the necessity for climate-resilient infrastructure and flexible water policies, highlighting the importance of region-specific climate adaptation strategies in Nigeria's river basins.

3.3 Five (5)-Year Moving Average Trend

The five-year moving average of annual rainfall in the Anambra-Imo River Basin over the 30-year period is presented in Figure 2 below. This smoothed trend line is plotted alongside the actual annual rainfall values to highlight long-term variations and cyclical patterns. The moving average technique reduces the influence of short-term fluctuations and helps to reveal periods of gradual increase or decline in rainfall, which are critical for long-term water resource planning and climate impact assessment.

This method of trend detection aligns with established hydrological modeling standards and has proven effective in previous basin analyses.

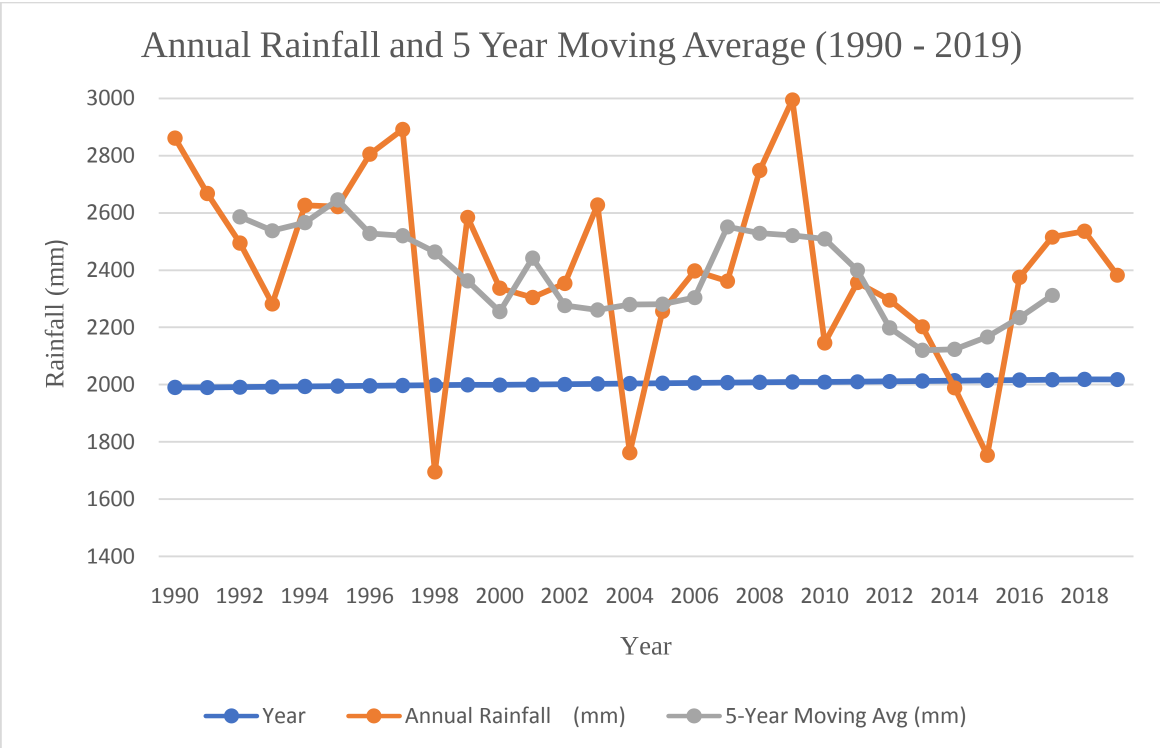

Figure 2: Five-Year Moving Average Trend of Annual Rainfall in the Anambra-Imo River Basin (1990–2019)

Discussion of Results in Figure 2: 5-Year Moving Average Trend (1990–2019)

1. The 5-year moving average smooths out annual fluctuations and highlights decadal rainfall patterns across the basin.
2. An upward trend is observed between 1995 and 2005, suggesting a period of generally higher rainfall.
3. A dip appears around 2004–2006, indicating possible consecutive years of rainfall reduction, reflected in the classified insufficient years.
4. After peaking around 2009–2010, a mild decline was observed in the moving average trend toward 2015.
5. **5.** This long-term trend is vital for forecasting and planning reservoir operations, irrigation

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 264-270 www.ijaem.net ISSN: 2395-5252

scheduling, and early warning systems in the river basin.

3.4 Rainfall Classification Summary

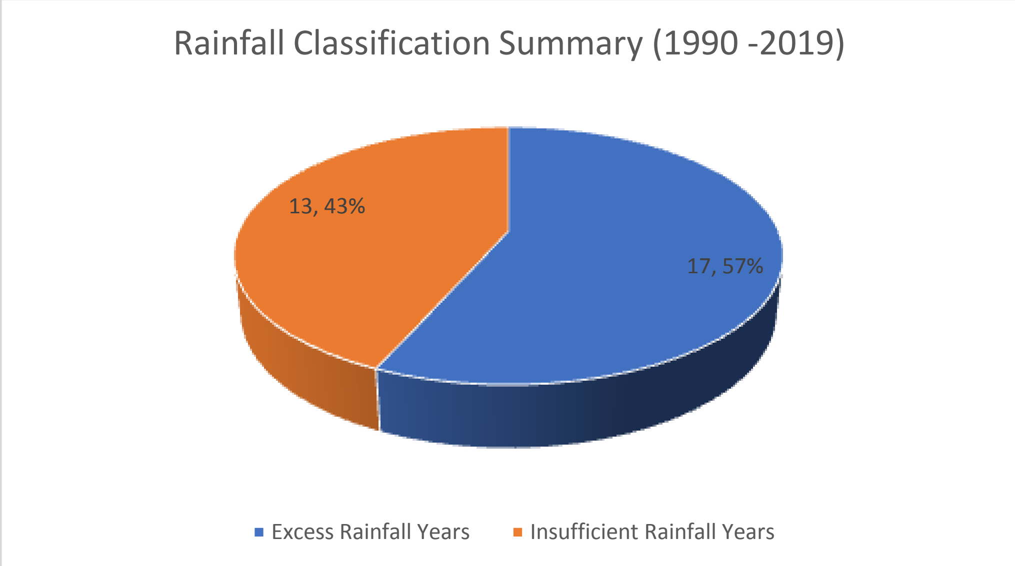

Figure 3: Rainfall Classification Summary (1990–2019)

Discussion of Figure 3

1. Figure 3 summarizes the distribution of rainfall years classified as either Excess Rainfall or Insufficient Rainfall based on deviation from the Average Annual Rainfall (AAR) baseline of 2407.76 mm.
2. Out of the 30 years analyzed, 17 years (57%) experienced Excess Rainfall, while 13 years (43%) experienced Insufficient Rainfall.
3. The chart reveals that wet years slightly outnumber dry years, indicating a marginal tendency toward above-average rainfall within the basin over the long term.
4. This distribution underscores the irregular and unstable nature of rainfall in the basin, where nearly half of the years were characterized by below-average rainfall.
5. The summarized classification reinforces the necessity for adaptive water resource planning that considers both potential surpluses and deficits, supporting proactive measures in flood control and drought mitigation across southeastern Nigeria.

3.4 Implications for River Basin Planning

The classification of rainfall into "Excess" and "Insufficient" categories provides a useful reference for basin management decisions. In years of excess rainfall, infrastructure such as dams, culverts, and irrigation channels must be prepared for overflow risks, while deficit years may necessitate rationing and aquifer recharge planning.

This variability emphasizes the need for climate-resilient infrastructure and adaptable water policies in the Anambra-Imo River Basin, highlighting the importance of region-specific climate adaptation frameworks.

IV. CONCLUSION

This study analyzed 30 years of annual rainfall records (1990–2019) for the Anambra-Imo River Basin, identifying significant inter-annual variability and hydrological anomalies. Using the computed long-term Average Annual Rainfall (AAR) of 2407.76 mm as a baseline, annual rainfall was classified into “Excess Rainfall” or “Insufficient Rainfall” years based on deviation from this benchmark. The application of a 5-year moving average further revealed underlying trends that are otherwise obscured by short-term fluctuations.

The analysis identified 17 years of Excess Rainfall and 13 years of Insufficient Rainfall, highlighting a highly variable rainfall regime, with notable dry years like 1998, 2004, and 2015 presenting potential drought risks, and wet years such as 2009 posing flood hazards. These findings underscore the importance of incorporating localized climate variability assessments into river basin management strategies.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 264-270 www.ijaem.net ISSN: 2395-5252

The study recommends:

i. Development of adaptive water resource planning frameworks.
ii. Implementation of early warning systems for drought and flood management.
iii. Strengthening of hydrological monitoring networks within the basin.

Overall, the study provides vital evidence to guide sustainable management of the Anambra-Imo River Basin and can inform climate adaptation policy for southeastern Nigeria.

REFERENCES

[1]. A. O. Odjugo, "General Overview of Climate Change Impacts in Nigeria," Journal of Human Ecology, Vol. 29, Issue 1, 2010, pp. 47–55. ResearchGate

[2]. S. Olaniran and G. Sumner, "Rainfall Variability in Nigeria," Theoretical and Applied Climatology, Vol. 50, Issue 1, 1994, pp. 33–44. ResearchGate

[3]. J. O. Ayoade, Introduction to AgroClimatology, University Press PLC, Ibadan, 2008. ResearchGate

[4]. F. C. Okorie, "Analysis of 30 Years Rainfall Variability in Imo State, Southeastern Nigeria," in Proc. International Assoc. of Hydrological Sciences, Vol. 366, 2015, pp. 131–136. PMC+2DergiPark+2Taylor & Francis Online+2

[5]. "Annual Rainfall Data Records (1990–2019)," Nigerian Meteorological Agency (NiMet), Lagos, 2020. Taylor & Francis Online

[6]. "Hydrological Year Book of Nigeria: 2019 Edition," Federal Ministry of Water Resources, Abuja, 2019.

[7]. C. Kolawole Ibe et al., "Projected Near-Future Changes in Precipitation Extremes over Anambra-Imo River Basin Inferred from CMIP6 HighResMIP," Discover Atmosphere, Vol. 2, Article 8, 2024, pp. 1–19. ResearchGate+3SpringerLink+3ResearchGate+3

[8]. A. N. Ezemerihe, "Hypothetical Assessment of Climate Variability Performance in Anambra-Imo River Basin Using Pearson's Correlation Analysis," PM World Journal, Vol. XIII, Issue VII, July 2024, pp. 1–14. Taylor & Francis Online+7pmworldlibrary.net+7PM World Journal+7

[9]. I. K. Itam, E. D. Uwah& C. Nwofoke, "Effects of Climate Variability on Forest Ecosystems in Taraba State, Nigeria," ResearchGate, January 2019. ResearchGate

[10]. I. Isagba et al., "Estimation of Stream Discharge of Ungauged Basins Using NRCS-CN and Remote Sensing Methods: A Case Study of Edo State, Nigeria," Int. J. Water Res. & Environ. Eng., Vol. 13, Issue 3, 2021, pp. 165–183. ResearchGate+1academicjournals.org+1

[11]. G. T. Amangabara, "Drainage Morphology of Imo Basin in the Anambra-Imo River Basin Area, Southeastern Nigeria," J. Geography, Environment and Earth Science International, Vol. 3, Issue 1, 2015, pp. 1–11. DergiPark