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Research Article

Rainfall Dynamics and Climate Shift in Tropical “Af” Zones: A Comparative Study of Nigeria and Sri Lanka (1981– 2014)

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Abstract

This study presents a comparative climatological analysis of rainfall characteristics and trends within the Köppen “Af” (tropical rainforest) climatic zone, focusing on Akwa Ibom State, Nigeria, and the Western Province of Sri Lanka from 1981 to 2014. While both regions share the “Af” classification, they are governed by distinct oceanic and atmospheric systems: the Atlantic Ocean and West African Monsoon for Nigeria, and the Indian Ocean and South Asian Monsoon for Sri Lanka. Utilizing descriptive and inferential statistical methods, the research identifies significant divergences in seasonal patterns and variability. Findings reveal that Uyo (Nigeria) exhibits a monomodal rainfall peak in July, whereas Gampaha (Sri Lanka) displays a bi-modal distribution with peaks in April/May and October. Uyo recorded a higher annual mean rainfall (2506.9 mm) and greater variability (SD = 58.48) compared to Gampaha (2096.3 mm, SD = 32.98), suggesting a more erratic and extreme hydro-climatic regime in the West African station. A weak positive correlation ($r = 0.0428$) indicates that despite sharing a climatic classification, the rainfall drivers in these regions operate independently. The study highlights a notable shift toward more intense and unpredictable rainfall events in the latter part of the study period (2010–2014), particularly in Uyo. These results underscore the necessity for localized adaptation strategies in water resource management, agriculture, and urban planning to mitigate the risks of flash flooding and seasonal shifts.

Keywords: Climatology, Rainfall Variability, Köppen “Af” Climate, Climate Shift, Uyo Nigeria, Gampaha Sri Lanka, Tropical Rainforest.

Introduction

Climatology, the scientific study of atmospheric behavior over extended periods, provides the statistical framework necessary to understand the aggregate weather patterns that define a region's environment [1]. Traditionally, a period of 30 years is required to establish a climatic baseline, though 20 years is often considered sufficient for theoretical trend analysis [2]. In the contemporary era, the impacts of climate are no longer merely academic; they dictate the rhythm of human life, influencing everything from agricul-

tural calendars and architectural designs to socio-economic stability and disaster preparedness [3].

Rainfall, as a primary climatic element, is particularly sensitive to global warming and atmospheric circulation changes. While global trends provide a broad overview, localized variations at the national and sub-national levels are critical for effective policy planning [4]. In the tropical “Af” zones—characterized by high temperatures and year-round humidity—even minor shifts in rainfall onset or

intensity can lead to significant ecological and human consequences. Recent studies have highlighted that rainfall in both West Africa and South Asia is becoming increasingly erratic, with a higher frequency of extreme events such as flash floods and prolonged dry spells [5-6].

Sri Lanka's climate is largely governed by the Indian Ocean monsoon system, which facilitates a systematic migration of rainfall across the island throughout the year [7]. Conversely, Nigeria's rainfall is driven by the interplay between the Tropical Maritime (mT) air mass and the Tropical Continental (cT) air mass, mediated by the Intertropical Convergence Zone (ITCZ) [8].

Despite these different drivers, both Uyo (Nigeria) and Gampaha (Sri Lanka) fall under the Köppen "Af" classification, sharing similar temperature profiles and high annual precipitation.

However, comparative studies across different continents within the same climatic zone remain scarce in the literature. This research seeks to bridge this gap by comparing the rainfall characteristics of Uyo and Gampaha. By analyzing 34 years of data (1981–2014), this study aims to determine the extent of rainfall variability, identify potential climate shifts, and provide a basis for intercontinental knowledge sharing on climate adaptation.

The Study Areas

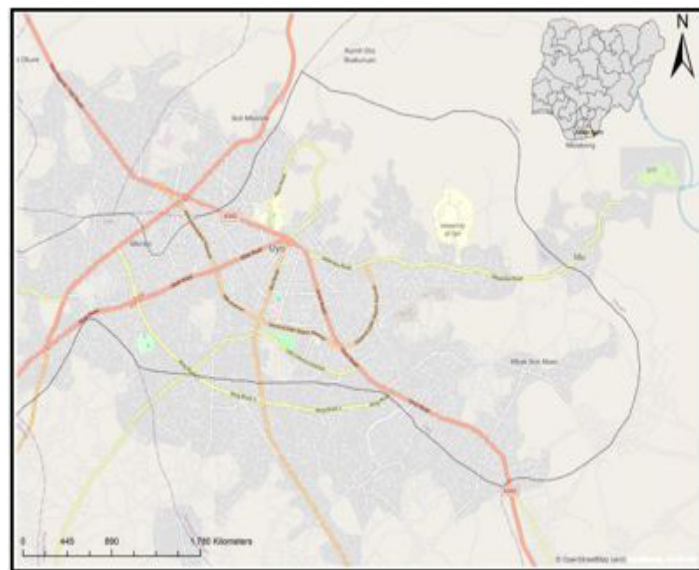


Figure1a: Nigeria showing Uyo the study area

Materials and Methods

Rainfall data for this study were sourced from the Central Bank of Nigeria (Monthly Rainfall Statistics) and the Sri Lankan Meteorological Agency (Gampaha District Station). The dataset spans 34 years (1981–2014), providing a robust baseline for climatological analysis.

Western Province, Sri Lanka (Gampaha)

The Western Province of Sri Lanka is situated between latitudes 6°04' N to 6°92' N and longitudes 79°65' E to 80°42' E. It is bounded by the Indian Ocean to the west and serves as the economic heart of the nation, housing the capital city, Colombo. The topography rises from coastal lowlands to central highlands, with a mean altitude of approximately 500m above sea level. The region is a hub for international trade, manufacturing, and higher education, making it highly sensitive to hydro-meteorological disruptions.

Akwabom State, Nigeria (Uyo)

Akwa Ibom State is located in Nigeria's South-South geopolitical zone, between latitudes 4°32' N to 5°33' N and longitudes 7°25' E to 8°25' E. Bounded by the Atlantic Ocean to the south, it features a landscape that transitions from mangrove swamps to tropical rainforests. As a major oil-producing state, its economy is a mix of petroleum extraction, agriculture, and fishing. The climate is influenced by the South-West trade winds (moisture-bearing) and the North-East trade winds (dry), resulting in a distinct rainy season from April to October and a shorter dry season.

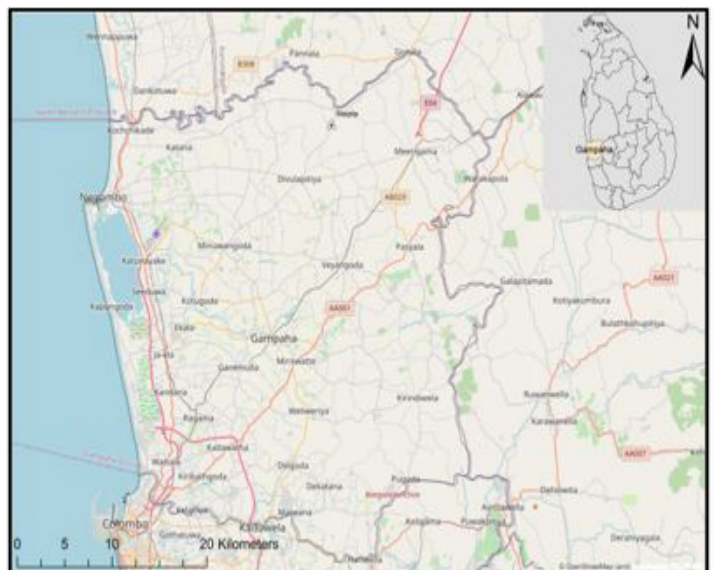


Figure1b: Sri Lanka showing the Gampaha District

Statistical Analysis

The data were homogenized into monthly and annual aggregates. Descriptive statistics, including the mean, standard deviation (SD), and coefficient of variation (CV), were employed to assess rainfall dispersion and reliability.

Rainfall Anomaly: Calculated as the difference between the observed rainfall and the long-term mean (Anomaly = $RF_{observed} - RF_{mean}$).

Inferential Statistics: Pearson Product Moment Correlation was used to test the relationship between the two stations, while the Student's t-test was applied to determine the statistical significance of the difference in mean rainfall.

To further enhance the rigour of the analysis and address potential non-normality in hydrological data, both parametric and non-parametric methods were employed. This approach ensures a comprehensive understanding of rainfall trends and variability.

Parametric Methods

Student's t-test: Used to compare the means of two groups (Uyo and Gampaha annual rainfall) to determine if they are significantly different.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

The formula for the independent samples t-test is:

Where:

$\bar{X}(1)$ and $\bar{X}(2)$ are the sample means.

$s_1(2)$ and $s_2(2)$ are the sample variances.
 n_1 and n_2 are the sample sizes.

Pearson Correlation Coefficient r : Applied to measure the linear relationship between the annual rainfall of Uyo and Gampaha. The formula is:

Where:

- n is the number of observations.
- $\sum xy$ is the sum of the products of the paired observations.
- $\sum x$, $\sum y$, $\sum x^2$, $\sum y^2$ are the sums of the observations and their squares.

Non-Parametric Methods

Mann-Kendall Trend Test: This test is widely used for detecting monotonic trends in hydro-meteorological time series data. It does not require the data to be normally distributed and is less sensitive to outliers. The test statistic S is calculated as:

Where:

x_j and x_k are sequential data values.

$\text{sgn}(x_j - x_k)$ is the sign function, which is 1 if $(x_j - x_k) > 0$, -1 if $(x_j - x_k) < 0$, and 0 if $(x_j - x_k) = 0$.

Sen's Slope Estimator: Often used in conjunction with the Mann-Kendall test to quantify the magnitude of the trend. The slope Q_i between each data pair is calculated as:

The median of these N slope values is Sen's slope estimator. A positive value indicates an increasing trend, while a negative value indicates a decreasing trend.

Results and Discussion

Seasonal Rainfall Characteristics

The analysis reveals two distinct rainfall regimes. Uyo exhibits a monomodal peak in July (391.05mm), followed by high values in August (355.21mm) and September (344.64mm). In contrast, Gampaha displays a bimodal peak characteristic of the South Asian monsoon, with the primary peak in October (372.94mm) and a secondary peak in April/May.

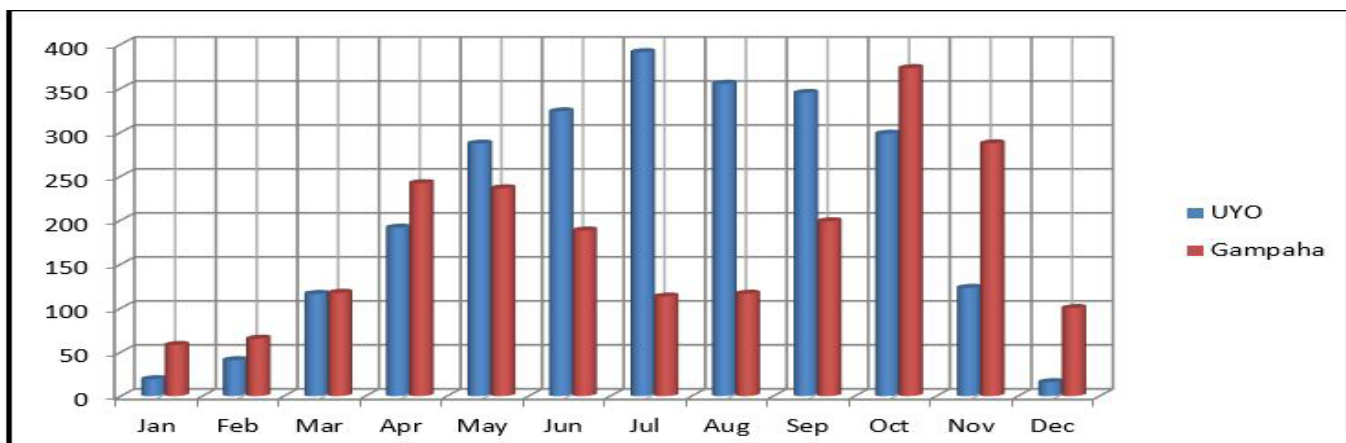


Figure 2: Seasonal Rainfall of the Study Areas. Rainfall Variability and Anomalies

Rainfall Variability and Anomalies

Uyo recorded a higher annual mean rainfall (2506.9mm) compared to Gampaha (2096.3 mm). However, the variability in Uyo is much more pronounced. The standard deviation for Uyo (58.48) is nearly double that of Gampaha (32.98), and the coefficient of variation (CV) for Uyo (27.99%) is significantly higher than Gampaha's (18.88%).

These metrics indicate that Gampaha's rainfall is more reliable and consistent. This can be attributed to its island

geography, where rain-bearing maritime winds are more persistent. In Uyo, the seasonal interplay between the moist Atlantic winds and the dry continental air mass creates a more volatile environment. The rainfall anomaly analysis further confirms this, showing that Uyo experiences more extreme departures from the mean, signaling a higher vulnerability to climate shifts.

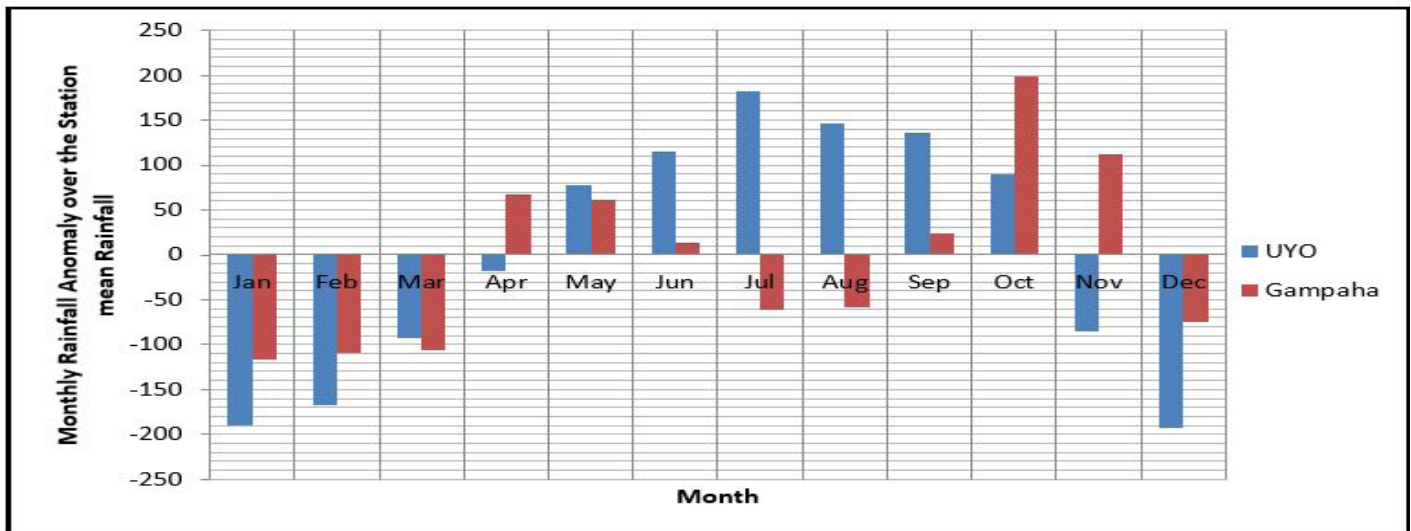


Figure 3: Rainfall Dispersions over the study areas.

Evidence of Climate Shift (2010–2014)

A critical finding of this study is the abrupt increase in annual rainfall in Uyo between 2010 and 2014. During this five-year window, the mean rainfall was 333.54 mm, representing a shift of 124.63 mm above the long-term station mean. This period of “supercharged” rainfall coincides with recent global observations of intensified tropical precipitation due to increased atmospheric moisture capacity in a warming climate [9], [10]. If this trend persists, it would constitute a formal climate change for the region, necessitating a complete overhaul of existing flood management and agricultural strategies.

Comparative Correlation

The Pearson correlation coefficient (r) between the annual rainfall of Uyo and Gampaha was calculated as 0.043 ($p = 0.810$), indicating a very weak and statistically insignificant positive linear relationship. The coefficient of determination (r^2) of approximately 0.18% suggests that the annual rainfall patterns in these two “Af” zones are largely independent. This reinforces the idea that despite sharing a climatic classification, the localized drivers (Atlantic vs.

Indian Ocean systems) are the dominant factors in determining rainfall behaviour. The Student's t -test ($t = 0.0053$) further confirmed that the difference in mean annual rainfall between the two stations is statistically significant.

Linear regression analysis of annual rainfall against year revealed distinct trends for each station. For Uyo, the regression equation is $Y = 3.78X - 7351.15$ with an R-squared value of 0.403 ($p < 0.001$), indicating a statistically significant increasing trend. For Gampaha, the regression equation is $Y = 0.998X - 1818.75$ with an R-squared value of 0.088 ($p = 0.088$), suggesting a weaker, non-significant increasing trend.

A descriptive analysis of the relationship is shown in Figure 4 and Figure 5, the annual rainfall distribution of the two stations.

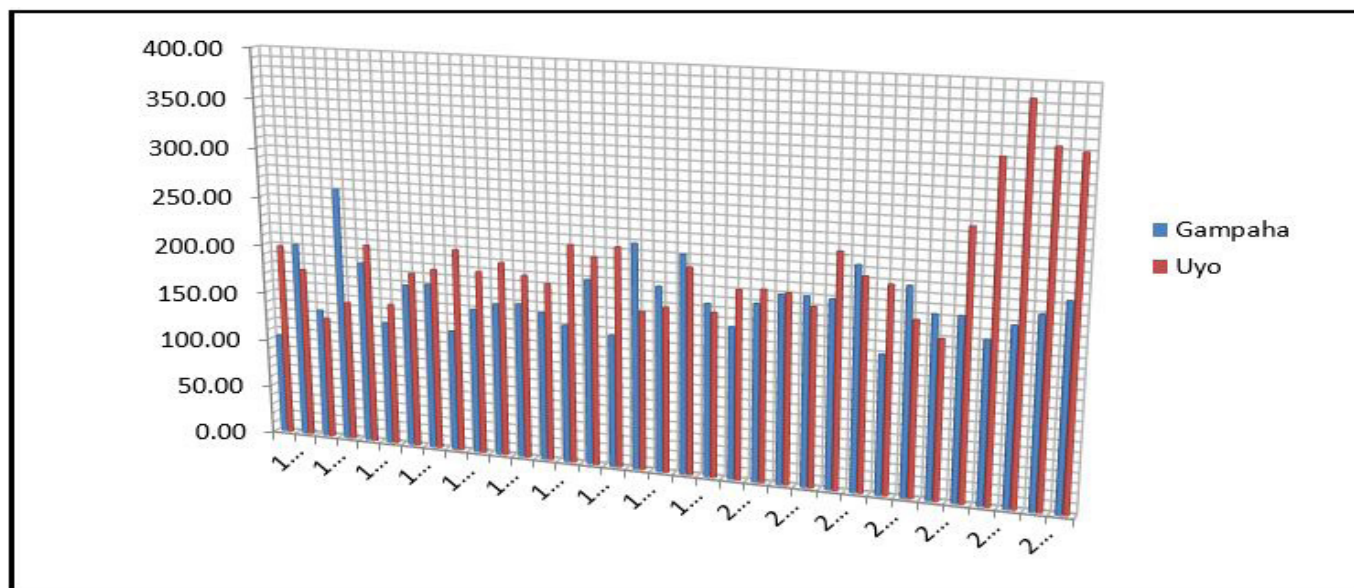


Figure 4: Annual Rainfall of the Study Areas from 1981-2014

The Annual rainfall anomaly was shown in Figure 5. The study of Figure 5 shows that Gampaha recorded positive rainfall distribution for 18 year out of the 34 years of study and 16 years of negative rainfall. This implies that 18 of the study years had rainfall greater than the station mean rainfall. On the other hand Uyo recorded 24 years of negative rainfall that is rainfall below the expected or mean rainfall of the station. The study shows that only 10 year during the study period at Uyo had annual rainfall greater than the station mean rainfall.

The sudden upsurge of rainfall between the years 2010-2014 was responsible for the high skewed rainfall anomaly in Uyo. The study shows that for the first half of the study period, only 3 year in Uyo and positive rainfall. That implies that it was only three years that rainfall occurrence exceeded the mean rainfall of Uyo. In the other half years of the study period, Uyo recorded 7 years of rainfall occurrence above the station mean rainfall. The study indicates a pattern that shows an increase in rainfall distribution over the years in Uyo, Nigeria.

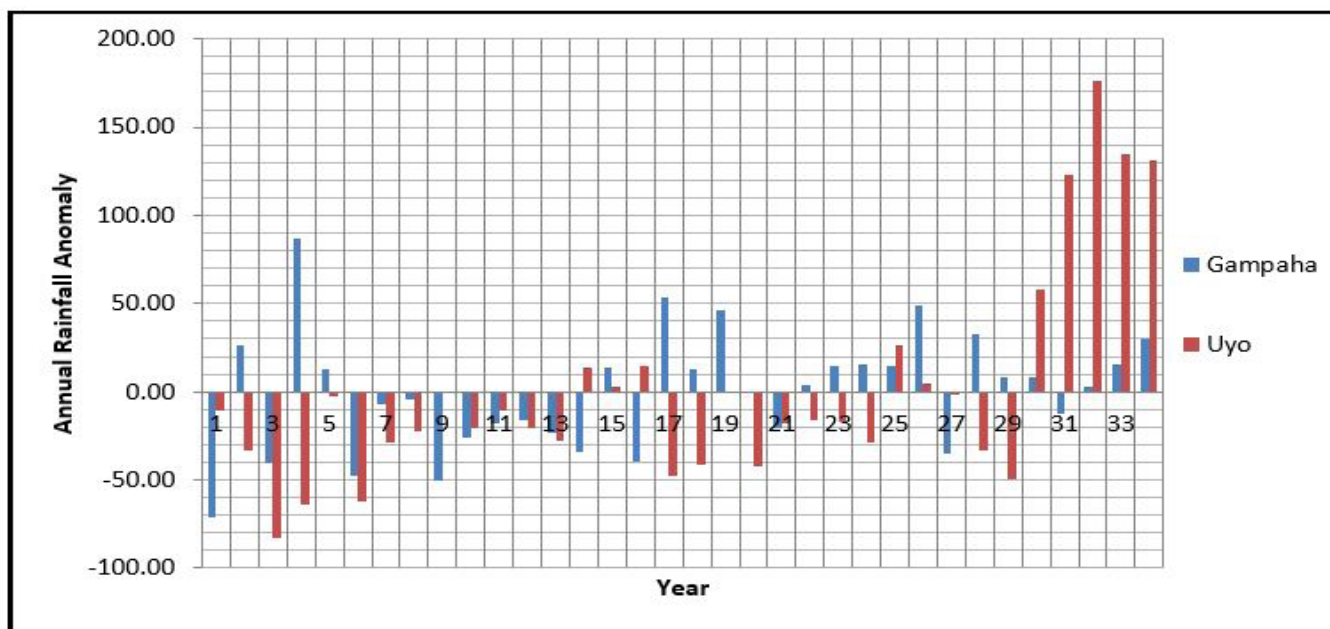


Figure 5: Annual Rainfall Anomaly for the study period (1981-2014)

Trend Analysis (Mann-Kendall and Sen's Slope)

To further investigate the temporal trends in rainfall, the Mann-Kendall test and Sen's slope estimator were applied to the annual rainfall data for both Uyo and Gampaha. The results are summarized in Table 1.

Station	Mann-Kendall S	p-value	Sen's Slope (mm/year)	Trend Significance
Uyo	217.0	0.0014	2.59	Significant ($p < 0.01$)
Gampaha	149.0	0.0282	1.33	Significant ($p < 0.05$)

Table 1: Mann-Kendall Trend Test and Sen's Slope Estimator Results for Annual Rainfall (1981-2014)

These results provide a robust, non-parametric assessment of the presence and magnitude of trends in the rainfall data. For Uyo, the results show a strong, statistically significant increasing trend in annual rainfall. For Gampaha, the trend is also positive and significant, but less pronounced. The visual representation of these trends is provided in Figures 6 and 7.

Annual Rainfall Trends

The long-term annual rainfall trends for both stations were visualized to complement the statistical analysis. Figure 6 and Figure 7 show the annual rainfall data plotted against time, with the linear regression trend line overlaid.

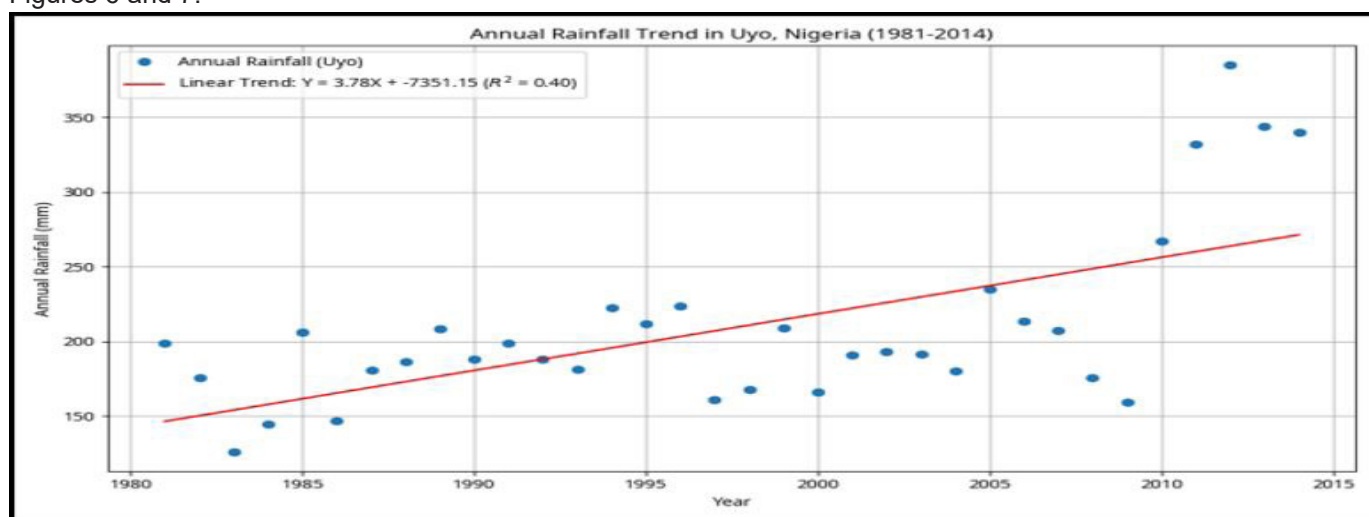


Figure 6: Annual Rainfall Trend in Uyo, Nigeria (1981-2014)

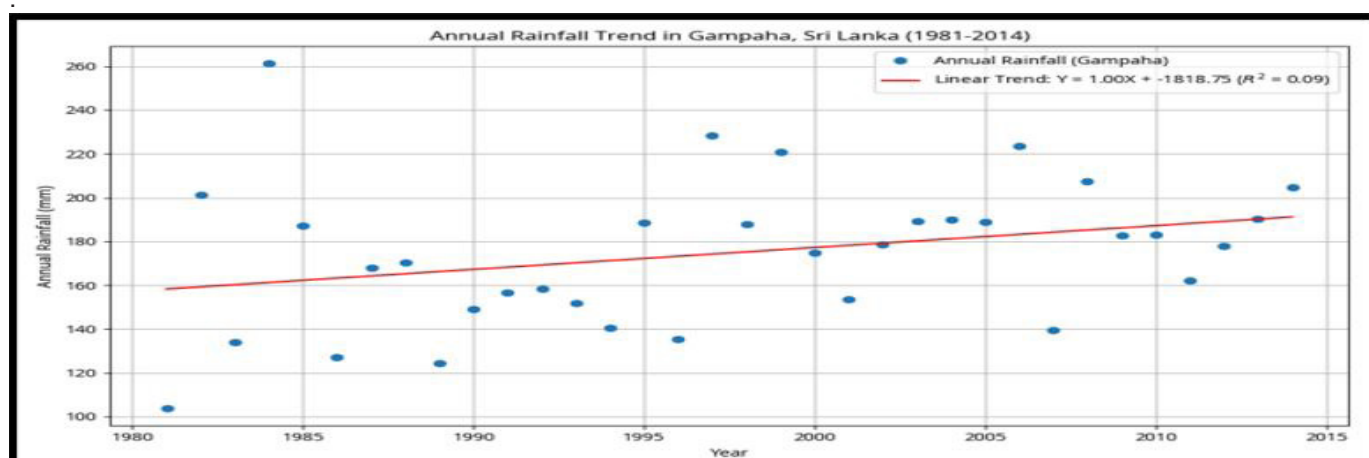


Figure 7: Annual Rainfall Trend in Gampaha, Sri Lanka (1981-2014).

The upward slope of the trend line for Uyo is visually apparent and statistically significant, as confirmed by the regression analysis. The trend for Gampaha is also positive but less pronounced.

Conclusion and Recommendations

This study has demonstrated that while Uyo and Gampaha both reside within the Köppen “Af” zone, their hydro-climatic realities are markedly different. Uyo is wetter and significantly more variable, while Gampaha enjoys a more reliable, bimodal rainfall distribution. The recent upsurge in rainfall intensity in Uyo (2010–2014) serves as a potent indicator of a regional climate shift.

Recommendations:

Infrastructure Resilience: Authorities in Akwa Ibom State must prioritize the development of robust drainage systems and flood-resilient infrastructure to cope with increasing rainfall intensity.

Climate-Smart Agriculture: Farmers in both regions, particularly in Uyo, should be encouraged to adopt flexible planting schedules and crop varieties that can withstand erratic moisture levels.

Integrated Water Management: Gampaha should leverage its more consistent rainfall by improving rainwater harvesting and storage to buffer against potential future dry spells.

Global Monitoring: There is an urgent need for continuous, real-time monitoring of rainfall trends across all “Af” zones to better understand the global mechanics of tropical climate shifts.

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