Decomposition of Monthly Rainfall Series: A Case Study of Ondo State, Nigeria

Alabi, Oluwapelumi; Adeolu, Abel;
Adam, Ganiyu Dada; Kayode Olarewaju Joseph
Department of Mathematics and Statistics, Rufus Giwa Polytechnic Owo,
Ondo State, Nigeria

Abstract
This study analyzes the decomposition of monthly rainfall series in Ondo State, Nigeria, over a 41-year period (1981–2021). Using time series decomposition techniques, the study separates the rainfall data into trend, seasonal, and irregular components to better understand its variability. The results reveal a clear seasonal pattern corresponding to the wet and dry seasons typical of the region. The trend component shows fluctuations without a consistent long-term increase or decrease, suggesting high inter-annual variability. The Holt–Winters exponential smoothing model was applied to assess the model's fit and forecast rainfall for 60 months (2022–2026). Findings indicate that rainfall variability significantly influences agricultural productivity, water resources management, and flood risk mitigation in Ondo State. The study contributes to the growing body of knowledge on climatic variability and supports evidence-based planning for sustainable agricultural and environmental management.

Keywords: Rainfall,TimeSeries,Decomposition, Seasonal Trend, Holt–Winters, Ondo State, Forecasting

1. Introduction

Rainfall is a critical component of the hydrologicalcycle, shaping the environment, supportingagriculture,and influencing socio-economic activities (Ayoade, 2004). In Nigeria, particularly in Ondo State, rainfall plays a significant role in agricultural productivity, water resource management, and economic development (Olaniran, 2002). Understanding rainfall patterns is essential for effective planning, resource allocation, and policy-making in sectors suchas agriculture and disaster management. Timeseriesanalysis enables the identification and decomposition of rainfall variability into its constituent components: trend, seasonality, and irregular fluctuations (Box et al., 2015). Trend analysis identifies long-term movements, seasonality captures recurring patterns, and irregular components account for random variations (Cryer & Chan, 2008).

Ondo State experiences distinct wet (April–September) and dry (October–March) seasons (Ologunorisa, 2004). As an agrarian state, variability in rainfall directly affects food security and livelihoods (Adefolalu, 2007). This study therefore focuses on decomposing monthly rainfall data to better understand the state's climatic dynamics and provide insights for sustainable development.

2. Related Work

Time series data consist of sequential observations recorded over time and are inherently stochastic (Nwachukwu, 2008). The value of time series analysis lies in its ability to model temporal dependencies and

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predict future outcomes based on past behavior (Paul, 2012).

In Nigeria, several studies have explored rainfall variability using time series methods. Ologunorisa (2004) and Adefolalu (2007) identified significant upward rainfall trends in southern regions, though regional variations persist. Rainfall in Nigeria displays pronounced seasonality, with alternating wet and dry periods (Olaniran, 2002).

Seasonaldecompositiontechniques, including additive and multiplicative models, are widely used to analyze such variability (Box et al., 2015; Hyndman & Athanasopoulos, 2018). The additive model assumes linear interactions between components, while the multiplicative model assumes proportional relationships. Both models are valuable for revealing patterns obscured by random fluctuations (Ojo et al., 2014).

3. Methodology

3.1 Study Area

Ondo State lies in southwestern Nigeria between latitudes 5°45′ and 7°52′N and longitudes 4°20′ and 6°05′E. It experiences a tropical climate with distinct wet and dry seasons. Rainfall supports the state's agriculture-driven economy, which relies heavily on crops such as cocoa, yam, and maize (Federal Ministry of Agriculture and Rural Development, 2016).

3.2 Data Source

Monthly rainfall data covering 41 years (1981–2021) were obtained from the Nigerian Meteorological Agency (NIMET). The dataset was cleaned and arranged chronologically for time series analysis.

3.3 Analytical Method

The study applied time series decomposition techniques to separate rainfall data into trend, seasonal, and irregular components.

The general mathematical representation of the decomposition approach:

$$Y_t = f(T_t, S_t, C_t, I_t)$$

where

Y_t is the time series value (actual data) at period*t*;

T_t is a deterministic trend or general movement component;

S_t is a deterministic seasonal component

C_t is a deterministic Cyclic component

I_t istherandomerror

The exact functional form of $f(\cdot)$ depends on the decomposition method used.

The additive model was expressed as:

$$Y_t = T_t + S_t + C_t + I_t$$

Trend, seasonal, cyclic and irregular components are simply added together to give the observed series.

The Holt–Winters exponential smoothing model was further employed to evaluate fitted values and forecast rainfall up to 2026, based on monthly data. Statistical analyses were conducted using R software and Microsoft Excel.

4. Results and Discussion

4.1 Rainfall Distribution

Figure 1 illustrates the rainfall distribution histogram, showing the frequency and density of rainfall occurrences. The red trend line highlights the overall probability distribution of rainfall amounts. The histogram reveals a predominance of lower rainfall values, with frequency decreasing as rainfall amount increases.

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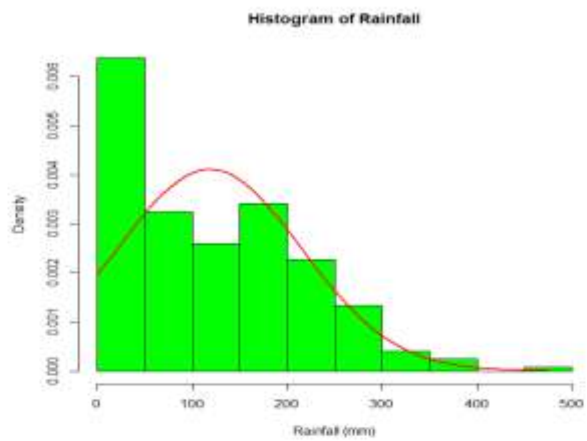

Figure 1: Histogram Showing Rainfall Distribution in Ondo State (1981–2021)

4.2 Time Series Trend

Figure 2 presents the time series plot of rainfall amounts over the study period. The plot indicates high inter-annual variability with no distinct long-term trend. Rainfall in Ondo State fluctuated significantly rather than showing a consistent increase or decrease. Such variability has implications for agricultural productivity, water resource planning, and flood risk management.

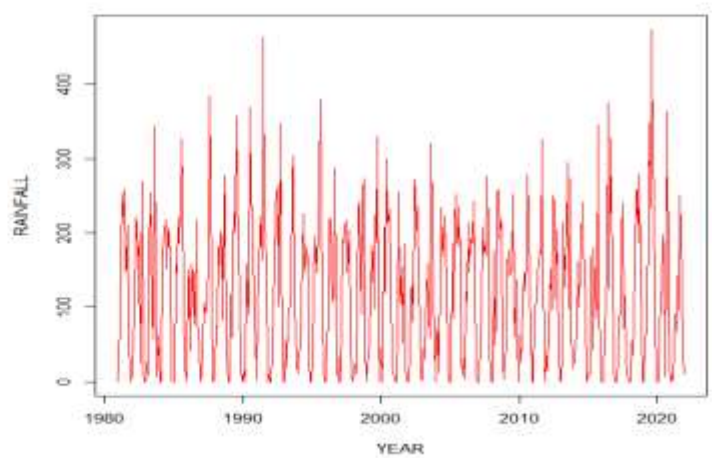

Figure 2: Time Series Plot of Rainfall Amounts in Ondo State (1981–2021)

4.3 Decomposition of Rainfall Series

Table2and Figure 3 show the decomposition of monthly rainfall into seasonal, trend, and residualcomponents.Theseasonal component highlightsregular fluctuations corresponding to wet and dry seasons. Positive values represent above-average rainfall in a month, while negative values denote below-average rainfall in a month. The trend captures the long-term direction of rainfall, while the residual reflects random climatic variations. The results reveal a clear seasonal pattern dry months (January–March and October–December) and wet months (April–

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September). Minor anomalies suggest the influence of short-term climatic fluctuations or localized weather disturbances.

Table 2: Decomposition of Rainfall Series Components (1981–2021)

Year	Month	seasonal	trend	remainder
1981	Jan	-107.873	145.3588	-37.49
	Feb	-87.1741	141.237	-31.66
	Mar	-33.3967	137.1151	-14.62
	Apr	15.05927	133.4144	104.83
	May	42.56157	129.7137	51.02
	Jun	78.16459	127.0461	53.39
	Jul	74.45057	124.3784	-50.63
	Aug	65.09808	122.1131	-34.51
	Sep	118.1749	119.8477	-27.42
	Oct	29.69033	117.0591	-90.85
	Nov	-82.4016	114.2704	-21.77
	Dec	-112.354	113.8264	-1.47
⋮	⋮	⋮	⋮	⋮
2021	Jan	-107.873	88.69637	27.28
	Feb	-87.1741	87.65782	0.02
	Mar	-33.3967	86.61928	-5.52
	Apr	15.05927	88.1209	-11.88
	May	42.56157	89.62252	-65.98
	Jun	78.16459	91.10342	-27.47
	Jul	74.45057	92.58432	-71.43
	Aug	65.09808	94.4722	92.33
	Sep	118.1749	96.36007	-17.13
	Oct	29.69033	98.96431	1.55
	Nov	-82.4016	101.5686	15.63
	Dec	-112.354	104.702	17.65

4.4 Forecasting Using Holt–Winters Model

Figure 4 displays the Holt–Winters fitted values, which closely match the observed data, confirming the model's reliability. A 60-month forecast (2022–2026) was generated to project rainfall trends. The forecast indicates moderate variability, suggesting continuity in historical seasonal behavior. However, the accuracy of the projections depends on the persistence of existing patterns, assuming no major climatic shifts occur during the forecast period.

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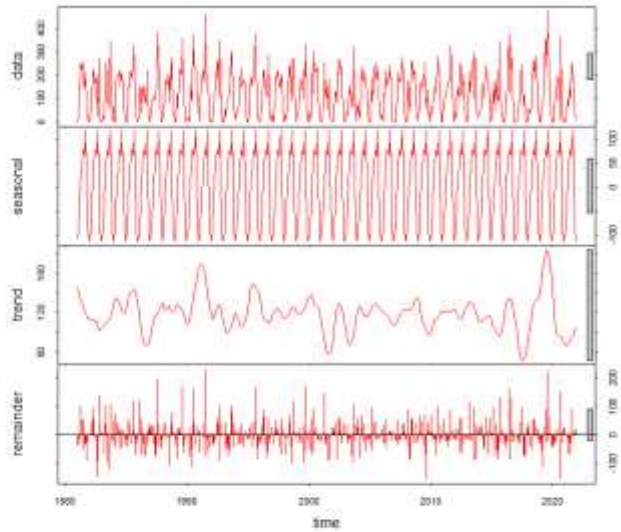

Figure 3: Decomposed Time Series Showing Trend and Seasonal Components

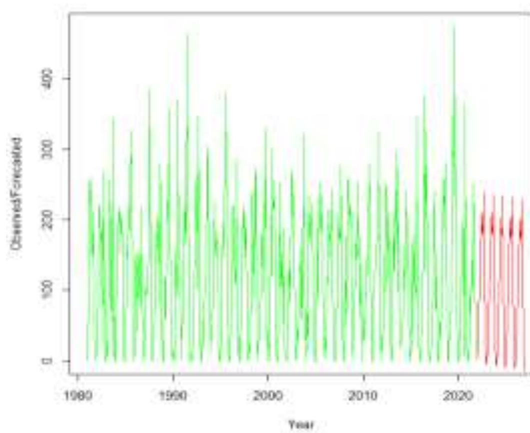

Figure 4: Forecasted Rainfall Values Using Holt–Winters Exponential Smoothing (2022–2026)

5. Conclusion and Recommendations

This study decomposed the monthly rainfall series of Ondo State into trend, seasonal, and irregular components. The findings highlight strong seasonality and high inter-annual variability, with no consistent long-term trend. Rainfall irregularities can significantlyimpact agricultural productivity, water management, and flood control measures.

It is recommended that policymakers and agriculturalplannersintegraterainfallvariabilit y analysis into early warning systems and irrigation planning. Further research should incorporatetemperatureandevapotranspiratio n data to enhance predictive accuracy and better understand climatic influences on regional hydrology.

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