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Comparative Evaluation of Satellite Measured Data with Ground Measured Data for Five Selected Rainfall Stations in Southwestern Nigeria

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Abstract
Accurate rainfall data is essential for hydrological applications, yet ground-based measurements remain sparse and irregularly distributed, particularly in developing countries. Satellite-derived precipitation estimates offer an alternative, but their accuracy must be validated before use. This study evaluates the agreement between ground-observed rainfall data from the Nigerian Meteorological Agency (NIMET) and satellite-derived data from POWER NASA across five stations in southwestern Nigeria (Abeokuta, Osogbo, Ibadan, Ikeja, and Akure) from 2002 to 2012. Descriptive statistical analyses, including mean, standard deviation, skewness, and kurtosis, were used to compare both datasets. The findings indicate that while POWER NASA generally records slightly higher mean rainfall values in most locations, NIMET data exhibit greater variability. The correlation coefficient (CC) between the datasets varies across stations, with the highest values recorded in Abeokuta (0.51) and Osogbo (0.50), indicating a moderate relationship, while other locations, particularly Akure (0.27), show weak correlations. These results suggest that satellite estimates may not fully align with ground observations due to factors such as; sub-cloud evaporation, seasonal variations, and localized precipitation patterns not captured by satellite sensors. The study suggests further validation before using satellite-derived rainfall data for critical hydrological applications in the region.

Keywords: *Rainfall data, NIMET, POWER NASA, ground-based observations, correlation analysis.*

1.0 Introduction

In hydrological studies, precise information on rainfall data is crucial for hydrological applications (Guo & Liu, 2016). Rainfall is arguably viewed as the most essential driving force for any hydrological model. Despite rainfall relevance for socioeconomic development, ground-based rainfall measurements are scarce and irregularly distributed, especially in developing nations (Behrangi et al., 2015; Gebremichael et al., 2014). Thus, there is a need for another source of rainfall data that will be reliable. With advancement in technology, rainfall data may be obtained using satellites; satellite-derived precipitation estimates are especially valuable when examining the interplay between precipitation and the landscape. However, none of the qualities of satellite data is enticing if the data are not accurate. Satellite-based precipitation products (SPPs) can only provide indirect estimates of rainfall. Particularly in tropical mountain regions, infrared and passive microwave sensors are affected by several limitations, from warm orographic rainfall to drizzle (Dinku et al., 2007). Therefore, while SPPs can capture the general spatial heterogeneity of precipitation, and despite technological advances, there remain significant uncertainties in the accuracy and resolution of SPP estimates over complex terrain (Derin et al., 2016; Hunink et al., 2014; Nesbitt and Anders, 2009).

Numerous studies had compared satellite-derived rainfall products with rain-gauge readings in the Sahel (Ali et al. 2005; Gosset et al. 2013; Jobard et al. 2011; Lamptey 2008; Laurent, Jobard, and Toma 1998; Nicholson et al. 2003a, 2003b; Roca et al. 2010). Nonetheless, these investigations are primarily executed at a regional level, encompassing numerous countries with varying physical and meteorological characteristics. Despite being limited in number, some studies have been conducted at the national level to assess satellite rainfall products. In Africa, the studies encompass Angola (Pombo, de Oliveira, and Mendes 2015), Ethiopia and Zimbabwe (Dinku et al. 2007; Hirpa, Gebremichael, and Hopson 2010), Kenya (Tucker and Sear 2001), Mozambique (Toté et al. 2015), and Uganda (Asadullah, McIntyre, and Kigobe 2008; Maidment et al. 2013). The outcomes of these studies differed due to evaluations conducted at various temporal and spatial scales.

There have been several studies comparing and validating satellite precipitation products with ground measurements (Dinku et al., 2007; Feidas, 2010; Guo & Liu, 2016). Before adopting satellite precipitation data to be used for hydrological applications in Nigeria, there is a need to confirm its comparativeness with the available ground-measured data; hence, the need for this study, which validates the comparativeness for the southwest rainfall stations of Nigeria.

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2.0 Materials and Methods

2.1 Study area

Southwestern Nigeria lies within longitude 20 48' - 60 0' E and latitude 50 5' - 90 12' N. Southwestern Nigeria is located in the southwestern part of Nigeria and shares land borders with the Republic of Benin in the west, Kogi and Edo States in the east, and Kwara State in the north. Its southern coast is on the Atlantic Ocean's Gulf of Guinea.

2.2 Method

This study uses secondary rainfall data from the POWER-NASA satellite products (available for download at www.power.larc.nasa.gov/data-access-viewer) in comparison to gauge-obsessed data from NIMET(available upon request at www.nimet.gov.ng). The dataset available for this study is limited to an 11-year period due to constraints accessing rainfall data. However, according to the guidelines set out by WMO (2018), a temporal range of 10 years is considered appropriate for conducting this type of analysis to obtain optimal and meaningful outcomes. Tables 1 and 2 show the dataset of ground-based and satellite-based data from 2002 to 2012, respectively.

Table 1. NIMET data on annual rainfall (mm) in Nigeria by states from 2002-2012

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Ikeja	1649.1	1039.9	2019.9	1484.9	1675.2	1649.1	1816	1391.7	1984.7	1764.3	1458.1
Abeokuta	1471.6	1118.4	1254.9	924.2	1142.1	876.2	1371.7	1465.5	1843.2	1863.4	1584.3
Akure	180.1	1406.8	1509.5	1317.1	1318.1	1405.7	1466.1	1309.6	1578.1	1643.2	1346.4
Osogbo	1293.5	1021.1	1164.2	1130.2	1469.7	1421.7	1597.6	1277.7	1956.4	1765.8	1946.5
Ibadan	1105.1	1022.7	1294.9	1192	1260.2	1218.8	889.4	1702.1	1945.6	1874.2	1346.2

Table 2. SATELLITE DATA (POWER NASA) ON ANNUAL RAINFALL (MM) IN NIGERIA BY STATES FROM 2002-2012

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Ikeja	1323.6	1323.6	1408.	928.1	1160.2	1766.6	1539.9	1608.4	2072.5	1545.1	1850.9
Abeokuta	1276.2	1371.1	1518.8	980.9	1323.6	1782.4	1592.6	1534.6	2040.8	1555.7	1835.2
Akure	1434.4	1418.6	1318.4	849.0	1191.8	1845.7	1386.9	1444.9	1682.2	1429.1	1745.5
Osogbo	1313.1	1408.0	1634.8	896.5	1234.0	1555.7	1408.0	13237	1613.7	1413.3	1687.5
Ibadan	1397.5	1471.3	1735.0	1054.7	1497.7	1724.4	1624.2	1529.3	2025.0	1613.7	1924.8

2.3 Accuracy assessment

Statistical metrics of the correlation coefficient (CC) were utilised to evaluate the performance of the satellite product over the ground-observed data from the period of 2002 to 2012. The correction coefficient (CC) is used to quantify the degree of the linear association between both datasets. Values close to 1 indicate a strong correlation between the POWER NASA and NIMET observed estimation.

3.0 Results and Discussion

Table 3 to Table 7 shows the descriptive analyses for the study areas' NIMET and POWER NASA rainfall data. The mean rainfall recorded by POWER NASA is slightly higher than NIMET in Abeokuta, Ibadan and Akure, while it is otherwise for Osogbo and Ikeja. The median followed a similar trend except for Osogbo and Akure where the median recorded are almost identical. The median values are generally close to the mean, indicating a fairly symmetric distribution, except in Akure, where the median is slightly higher than the mean for NIMET, suggesting skewness. A similar trend has been reported in studies such as Odekunle et al. (2014) and Oladosu et al. (2020), where satellite-based rainfall products tended to report higher rainfall values compared to ground observations in West Africa. Across all stations, NIMET data exhibits higher standard deviations compared to POWER NASA indicating greater variability in the dataset, which may be due to localized influences (e.g., microclimate effects, station errors) that are not captured in gridded satellite datasets. This aligns with the findings of Dinku et al. (2008) and Satgé et al. (2020), who observed that satellite data smooth out extreme values and local anomalies.

The values of kurtosis and skewness obtained showed that the data is normally distributed but slightly skewed to the right for Abeokuta, Osogbo, and Ibadan for the NIMET data and otherwise for the POWER NASA data, while the skew is shifted to the left for Ikeja and Akure stations for both datasets except for the

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POWER NASA data for Ikeja that is almost symmetrical, the NIMET data in Akure station shows strong negative skewness, meaning there are extreme low values affecting the distribution.

Table 3: Descriptive analysis of the NIMET and POWER NASA datasets for Abeokuta station

	NIMET	*POWER NASA*
Mean	1357.61	1528.34
Standard Error	99.39	88.23
Median	1371.70	1534.57
Standard Deviation	329.63	292.62
Sample Variance	108657.27	85629.27
Kurtosis	-0.86	0.29
Skewness	0.17	-0.06
Range	987.20	1059.96
Minimum	876.20	980.86
Maximum	1863.40	2040.82
Sum	14933.70	16811.71
Count	11	11

Table 4: Descriptive analysis of the NIMET and POWER NASA datasets for Osogbo station

	NIMET	*POWER NASA*
Mean	1458.62	1408.01
Standard Error	97.54	67.54
Median	1421.70	1408.01
Standard Deviation	323.51	224.00
Sample Variance	104658.61	50173.83
Kurtosis	-1.07	1.70
Skewness	0.42	-1.03
Range	934.90	791.02
Minimum	1021.50	896.48
Maximum	1956.40	1687.50
Sum	16044.80	15488.08
Count	11	11

Table 5: Descriptive analysis of the NIMET and POWER NASA datasets for Ibadan station

	NIMET	*POWER NASA*
Mean	1350.11	1599.77
Standard Error	103.84	79.26
Median	1260.20	1613.67
Standard Deviation	344.39	262.87
Sample Variance	118604.49	69100.87
Kurtosis	-0.55	1.01
Skewness	0.73	-0.39
Range	1056.20	970.31
Minimum	889.40	1054.69
Maximum	1945.60	2025.00
Sum	14851.20	17597.46
Count	11	11

Table 6: Descriptive analysis of the Ikeja station's NIMET and POWER NASA datasets

	NIMET	*POWER NASA*
Mean	1630.26	1502.45
Standard Error	84.68	97.72
Median	1649.10	1539.84
Standard Deviation	280.86	324.11
Sample Variance	78884.70	105049.34
Kurtosis	0.74	-0.01
Skewness	-0.63	0.02
Range	980.00	1144.34
Minimum	1039.90	928.12

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	NIMET	*POWER NASA*
Maximum	2019.90	2072.46
Sum	17932.90	16526.95
Count	11	11

Table 7: Descriptive analysis of the NIMET and POWER NASA datasets for Akure station

	NIMET	*POWER NASA*
Mean	1316.43	1431.50
Standard Error	118.45	82.29
Median	1405.70	1429.10
Standard Deviation	392.84	272.93
Sample Variance	154325.68	74491.93
Kurtosis	8.81	1.18
Skewness	-2.83	-0.57
Range	1463.10	996.68
Minimum	180.10	849.02
Maximum	1643.20	1845.7
Sum	14480.70	15746.48
Count	11	11

Table 8, shows the correlation between the POWER NASA precipitation product and NIMET's observed ground data across different locations in the study area. Notably, the result displayed that there is no regular correlation among the products in the study region, as the highest value of correction is recorded at the Abeokuta and Osogbo Stations with values of 0.51 and 0.50, respectively, indicating a moderate relationship between both data sets. Studies by Dinku et al. (2008, 2011) demonstrated that satellite rainfall products often correlate moderately to weakly with ground data over regions with complex climate and terrain, especially in tropical and sub-Saharan Africa. All other stations returned a value less than 0.5, with the Akure station recording the lowest value, indicating a weak relationship. These inconsistencies are in line with the findings of Odekunle et al. (2014) between station observations and satellite rainfall data across Nigeria, especially in areas affected by convective rainfall and coastal influences, such as the southwest. The result might suggest that the satellite data does not match the ground-observed data or that other factors may affect the data obtained. Oladosu et al. (2020) evaluated various stations in Nigeria and reported correlation values ranging from 0.30 to 0.60, depending on station location and data source, which align closely with the current results. The sub-cloud evaporation phenomenon, in which water evaporates before reaching the surface, may also be one of the reasons contributing to lower correlations of satellite precipitation products (SPPs) in annual precipitation estimation (Aksu & Akgül 2020). Averaging data over a longer period, such as a year, can smooth out important short-term fluctuations or variations, reducing the alignment between the two datasets. Satellite-based yearly data might incorporate more aggregated and generalised measurements that deviate from localised, ground-based yearly averages. Also, a full year's average can hide seasonal variations by satellites, whereas ground-based stations track the extremes more precisely. Aggregated yearly data by satellites can amplify the effects of missing or inconsistent data, lowering the correlation.

Table 8: Correlation Coefficient between NIMET and POWER NASA Rainfall Data for 2002-2012

Station Name	Correlation Value	Interpretation
Abeokuta	0.51	Moderate positive correlation
Osogbo	0.50	Moderate positive correlation
Ibadan	0.43	Weak to Moderate correlation
Ikeja	0.29	Weak correlation
Akure	0.27	Weak correlation

4.0 Conclusion

Satellite precipitation data, which are a viable substitute for obtaining rainfall data in a range of hydro-climatic applications at both global and regional scales, require local validation. This evaluation of the accuracy of satellites' precipitation data in comparison to ground observations is necessary at the local scale, notwithstanding the advantages of the former in terms of spatial and temporal resolution and data availability. This study compared yearly ground-observed data (NIMET) with satellite data (POWER NASA) for five different stations in southwest Nigeria from 2002 to 2012. Overall, the correlation coefficient between both datasets was found to be weakly

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correlated. The study therefore recommends further studies on the monthly and daily correlation of the dataset.

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