E-ISSN: 1116 - 2759 P-ISSN: 3027-0111
MPRI-EDIR | INTERNATIONAL JOURNAL OF EARTH DESIGN AND INNOVATION RESEARCH
VOL. 08 NO. 4 – APRIL, 2025

EVALUATING THE INTEGRATED MULTI-SATELLITE RETRIEVAL FOR GLOBAL PRECIPITATION MEASUREMENT (IMERG) SATELLITE DATA FOR DISASTER RISK REDUCTION IN FOUR RIVER BASINS OF WEST AFRICA

IBRAHIM MUHAMMAD MAGAJI[1,2*]; IBRAHIM MUHAMMED[2]; & MUBI AISHATU MOHAMMED[3]

[1]Department of Surveying and Geoinformatics Abubakar Tafawa Balewa University, Bauchi Nigeria. [2]Department of Surveying and Geoinformatics Modibbo Adama University Yola Nigeria. [3]Department of Geography Modibbo Adama University Yola Nigeria
Corresponding Author: mmibrahim@atbu.edu.ng
DOI: https://doi.org/10.70382/mejedir.v8i4.038

Abstract

Precipitation is a crucial part of the climate system in the West Africa and has a major impact on agriculture, water resources, and economic activity. This study evaluates the Integrated Multi-satellite retrieval for global precipitation measurement (IMERG) precipitation in four river basins: Chad, Niger, Senegal, and Volta. But the difficulties in measuring precipitation accurately have led to the use of data from the [redacted]

IMERG satellite data from 2002 to 2022. The NASA Earth Explorer provided the data. The evaluation was conducted using the Standardized Precipitation Index (SPI), Coefficient of Variation (CV), and Standard Deviation (SD) techniques. The findings reveal an unequal distribution of precipitation during the studied period. According to the rainfall distribution in West Africa, the lowest rainfall was recorded in

Keywords:
Retrieval, Precipitation, Climate, Hydrological, Spatio-temporal, Variability, Moisture, Basin

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2004 (110.74 mm in Chad), followed by Niger (706.64 mm in 2013), Senegal (131.84 mm in 2002), and the Volta basin (986.13 mm in 2013). The highest rainfall was recorded in 2012, 2022, 2010, and 2022 (400.78 mm, 1815.60 mm, 580.08 mm, and 1968.60 mm for Chad, Niger, Senegal, and Volta basins, respectively). Additional findings indicate a growing trend in each of the four river basins. The study also emphasizes the value of satellite-based precipitation data in tracking and comprehending hydrological dynamics in West Africa and suggests using IMERG data to support climate research and resource management in the area.

Introduction

BACKGROUND

When it comes to groundwater recharge, precipitation is a crucial component especially in West Africa, precipitation in West Africa is seasonal and changes according to the Inter Tropical Convergence Zone's (ITCZ) latitudinal migration; from April to October, the Sahel and much of West Africa records high levels of precipitation annually. Altitude and physiographic characteristics have a significant impact on the region's annual and monthly rainfall distribution, in addition to the headway of the ITCZ and the influence of atmospheric movement features like the African Easterly Jets (AEJ), West African Westerly Jets (WAWJ), and Tropical Easterly Jets (TEJ) also have greatly influence on these vital recourses. The highlands of Guinea, Sierra Leone, and Cameroon, for example, gets more precipitation along the Guinea Coast than the nearby lowlands in the Central Sahel.

Understanding the space and time precipitation changes in West Africa is critical and important for many purposes, including climate studies, environmental studies, global rainfall studies, water resource planning and management, and groundwater monitoring and evaluations. It plays a major role in applications linked to hydrometeorology since it is a crucial variable that represents mass interchange and energy stability in the climate system all over the world (Wanders, N., and E. F. Wood, 2015; Alavinia, S.H.; and Zarei, M. 2021).

Obtaining precise estimations of precipitation in place and time is essential for hydrological studies at the regional or global scale. In general, there are three major sources of precipitation data that are available which includes remote

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sensing measurements, model simulations, and ground-based observations (Derin, et al., 2019; Esmaeilpour, et al., 2021). The most precise precipitation data is obtained locally from ground-based observations; however, these observations generalize the spatial representativeness of their points to broad spatial extents, particularly across poorly gauged areas especially in West Africa and other developing countries, which might result in some systematic and random inaccuracies via areal interpolation which is the most normal method of spatial interpolation for hydrological works. Precipitation measurements have historically depended on ground stations, which are scarce and unable to offer a complete picture of precipitation patterns because of their limited spatial coverage and problems with data quality as well as other issues (Huffman, et al., 2020; Rahmati, et al., 2021).

A number of satellite rainfall datasets have been utilized in hydrometeorological researches globally as well as regionally, including the Climate Prediction Center Morphing Method (CMORPH), Tropical Rainfall Measuring Mission (TRMM), Multi-satellite Precipitation Analysis (TMPA), Global Satellite Mapping of Precipitation (GSMaP), Integrated Multi-satellite retrieval for global precipitation measurement (IMERG), and Remotely Sensed Precipitation Estimation from Information using Artificial Neural Networks (PERSIANN). Since 1998, the Tropical Rainfall Measuring Mission (TRMM)TMPA datasets have been the largely used and reliable satellite-based rainfall data (Mondal, et al., 2018).

Based on the spatiotemporal variability of the Integrated Multi-satellite retrieval for global precipitation measurement (IMERG) data, the study's main objective is to ascertain whether the new dataset is proper for hydrometeorological studies in West Africa or otherwise. This present research provides important insights into the space and time variability of the IMERG data to aid the actual algorithm developers in optimizing the precipitation as well as the accuracy.

Previously there are number of researches have evaluated the spatiotemporal variability of satellite precipitation products and their impact on groundwater. Integrated Multi-satellite retrieval for Global Precipitation Measurement (IMERG) Satellite-based precipitation products have been used extensively in hydrological studies owing to their great spatiotemporal resolution and capability to estimate precipitation over large areas. The IMERG data, which combines observations from multiple satellites, provides improvements in value and space and time resolution of rainfall data compared to the TMPA (Tang, et al., 2020).

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Alsumaiti, et al. (2020) Compared the functioning of global precipitation measurement IMERG to nine other satellite reanalysis datasets. They found that GPM IMERG acted well in netting precipitation changes at different spatial and temporal scales, in similar research, Zhang, et al. (2019) evaluated the performance of Climate Prediction Center Morphing Method (CMORPH) and IMERG products over the United Arab Emirates. In terms of capturing precipitation variability, they discovered that IMERG outperformed CMORPH. In a humid area in China, Liu, et al., (2020) assessed the hydrologic use of tropical rainfall measurement mission (TRMM) and global precipitation measurement products. The GPM IMERG product outperformed the Tropical Rainfall Measuring Mission (TRMM) in the study's capacity to capture the temporal and geographical variability of precipitation, which is essential for groundwater recharging. In a similar vein, Wang, et al. (2019) assessed the precision of daily rainfall projections for the Yangtze River Basin in China using the global precipitation measurement level-3 final output obtained from the IMERG algorithm. The space and time changes of precipitation, which is essential for groundwater recharging, was shown to be well captured by the IMERG product.

In the Beijing River Basin, China, Siuki et al. (2020) assessed the hydrological usefulness of IMERG, a satellite-based precipitation product. They discovered that it can be applied to water resource administration and hydrological studies. Baik, et al. (2015) carried out a thorough assessment of tropical rainfall measurement mission (TRMM) and GPM-IMERG satellite precipitation data. The study competed the performance of simulated streamflow from various precipitation inputs and demonstrated that the GSMaP-Gauge product had the best performance in streamflow simulation, followed by IMERG-C. They discovered that when it came to capturing precipitation variability at various temporal scales, GPM-IMERG outperformed TRMM. The spatiotemporal variability of remotely sensed precipitation data from COMS and Tropical Rainfall Measuring Mission (TRMM) in the Korean peninsula, East Asia, was investigated by Gebremichael, et al. (2020).

According to the study, the Integrated Multi-satellite retrieval for global precipitation measurement (IMERG) product performed better than Tropical Rainfall Measuring Mission (TRMM) in capturing precipitation's spatial and temporal variability, which is vital for groundwater recharge.

The precision of medium-range (1–15 days) rainfall forecasts from the Global Forecast System (GFS) on watersheds of eight main dams in the Niger river basin

Selingue, Markala, Goronyo, Bakolori, Kainji, Jebba, Dadin Kowa, and Lagdo Dam was analyzed using IMERG merged satellite gauge rainfall observations. The findings show that the meteorological system, timescale, and spatial scale all affect how accurate the global forecast system (GFS) forecast is.

The studies reviewed indicate that satellite-based precipitation products, specifically the IMERG product, can provide precise estimates of rainfall that are significant for groundwater storage. Other studies, such as (Bakhtar, et al., 2022) have evaluated IMERG in various parts of the world and recommend its use at a regional scale. Understanding the impact of precipitation on groundwater requires the capacity to capture the spatiotemporal changes of precipitation, which these products can provide. From 2002 to 2022, the four major river basins of West Africa the Chad, Niger, and Senegal basin as well as the spatiotemporal variability of rainfall are assessed in this paper using IMERG data.

MATERIAL AND METHOD

The Study Area

The study area comprises of sixteen countries of Benin, Burkina Faso, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo, with a total area of around 6.14 million km³ as in (Figure 1). West Africa is situated between latitudes 4^{O}N and 27^{O} N and longitudes 15^{O} W and 16^{O} E. The southern boundary of this location is the Atlantic Ocean. The Sahara Desert is located in the northward, and the Cameroon Mountains border the eastern boundary (Ibrahim, et al., 2024).

West Africa's precipitation patterns exhibit significant spatial and temporal variability. Spatially, coastal regions like Ghana, Côte d'Ivoire, and Nigeria receive high precipitation (>2000 mm/year), while the Sahel region, including Mali, Burkina Faso, and Niger, receives low precipitation (<500 mm/year). The Guinea savannah, covering Senegal, The Gambia, and Guinea, experiences moderate precipitation (1000-1500 mm/year). Temporally, precipitation peaks in August-September, with low precipitation in December-January. The Sahel region exhibits high interannual variability, while coastal regions show moderate variability. Regional precipitation patterns are influenced by climate drivers like the West African Monsoon, Intertropical Convergence Zone, and African Easterly Jet. Climate drivers such as Atlantic Multidecadal Oscillation, El Niño-Southern Oscillation, and African Easterly Wave Activity also impact precipitation.

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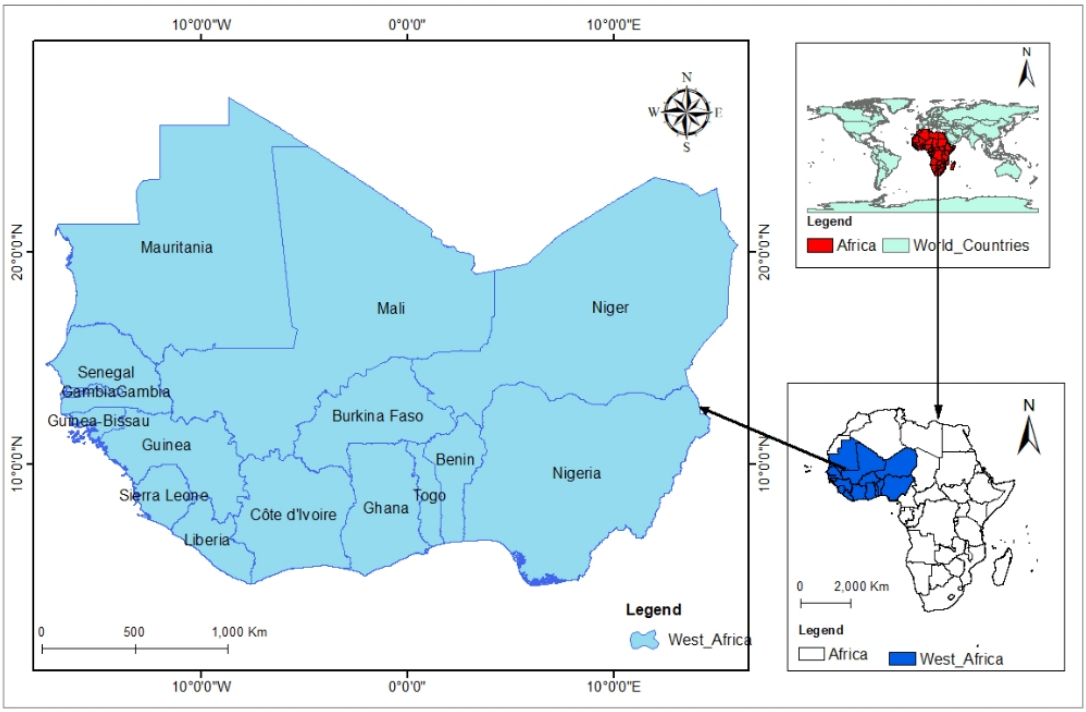


Figure 1: Map of the study Area
Source: Author 2025

West Africa's precipitation patterns exhibit significant spatial and temporal variability. Spatially, coastal regions like Ghana, Côte d'Ivoire, and Nigeria receive high precipitation (>2000 mm/year), while the Sahel region, including Mali, Burkina Faso, and Niger, receives low precipitation (<500 mm/year). The Guinea savannah, covering Senegal, The Gambia, and Guinea, experiences moderate precipitation (1000-1500 mm/year). Temporally, precipitation peaks in August-September, with low precipitation in December-January. The Sahel region exhibits high interannual variability, while coastal regions show moderate variability. Regional precipitation patterns are influenced by climate drivers like the West African Monsoon, Intertropical Convergence Zone, and African Easterly Jet. Climate drivers such as Atlantic Multidecadal Oscillation, El Niño-Southern Oscillation, and African Easterly Wave Activity also impact precipitation. Trends indicate decreasing precipitation in the Sahel region (-1.5 mm/year) and increasing precipitation in coastal regions (1.2 mm/year). Extreme events like droughts and floods frequently occur, affecting agriculture, water resources, and human health. Understanding West Africa's precipitation variability is crucial for climate modeling, agricultural

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planning, and water resource managing to mitigate the effects of climate variability (Muhammed, I. 2011).

The soils of West Africa are generally poor in nutrients, particularly in the north of the region where the Sahara Desert encroaches upon the land. The soils are often sandy and lack organic matter, making it difficult for plants to grow. In the south, the soils tend to be more fertile, with higher levels of organic matter and nutrients. The vegetation of West Africa is also diverse, and varies according to the region. In the north, where droughts are frequent, the landscape is dominated by sparsely spread shrubs and trees adapted to the harsh conditions, such as acacias and baobabs. In the Sahel region, a band of semi-arid land that stretches across the continent, grasslands and scrub forests are common. In the southern part of West Africa, the vegetation is lusher due to higher levels of rainfall. The Guinean forest-savanna mosaic covers huge areas of West Africa, and is characterized by a mix of grasslands, savannas, and forests.

DATA

Global Precipitation Measurement

The Japan Aerospace Exploration Agency (JAXA) and the National Aeronautic Space Administration (NASA) collaborated to create the Global Precipitation Measurement (GPM) satellite, which is designed to provide advanced observations of precipitation (rain, snow, and sleet) globally. The GPM mission is a universal satellite network that gives advanced worldwide rainfall and snowfall monitoring, building on the achievements of the tropical rainfall measurement mission (TRMM). The dual-frequency precipitation radar, which gives information on the three-dimensional structure of precipitating particles, and the global precipitation measurement Microwave Imager, that arrest precipitation intensities and parallel patterns, are installed on the main satellite, which was began in 2014 February.

Precipitation data from nine multinational satellites is integrated by GPM-IMERG: Metrological Operational Satellite (Metop-A), Metrological Operational Satellite (Metop-B), Global Precipitation Measurement (GPM), Global Change Observation Method Water 1 (GCOM-W1), National Oceanic and Atmospheric Administration (NOAA-18), National Oceanic and Atmospheric Administration (NOAA-19), Defense Metrological Satellite Programme Flight (DMSP F-16), Defense Metrological Satellite Programme Flight (DMSP F-17), and Defense Metrological

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Satellite Programme Flight (DMSP F-18). As advised by Khaki, et al. (2021) the "Final Run" product of IMERG-V04A has been used, calibrated using the gauge-based Global Precipitation Climatology Centre (GPCC) study.

Precipitation estimates for the region covering 60° S and 60° N are provided by the GPM IMERG V06 product at a semi-hourly time step and a spatial resolution of 0.1-degree grids. The IMERG technique combines the estimations from the GPM core observatory with multi-satellite recoveries from the passive microwave these recoveries are gridded, intercalibrated, and combined to get the final result. A new homogenous GPM-TRMM calibration, and adjustments to the Kalman filter procedure and the quality index were among the enhancements made to the algorithm to improve the data accuracy of IMERG (Huffman, et al., 2019).

The global precipitation measurement concept focuses on the placement of a "Core" satellite with a sophisticated radiometer scheme to measure rainfall from space and work as a reference normal to unify rainfall data from a group of research and operational satellites. By improving global precipitation measurements, the GPM mission improved our thoughtful of global water and energy series, enhanced our ability to forecast extreme actions that lead to natural menaces and disasters, and expanded our current abilities in using timely and accurate precipitation information to directly profit the society. In this study, the spatiotemporal variability of IMERG precipitation was assessed using the GPM-IMERG Final Run V06 over West Africa from 2002 to 2022 (Alemu, et al., 2019).

METHODS

The methods employed to evaluate the spatiotemporal variability of satellite precipitation (IMERG) data across West Africa were examined in order to analyze the spatiotemporal variability of IMERG precipitations over the region, as shown in Figure 2. In addition to providing useful suggestions for the application of IMERG data in West Africa, this analysis supports the future development and improvement of IMERG systems. The two metrics for assessing variability used in this study were SD and CV.

The most often used indicator of variability is the standard deviation (SD), which is represented as follows in equation 1:

$$SD = \sum \sqrt{\left(\frac{(x-x)^2}{n-1}\right)} \quad (1)$$

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x is the mean precipitation, x is the yearly precipitation, and SD is the standard deviation.

n is the number of observations, and ∑ is the sum of all X variables.

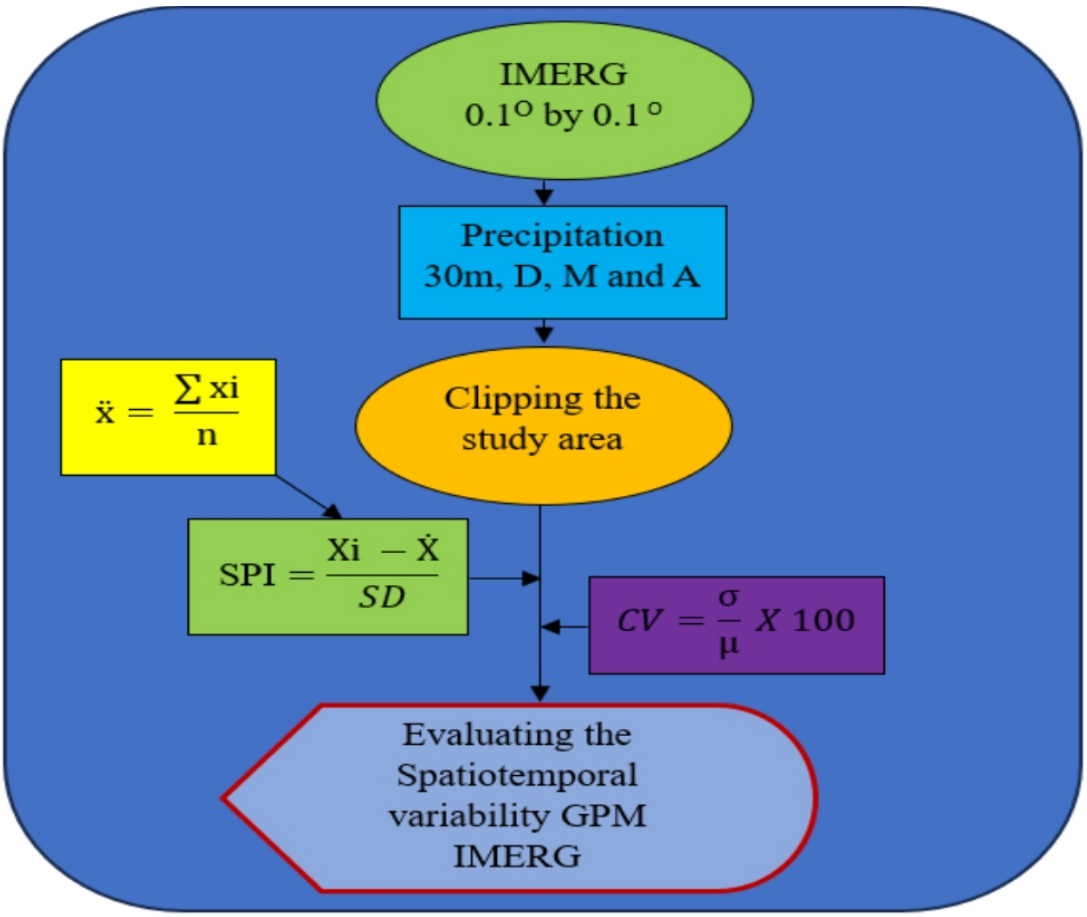


Figure. 2: Flow chart of the methodology

Source: Author 2025

Variability Coefficient

Equation 2 requires that the SD be standardized by dividing it by the mean and then multiplying the result by 100 in order to determine the coefficient of variation. When a yearly series is naturally assigned, the CV is a good metric for comparison purposes since it assesses the relative distribution of variables from the mean. The annual rainfall study was carried out for four selected points of major river basin as shown in table 1 in order to investigate the occurrence of rainfall in West Africa. CV and SPI were used to analyze changes and trends in precipitation at a yearly scale over the historic era.

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$$CV=\sigma/\mu \times 100 \quad (2)$$

μ is the mean (ẍ) rainfall σ is the SD. Low (CV<20), moderate (20<cv30) rainfall changes were observed (McKee, et al., 1993).

Table 1: location of river basin points selected for the analyses

River Basin	Dam	Latitude	Longitude	Temporal Resolution
Chad	Lake Chad	13.764186	13.418732	2002 -2022
Niger	Kaiji Dam	10.396536	4.599645	2002 -2022
Senegal	Maka Diama Dam	16.287622	-15.82206	2002 -2022
Volta	Lake Volta	7.396831	0.211018	2002 -2022

The SPI equation 3 was used in the evaluation of the precipitation of West Africa, positive result of SPI shows greater than the average value, while the minus SPI value shows less than average precipitation, values of SPI are shown in Table 2 as suggested by (McKee, et al., 1993).

$$SPI = \frac{Xi - \dot{X}}{SD} \quad (3)$$

where X_i stands for the yearly rainfall for the period understudy; $\dot{X}$ represents the long-term average yearly rainfall for the observation period and SD corresponds to the standard deviation of yearly rainfall during the observed period

Table 2: SPI Values

	Value	Rating
a.	≥ 2	Extreme wetness
b.	< 2 ≥ 1.5	Severe wetness
c.	≥ 1 < 1.5	Moderate wetness
d.	≥ 0.5 < 1	Mild wetness
e.	< 0.5	Normal wetness
f.	> -0.5	Normal dryness
g.	≥ -0.5 < -1	Mild dryness
h.	≥ -1 < -1.5	Moderate dryness
i.	> -2 ≤ -1.5	Severe dryness
j.	≤ -2	Extreme dryness

Source: McKee, et al., 1993

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RESULTS AND DISCURSIONS

Spatiotemporal Variability of IMERG over West Africa 2002-2022

Figure 3 shows monthly time series of IMERG in the study area. Additionally, movement in spatial patterns of precipitation in the area indicate a rise between 0 mm year^{-1} and up to 1700 mm year^{-1} with a slight increasing trend of 0.0003 mm month^{-1}, which is consistent with the findings of (Ndehedehe, et al., 2016), The monthly timeseries for the period under study were obtained using the total daily precipitation.

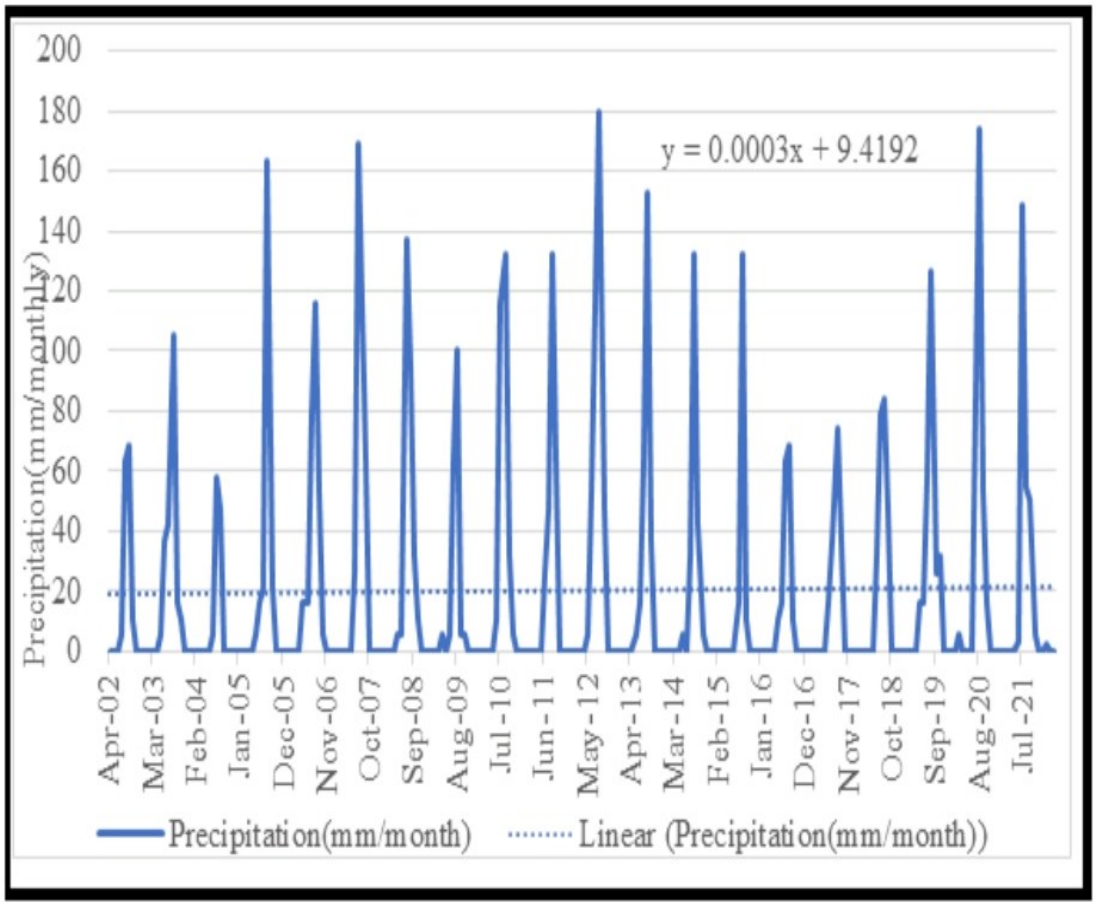


Figure. 3: Time series of monthly Precipitation over the study area (2002-2022)
Source: Author 2025

Annual Variability of Satellite Precipitation (IMERG) 2002-2022

Figure 4 displays the annual distribution of rainfall, Figure 5 displays the yearly rainfall estimates of IMERG, and Figure 6 displays the average precipitation for the

complete study time. Precipitation rises from north (0mm) to south (>1700mm), with values ranging from 0 mm year^{-1} in the far northern areas (Northern Mauritania, Mali, and Niger) to more than 1700 mm year^{-1} in the southern regions (Southern Nigeria, Guinea, Serra Leone, and Liberia). This shows that precipitation properties change with elevation, latitude, and longitude; the outcome is consistent with those of Pirmoradian, et al. (2022).

The topography and geography of the studied area mostly impact the spatial distribution of rainfall, according to analyses. The yearly range of precipitation is depicted in Figure 5, with the lowest precipitation in 2013 (574.805 mm) and the highest precipitation in 2022 (1111.013 mm).

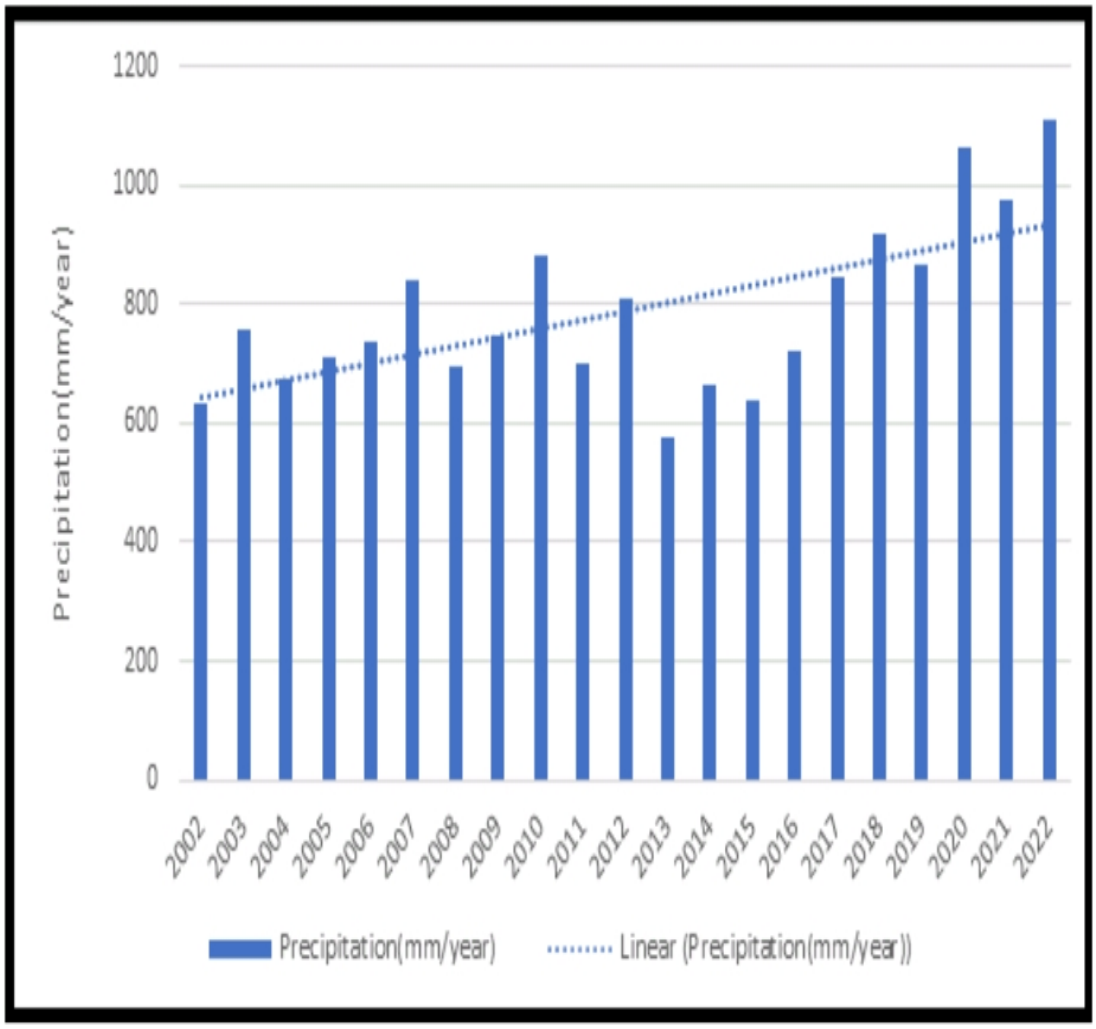


Figure. 4: Annual distribution of Precipitation on yearly basis
Source: Author 2025

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The change of ITCZ can be used to explain why precipitation dropped from southernly to the northernly portion of the sites under study. Figure 5 shows a division that represents high and low rainfall levels. The monsoon, which are wet and cold air masses, is separated from the Harmattan, a dry air mass that originates in the Sahara Desert, by the ITCZ. The amount of precipitation is also indirectly induced by atmospheric circulation characteristics of African Easterly Jets (AEJ), West African Westerly Jets (WAWJ), and Tropical Easterly Jets (TEJ). The region's annual and monthly rainfall distribution is significantly influenced by altitude and physiographic features; for example, the Central Sahel's highlands, like Sierra Leone, Guinea, and Liberia, receive a lot of rainfall than the nearby lowlands. The spatiotemporal variability is displayed annually Figure 6.

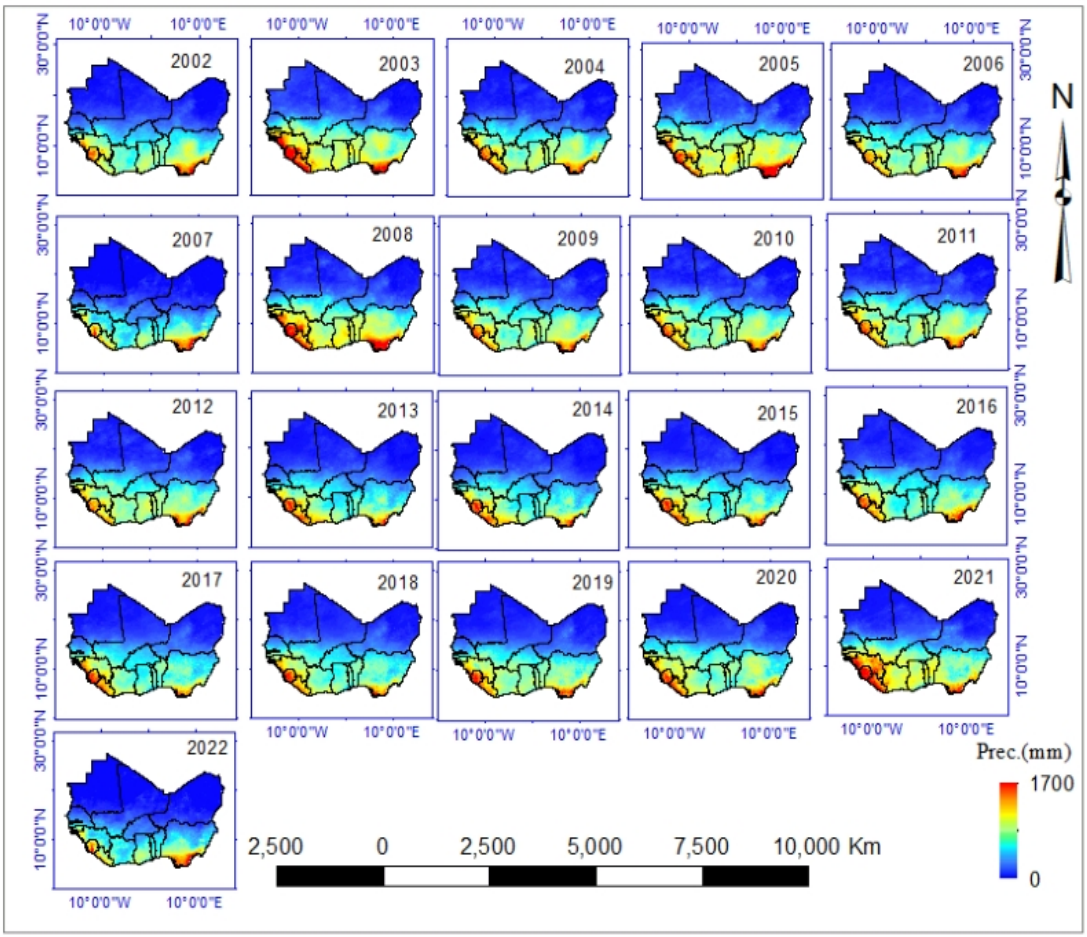


Figure. 5 The spatiotemporal distribution of Precipitation on yearly basis
Source: Author 2025

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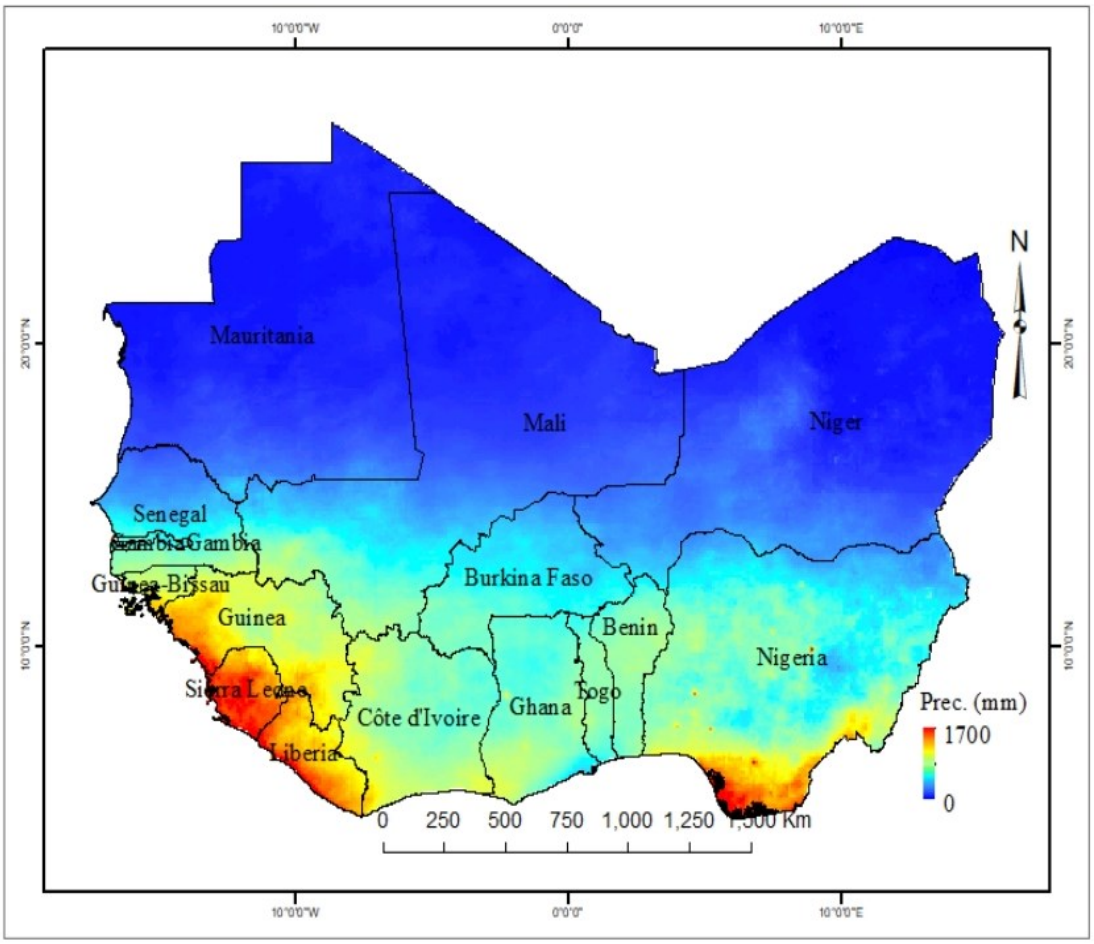


Figure. 6: The spatial distribution of Precipitation for the entire study period
Source: Author 2025

Variability Analysis of IMERG in West African River Basins and its implication on soil moisture in four river basins

The variability was evaluated and drought was assessed in four river basins of West Africa (Figure 7) and the information of the points use in the evaluation are shown in Table 3. these points are selected for the analysis due to their wider geographic coverage, providing insights into various hydrological and climatic conditions in the region and they are important homes of water for irrigation, home use, and industrial reasons, making the analysis crucial for understanding water availability and sustainability, as a transboundary basin, they present an opportunity to study and address challenges associated with managing shared groundwater resources.

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The description of table 3 served as the basis for the classification of droughts and extreme rainfall events employed in this investigation Standardized indices, such as the standardized precipitation index and the standardized runoff index, are frequently used to describe the drought phenomenon. One widely used drought index is the SPI. It is normalized so that other water variables and hydrological amounts, like snowfall, lakes, streamflow, soil moisture, and groundwater, may be computed and expressed similarly for wetter and drier regions.

Table 3 location of river basin points selected for the analyses

River Basin	Dam	Latitude	Longitude	Temporal Resolution
Chad	Lake Chad	13.764186	13.418732	2002 -2022
Niger	Kaiji Dam	10.396536	4.599645	2002 -2022
Senegal	Maka Diama Dam	16.287622	-15.82206	2002 -2022
Volta	Lake Volta	7.396831	0.211018	2002 -2022

Source: Author 2025

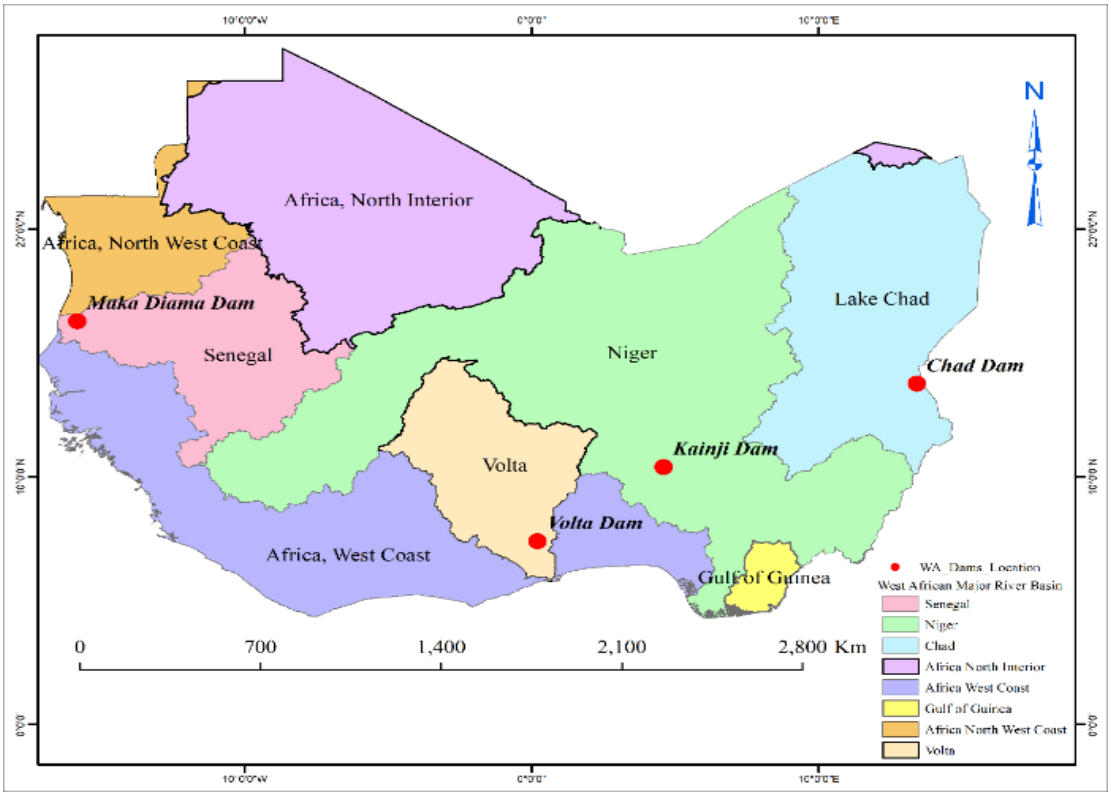


Figure. 7: spatial distribution of major river basins of West Africa

Source: Author 2025

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Variability Analysis of Satellite Precipitation in Chad Basin

Findings revealed that the mean rain fall for the entire study period is 246.31mm and the standard deviation was calculated as 74.71 using equation 1, the least yearly rainfall received in Chad basin was in 2004 with 110.74 mm whereas the topmost was in 2012 with 400.78 mm, additional result indicates a drop in rainfall value from 400.78 mm in 2012 to 158.20 mm in 2015. Result similarly displays that there was a constant increase in the yearly rainfall amount from 163.48 mm in 2017 to 332.23mm in 2020, respectively this result is coinciding with the results of (Burgess, et al., 2007).

The SPI pattern given in Table 4 indicates that an extreme wetness year was identified in 2012 with extreme wetness of SPI of >2 followed by 2007 and 2020 with severe wetness of SPI value of 1.72 and 1.15 respectively, further result shows mild wetness in 2006, 2008, 2022 with SPI of 0.52 each and 2010 with SPI of 0.66 recorded whereas 2021 recorded moderate wetness with SPI= 1.31 respectively, further analyses also shows that 2011, 2013, 2019 and 2021 has normal wetness with SPI of 0.30, 0.37, 0.37 and 0.22 respectively, furthermore 2004 has the severe dryness with SPI of -1.82, Figure 8. For the variability coefficient of rainfall in Chad basin which was calculated using equation 2, shows the region has high variability with (30.33%) CV>30. With 33.81 mm year-1, the total trend of IMERG precipitation in the Chad basin is likewise increasing over time. In order to support agricultural production in West Africa, the observed differences in the spreading of precipitation are probably indicative of the availability of soil moisture.

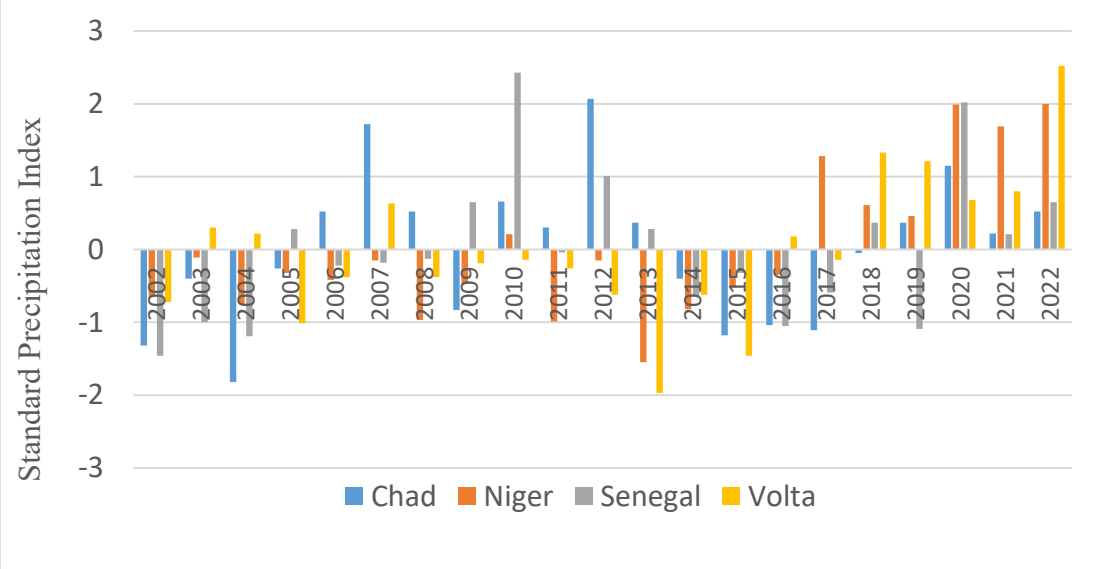


Figure 8: Standard Precipitation Index of Chad, Niger, Senegal and Volta basins
Source: Author 2025

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Variability Analysis of Satellite Precipitation in Niger Basin

Results revealed that the mean rainfall for the entire study period is 1190.36mm and the standard deviation was 313.04 calculated using equation 1, the least yearly precipitation obtained in the Niger basin was in 2013 with 706.64 mm while the peak was in 2022 with 1815.6 mm. Result also shows that there was a consistent rise in the annual rainfall from 706.64 mm in 2013 to 1592.6 mm in 2017 respectively, the rainfall pattern presented in Table 4 shows a severe wetness in 2020, 2021 and 2022 with SPI value of 1.9, 1.69 and 2,00 respectively, further result shows that 2018 has mild wetness with SPI of 0.61 while 2010 and 2019 recorded normal wetness SPI value of 0.21 and 0.46 during the study period Figure 8. Furthermore 2013 has the moderate dryness with SPI of -1.55. and for the variability coefficient of rainfall in Niger basin which was calculated using equation 2, shows the region has moderate variability with 26.29 which is (26.29%) (20<CV<30), this is consistent with the result of (Skaskevych, et al., 2020). With 5.56 mm year-1, the total trend of IMERG rainfall in the Niger basin is likewise slightly increasing over time. In order to support agricultural production in West Africa, the observed variances in the distribution of rainfall are probably indicative of the availability of soil moisture.

Table 4: Standard Precipitation Index of four river basins

Year	SPI	SPI	SPI	SPI
2002	-1.32	-0.65	-1.46	-0.72
2003	-0.40	-0.11	-1.00	0.30
2004	-1.82	-0.75	-1.19	0.22
2005	-0.26	-0.32	0.28	-1.01
2006	0.52	-0.42	-0.22	-0.38
2007	1.72	-0.15	-0.18	0.63
2008	0.52	-0.97	-0.13	-0.38
2009	-0.83	-0.47	0.65	-0.19
2010	0.66	0.21	2.43	-0.14
2011	0.30	-0.99	-0.04	-0.26
2012	2.07	-0.15	1.01	-0.62
2013	0.37	-1.55	0.28	-1.97
2014	-0.40	-0.82	-0.64	-0.62
2015	-1.18	-0.52	-0.32	-1.46

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Year	SPI	SPI	SPI	SPI
2016	-1.04	-0.35	-1.05	0.18
2017	-1.11	1.28	-0.59	-0.14
2018	-0.05	0.61	0.37	1.33
2019	0.37	0.46	-1.09	1.21
2020	1.15	1.99	2.02	0.68
2021	0.22	1.69	0.21	0.80
2022	0.52	2.00	0.65	2.52

Source: Author 2025

Variability of Satellite Precipitation in Senegal Basin

Findings in revealed that the mean rainfall for the entire study period is 299.98 mm and the standard deviation was calculated using equation 1 as 115.138, the least yearly precipitation obtained in the Senegal basin was in 2002 with 131.84 mm though the topmost was in 2010 with 580.08 mm, similarly result indicates a drop in rainfall value from 416.60 mm in 2012 to 226.76 mm in 2014. Result also indicates a constant increase in the yearly precipitation amount from 179.30 mm in 2016 to 342.77mm in 2018, respectively. The rainfall pattern presented in Table 4. shows that an extreme wetness years were detected in 2010 and 2020 with extreme wetness of SPI of >2 each, further result shows that four years, 2005, 2013, 2018 and 2021 have normal wetness with SPI of 0.28. 0.28, 0.37 and 0.21 during the study period, furthermore 2002 has the severe dryness with SPI of -1.46. also, three other years 2004, 2016 and 2019 shows moderate dryness with SPI -1.19, -1.05 and -1.09 respectively figure 8, for the variability coefficient of rainfall in Senegal basin which was calculated using equation 2, shows the region has high variability with 38.38 which is (38.38%) CV>30. The total trend of IMERG precipitation in Senegal basin is also showing slight increase over time with 2.45 mmyear^{-1}. The identified changes in the precipitation distribution are possibly to have suggest for soil wetness availability to help crop harvesting in West Africa.

Variability Analysis of Satellite Precipitation in Volta Basin

Findings revealed that the mean rain fall for the entire study period is 1417.114 mm and the standard deviation was 218.87 calculated using equation 1, the least yearly precipitation received in the Volta basin was in 2013 with 986.13 mm whereas the topmost was in 2022 with 1968.6 mm, the rainfall pattern presented in Table 5.2 shows that there are severe wetness years were detected in 2018 and 2019 with

SPI of 1.33 and 1.21, further result shows that three years, 2003, 2004 and 2010 have normal wetness with SPI of 0.30. 0.22 and 0.18 during the study period, furthermore 2013 and 2015 has the severe dryness with SPI of -1.46 and -1.97. also 2004, 2016 and 2019 shows moderate dryness with SPI -1.19, -1.05 and -1.09 respectively figure 8, for the variability coefficient of rainfall in Volta basin which was calculated using equation 2 shows the region has low variability with (15.44%) CV<20. Overall trends shows that there is increasing trend from 2002 to 2022 with 16.54 mm $year^{-1}$. The identified changes in the precipitation distribution are possibly to have suggested for soil moisture disposal to help crop harvesting in West Africa.

The study found that precipitation patterns varied and were variable throughout West Africa, especially in the four river basins that were chosen. One indicator of climate variability in the study area is the unequal distribution of precipitation. Additionally, the research area is vulnerable to both flood and drought occurrences, as indicated by the mixed SPI outcome of the wet, mild-wet, and dry periods. Studies like Macdonald, et al., (2021) have specified that such variations can negatively affect agriculture and water management, even though nearly all four river basins studied showed different variability, with the Volta basin showing low variability (15.44%), the Niger basin showing moderate variability (26.29%), and the Senegal and Chad basins showing high variability in rainfall amount for the understudied periods (38.38% and 30.33%) respectively.

Conclusions and Recommendations

This paper has offered a comprehensive evaluation of the IMERG precipitation dataset about four major river basins in West Africa: Chad basin, Senegal basin, Niger basin, and Volta basin respectively. Through a thorough analysis, we assessed the accuracy, reliability, and applicability of IMERG data in capturing rainfall dynamics within these basins. Our findings shows that while IMERG exhibits strong agreement with ground-based observations in certain areas, inconsistencies remain, especially in regions with limited in-situ data.

The performance of IMERG differs across different temporal and spatial scales, with seasonal variations affecting its accuracy. The dataset manages to perform better during high-rainfall times but may struggle with portraying acute precipitation events. Despite these limitations, IMERG remains a valuable tool for hydrological applications, climate studies, and water resource management in

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West Africa, offering a viable alternative to traditional rain gauge measurements in data-scarce regions.

Future research needs to be done and should be centered on refining satellite-based precipitation estimates through bettered calibration techniques, combination with ground-based networks, and the integration of advanced machine learning models effectively. Additionally, further research is necessary to evaluates the influence of IMERG's uncertainties on hydrological modeling and water resource planning in the region. Strengthening collaboration between meteorological agencies, researchers, and policymakers will be crucial in enhancing precipitation monitoring and supporting sustainable water management strategies in West Africa. In conclusion, while IMERG presents some challenges, its potential for improving precipitation estimation and supporting climate resilience efforts in West Africa is undeniable will further enhance its utility, contributing to better-informed decision-making and regional development.

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