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Analysing Spatial Variability of Monsoon Rainfall over West Africa

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Climate variability and changes have become a topic of increasing importance in recent decades due to extreme climate events such as floods and droughts, which profoundly impact socioecological systems across West Africa during the monsoon months. This study analyses and updates rainfall variability and spatial trends during these crucial months using monthly gridded rainfall data from 1950 to 2022. We applied the ordinary least square regression test, Buishand's, Standard normal homogeneity and Pettitt's tests for trend and change point detection analyses at a 5% significant level. The spatial variability and trends in rainfall were examined across three time periods: 1950-2022, 1963-1992, and 1993-2022. Change-point detection analysis revealed that

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there had been significant changes in the monsoon months' rainfall variability within the study period except in August. The detection of both positive and negative trends, representing trends toward wetter and drier conditions respectively, provides valuable insights for understanding and managing the impacts of climate variability and change for the most vulnerable areas.

Keywords: Trend analysis; changepoint analysis; spatial pattern; rainfall; monsoon; West Africa.

1. INTRODUCTION

Rainfall, a vital weather variable in the tropics, moderates ecological systems and is the primary water source, influencing natural vegetation, land use, and the economic viability of water-dependent sectors [1-3]. In West Africa, rainfall is predominantly influenced by the West African monsoon system [4-6]. Understanding the spatial patterns and trends of rainy season rainfall is vital for monitoring and managing the impacts of climate variability and changes [7], as rainfall changes may affect the distribution of soil moisture, runoff, and frequency of floods and droughts.

Extended or abrupt changes in climatic variables have been shown to alter the deliverable, geographical, and spatiotemporal variability of socioecological systems in a region [8-13]. Nowadays, along with the gradual trends in all the climatic parameters, exploring the abrupt change, i.e., a shift in time series, has also become an integral part of climate change and variability analysis [3,14]. A trend indicates a gradual change occurring over a specific period, while the change point occurs abruptly and often changes the weather variable, such as rainfall or temperature, into a wholly altered regime. Though studies relating to trend analysis of climatic variables enormous in scientific literature, change point analysis is still limited, especially in climate studies over West Africa [15-17]. Analysing a given climate time series without considering the change point and trend may misrepresent the time series pattern of a given phenomenon [16,18,19]. In order to avoid this challenge, analysing both trend and change points leads to an improved understanding of rainfall variability, especially in West Africa, where rainfall is the determining variable for most socio-economic development and hazards.

Previous studies have documented considerable interannual and decadal variability in West African rainfall [20-24] as well as at the intra-annual (seasonal) time scales [1,25]. while much research has been carried out over the West African monsoon region, limited research has addressed the challenge of rainfall variability from the joint analysis of trend and changepoints in climate variables in the region [26,27,17,28,29]. Using the ensemble mean of six regional climate models, Ilori and Ajayi [17] found that change points occurred in rainfall and temperature series in the 1970s and 1980s, while a significant increasing trend is observed in temperature in all climatic zones. Ogungbenro and Morakinyo [30] show common change points and transitions from dry to wet (upward shift) in all climatic zones in Nigeria. Sarr et al. [29] analysed changes in temporal trends using a Bayesian multiple change point detection procedure in thirty-one stations across Senegal from 1950 to 2007. They found that significant changes in trend were almost always consistent across Senegalese regions, with a few years' differences in the changes' occurrence dates. Sanogo et al. [31] show that most stations in the Sahel show a statistically significant positive rainfall trend for annual totals. Ndehedehe et al. [25] found notable declines (approximately 40 mm/year) in rainfall in Guinea and Nigeria during 1980–1989, Cameroon and eastern Nigeria showed declines in rainfall during the 2000–2009 period and over most parts of the coastal areas of the Guinea coast during 2010-2016 period.

However, in recent times, there have been limited studies on the spatial trend and changes in rainfall over the West African region. While the above-reviewed studies and others have explored rainfall trends and variability in the region, there is still a need to re-examine the spatial pattern and trend in rainfall during the monsoon months over West Africa in order to understand better the nuanced pattern of recent changes in rainy season pattern over most parts of the region. This paper, therefore, provides an updated analysis of ongoing rainfall changes in the monsoon season (June–September) using high-quality rainfall observations from 1950 to 2022. Three distinct periods were considered for the spatial pattern: 1950-2022, 1963-1992, and 1993-2022. The period from 1950 to 2022 provides a robust basis for trend analysis for the entire study period, while the sub-periods 1963-1992 and 1993-2022 explore shifts corresponding to different climate phases in the region.

2. MATERIALS AND METHODS

2.1 The Study Area

West Africa extends from latitudes 2 to 25 degrees north and longitudes 20°W to 15°E of the Greenwich meridian (Fig. 1). The region is bordered by the Atlantic Ocean to the south and west, Western Saharan, Algeria and Libya to the North, Chad and Central African Republic to the east, with a total land and water area of approximately 7,832,486 km². The region's rainfall pattern follows the seasonal movement of the Inter-Tropical Discontinuity that reaches its northernmost position of 21°–22°N in August [32].

2.2 Data

We use gridded observational monthly rainfall product from the Climate Research Unit (CRU) TS v. 4.07 [33], which covers only lands at a resolution of 0.5° and spans from 1901 to the present. CRU absolute monthly values of climate variables were derived from the combination of an existing climatology and the station anomalies interpolated into grid cells covering the global land surface (excluding Antarctica). The sources of CRU monthly climate data were mainly from the World Meteorological Organization internationally exchanged stations (~2400 stations), National Climatic Data Center stations for WMO (~1500 stations), and the World Weather Records decadal data publications (~1700 stations) [34]. The CRU data sets have been extensively used in rainfall studies

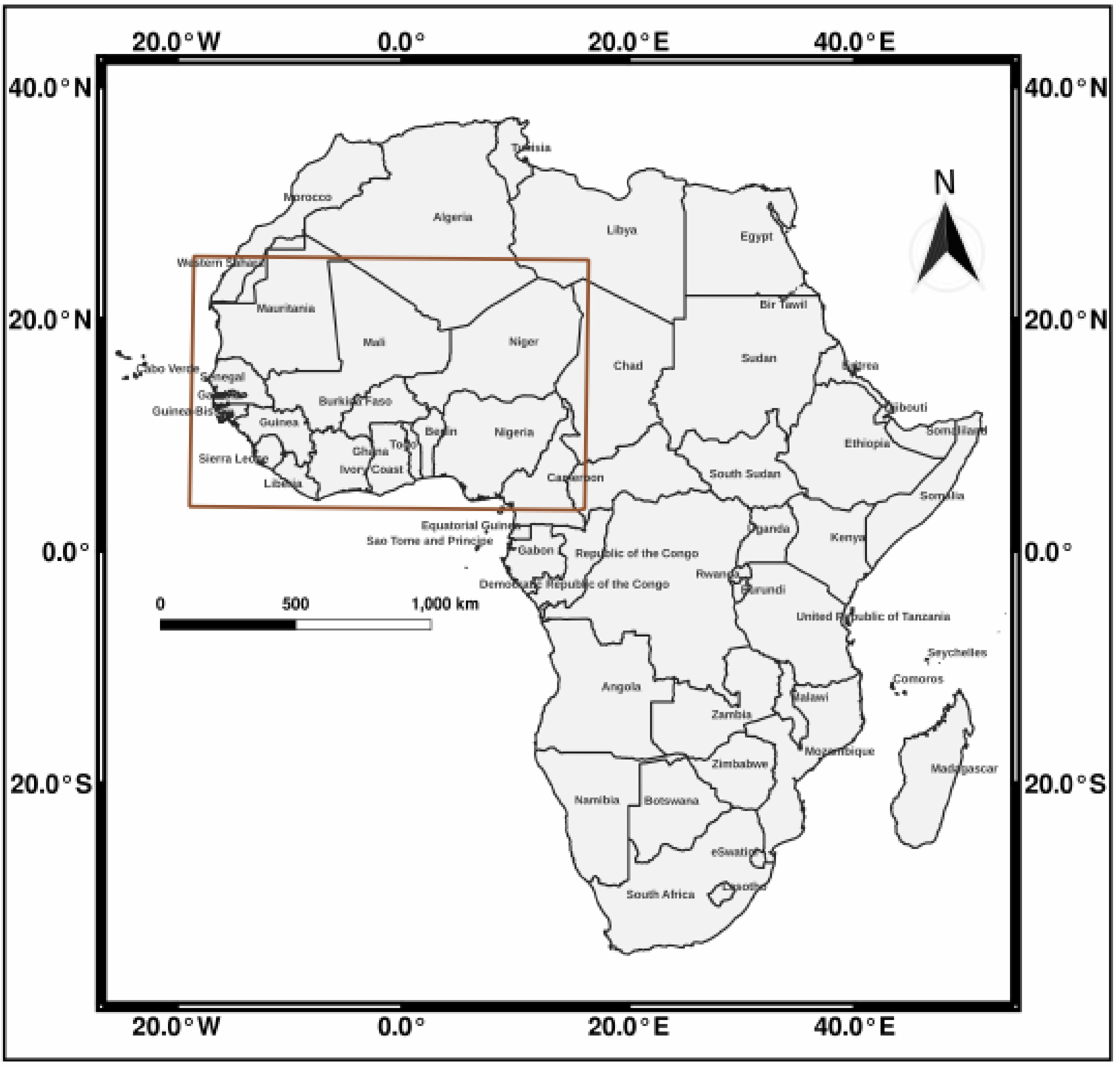

Fig. 1. Africa showing the study area enclosed in a rectangle

in West Africa. This study specifically focused on June-July-August-September, which jointly accounts for more than 58% of the annual rainfall regime in the Guinean Coast and 84% in the Sahel [6].

2.3 Data Analysis

The mean statistic is used in the study to determine the mean state of rainfall in the study area between 1950 and 2022. The standard deviation shows the absolute variability in rainfall for the three study periods.

Spatial patterns and trends are assessed using parametric trend analysis and spatial autocorrelation methods. This method involves applying a linear equation to the collected dataset, establishing a relationship between two variables: the dependent variable and the independent variable. The following equation typically represents the linear regression model:

$$Y = a + bX \quad (1)$$

where Y is the dependent variable, X is the independent variable, b is the slope of the line, and a is the intercept constant. A positive and negative value of b indicates that the data tend to increase or decrease with time, respectively. The t-test determines whether the linear trends significantly differ from zero at the 5% significance level.

Three single changepoint detection methods were employed in the study: the Pettitt test, the Buishand range test and the Standard Normal Homogeneity Test. A brief description of these methods is presented below:

Pettitt's test (PT) [35] is commonly used to detect a single change point in a time series with continuous data. In this test, the null hypothesis (H_0), which states that no change exists in the time series, is tested against the alternative hypothesis (H_1) with changes in the mean. The significance level at α = 0.05 (95%) was also used in this test. The tests can recognise shifts in time series and their corresponding year of change.

The Buishand range test (BRT) [36] detects shifts in the mean of any given time series by comparing the cumulative deviations from the mean before and after the times of discontinuities. It is calculated as:

$$R_b = \frac{maxS_k - minS_k}{\sigma}, where S_k = \sum_{i=1}^{k}(x_i - \acute{x}) \quad (2)$$

The p-value is considered with a Monte Carlo simulation by m replicates.

Standard Normal Homogeneity Test (SNH) [37] compares the mean of the first n observations with the mean of the remaining (n–k) observations with n number of data points.

The Pettitt test is a nonparametric test that does not require the assumption of a normally distributed time series; the opposite is true for the Buishand range test and the Standard Normal Homogeneity Test (SNH) [26].

The spatial trend was analysed for three periods: the whole period (1950 to 2022), the drier period (1963 to 1992), and the more recent period (1993 to 2022).

These methods allow for identifying hotspots where significant increases or decreases in rainfall have occurred, thereby providing insights into the regional pattern of rainfall variability.

3. RESULTS AND DISCUSSION

The mean annual cycle of rainfall (Fig. 2a) shows that the rainy and dry months are well-defined over West Africa. Here, we define rainy(dry) months as those with mean rainfall above (less than) 50 mm. The rainy season occurs between April and October, while November to March are the dry months. The three periods under investigation depict a similar seasonal cycle, with the four months with the highest rainfall being August and September (shaded months). These four months account for most of the annual rainfall and experiences the highest year-to-year variability, as depicted in Fig. 2b. The 1963-1992 period witnessed the highest level of variability, while the 1993-2022 period experienced relatively the most minor variability among the three periods. August is the month with the most rainy and variable over the study area, and its rainfall amount has increased considerably in the 1993 to 2022 period relative to the entire period and the 1963-1992 periods, respectively. This pattern signifies that the rainy months exhibit the most variability, significantly impacting planning as the expected rainfall tends to vary yearly. Subsequent results are presented only for the four core rainy months.

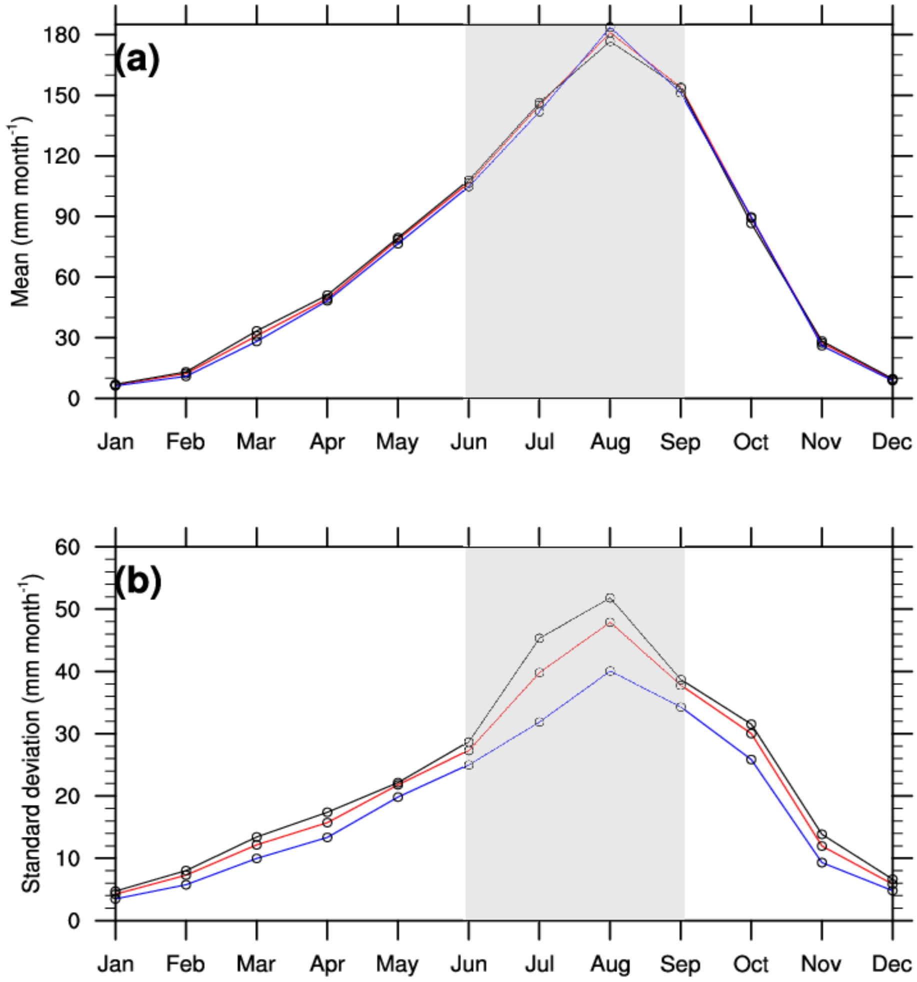

Fig. 2. Seasonal cycle of the (a) mean and (b) standard deviation of rainfall averaged over West Africa during the three study periods: Red (1950-2022), black (1963-1992) and Blue (1993-2022)

The spatial patterns of the rainy month's rainfall over West Africa are shown in Fig. 3a-d. In June (3a), the mean rainfall is concentrated along the coastal areas, particularly in the western regions, with rainfall amounts ranging from 50 to 450 mm per month. Central and eastern parts of the Sahel exhibit minimal rainfall. Moving to July (3b), the rainfall extends further north into the Sahel, with similar intensity and a notable increase in rainfall over the sudanian region. August (3c) shows the peak of the rainy season, with the highest rainfall (450-950 mm per month) occurring in the coastal areas of West Africa, particularly over Sierra Leone, Liberia, and the western parts of Nigeria. The rainfall belt extends significantly northward, encompassing much of the Sahel region. By September (3d), the rainfall patterns remain robust, with high rainfall amounts persisting along the coastal regions and slightly reduced but still significant rainfall across the Sahel. The heaviest rainfall areas in September are similar to those in August, but the intensity decreases slightly.

Fig. 3e-h show the standard deviations of rainfall over the rainy month in West Africa. The spatial variation of rainfall exhibits homogenous and zonal patterns in different rainy months, with the variability highest in areas with higher mean rain, such as the coastal areas of West Africa. In June, the highest variability on a year-to-year basis occurs most around the Guinea to Ghana coasts, Niger Delta and Western Cameroun. These areas record a variability of more than 200mm. Also, in the areas north of Latitude 16 degrees, some parts of Nigeria record less variability with rainfall standard deviation less than 50 mm yearly. A similar pattern is observed in July to September, especially over the coastal areas. However, in July, variability of about 150mm occurs around the Lake Chad basin and the coastal regions.

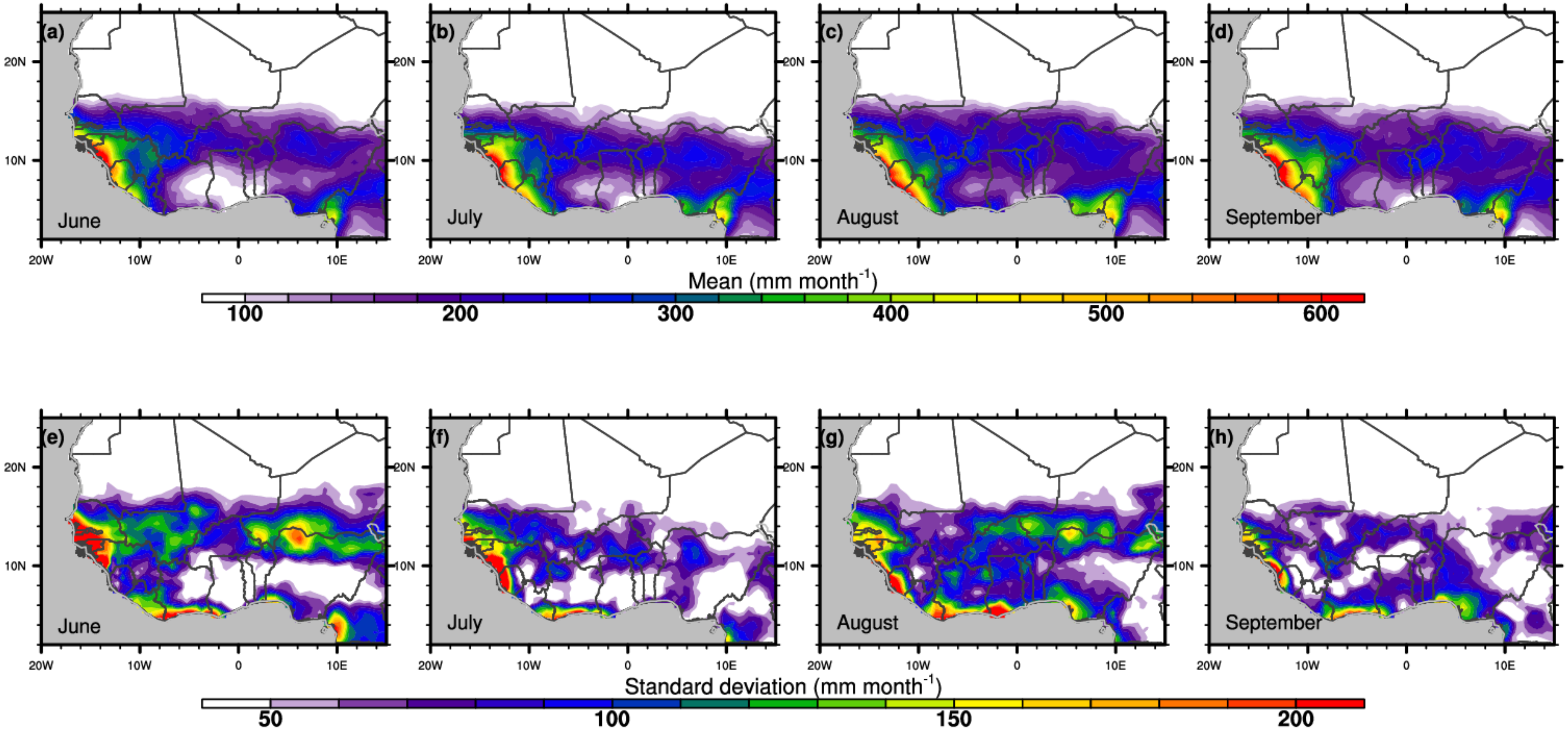

Fig. 3. Rainy months mean and standard deviations of rainfall over West Africa (1950-2022)

The absence of notable differences in the annual cycle of mean rainfall during the three periods buttresses the idea that the mean annual rainfall cycle has remained relatively the same during the three periods. This may be due to variability in intraseasonal rainfall properties such as frequencies, intensity and duration [38,39]. The observed variability in the annual cycle (Figs. 2b and 3b) shows notable temporal changes in the three periods, as months and areas of higher rainfall occurrence depict higher variability. June, July and September show a significant decline, while August rainfall trend has remained relatively stable over the entire period. Since the Sahel pattern of rainfall variability is the leading mode of West African rainfall, this result supports Nicholson [1], who states that anomalies in August and September significantly contribute to the enhanced inter-annual variability in Sahel rainfall. A similar result was reported by Djaman, Sharma, Rudnick, and Koudahe [40] for Togo.

Fig. 4 depicts the interannual rainfall variability over West Africa during June, July, August, and September from 1950 to 2022. Each panel (a-d) represents a different month, showing standardised rainfall anomalies with a superimposed linear trend line. The blue bars represent positive anomalies, indicating wetter-than-average conditions, while the red bars denote negative anomalies, corresponding to drier-than-average conditions. The trend for each month is also indicated in the upper right corner of each plot.

In June (Fig. 4a), the trend is significantly negative at -0.17 mm/yr, indicating a gradual decline in rainfall. The rainfall variability shows a significant shift around the 1970s, with more frequent negative anomalies from the late 1960s to the 1980s, corresponding to a period of dryness. However, from the 1990s onward, there was an increase in positive anomalies, suggesting some recovery, though the overall trend remains negative. For July (Fig. 4b), the trend is more pronounced at -0.28 mm/yr, highlighting a more substantial decline in rainfall over the years. The 1950s and 1960s show frequent positive anomalies, while the 1970s to the late 1980s are marked by persistent negative anomalies, reflecting significant drought events. Although there is a slight increase in positive anomalies after the 1990s, the negative significant trend indicates an overall reduction in July rainfall. In August (Fig. 4c), the trend is almost neutral at -0.01 mm/yr, suggesting that there is little to no long-term change in rainfall during this month over the observed period. The anomalies are more evenly distributed between positive and negative values, indicating considerable interannual variability without a strong trend. This could imply that while there have been periods of both dry and wet conditions, the overall rainfall in August has remained relatively stable over the decades. September (Fig. 4d) shows a negative trend of -0.21 mm/yr, indicating a reduction in rainfall over time, though not as strong as in July. The anomalies reflect a pattern similar to July's, with more positive anomalies in the 1950s and 1960s, followed by more frequent and intense negative anomalies during the 1970s and 1980s. From the 1990s onwards, there was an increase in positive anomalies, yet the overall downward trend suggests a decrease in rainfall during September.

These plots collectively illustrate the changing nature of the West African monsoon. There has been a noticeable decline in rainfall during the core monsoon months, particularly in July and September, likely influenced by broader climate variability and trends.

Table 1 shows the results of the single changepoint analysis for rainfall during the monsoon months. Here, we employed PT, SNH and BRT. In June, the three changepoint tests detected the same year of significant change in 1969. In contrast, in July, all three showed a significant change; the Bushand range test and Pettitt's test showed the change year to be 1974, while the Standard Normal Homogeneity test year of change was 1969. In August, all three methods detected the same 1971 as the probable year of change; BRT classified the change as significant, while SNH and PT showed otherwise.

Furthermore, in September, significant change was detected in all the changepoint point methods; however, they show different years of change: BRT (1971), SNH (1967), and PT (1970). These divergent change point characteristics indicate differing algorithms and dynamics of rainfall variability in the region.

The three change point methods detected significant shifts in rainy months' rainfall in the late 1960s and early 1970s, with statistically significant changes in June and September. This is in contrast with the findings of Ilori and Ajayi [17], who detected no change point in rainfall over the Sahel region of West Africa during

1961-2000 in all three change point detection methods. The difference may be due to differing periods and temporal scales.

Fig. 5 presents the spatial patterns of June rainfall trends over West Africa for three periods. The rainfall trends are measured in mm/year and are colour-coded, with blue shades indicating increasing trends and red shades indicating decreasing trends. The scale ranges from -4 mm/year (dark red) to +4 mm/year (dark blue). Areas with statistically significant trends are marked with black dots. During 1950-2022 (Fig. 5a), notable increases in rainfall are observed in regions of central and eastern Nigeria, northern Ghana, and parts of the western Sahel (southern Mauritania, north of Senegal). At the same time, significant decreases are seen along the Guinea coast, particularly in southern Guinea, Sierra Leone, and Liberia.

In Fig. 5b, few regions show increasing trends. Some increases are observed in northeastern Nigeria and parts of southern Mali, with extensive decreasing trends evident across the Guinea coast, including Guinea, Sierra Leone, and Liberia, extending into south Cote d'Ivoire and Ghana during 1963-1992. However, Fig. 5c depict the rainfall trend from 1993 to 2022, with central Nigeria and parts of the western Sahel (southern Mauritania, northern Senegal) showing increase in rainfall. Significant decreases are observed along the Guinea coast and southwestern Nigeria, extending into parts of the southern Cote d'Ivoire and Ghana.

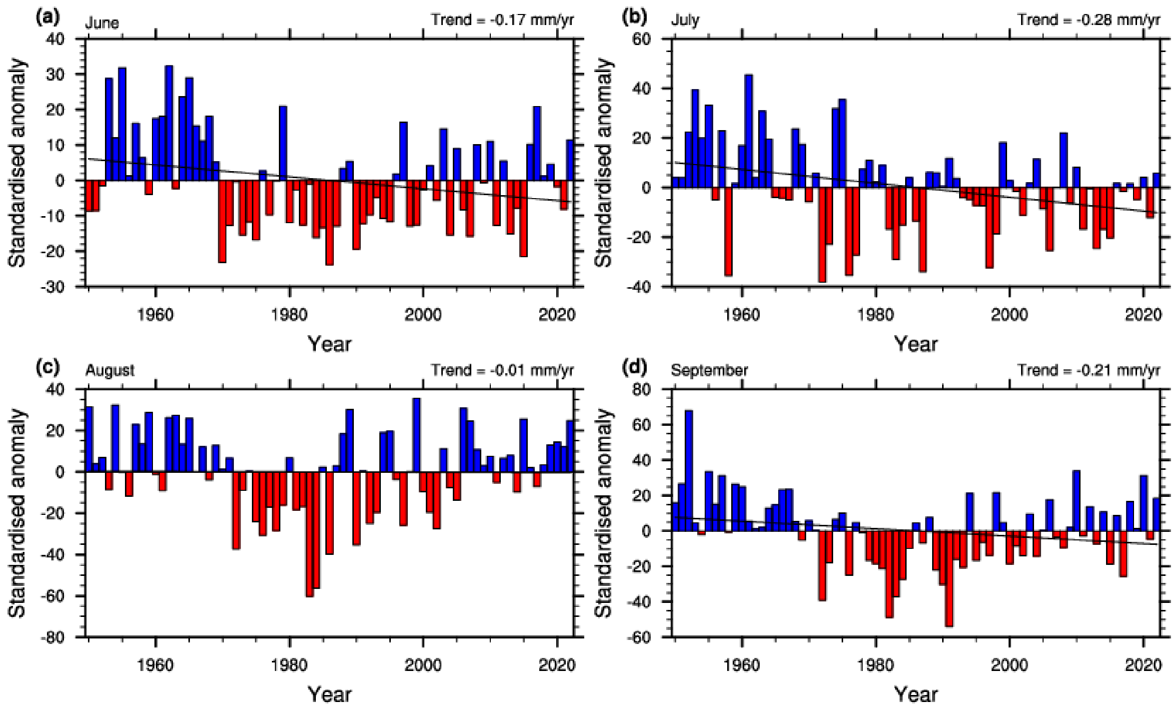

Fig. 4. Interannual variability of rainy months rainfall over West Africa

Table 1. A single change point analysis for West African domain-averaged rainfall (1950-2022) showed significance at a 95% confidence level

Month	Buishand range test		Standard normal homogeneity test		Pettitt's test	
	Year of change	Significance	Year of change	Significance	Year of change	Significance
June	1969	Significant	1969	Significant	1969	Significant
July	1974	Significant	1969	Significant	1974	Significant
August	1971	Significant	1971	Not significant	1971	Not significant
September	1971	Significant	1967	Significant	1970	Significant

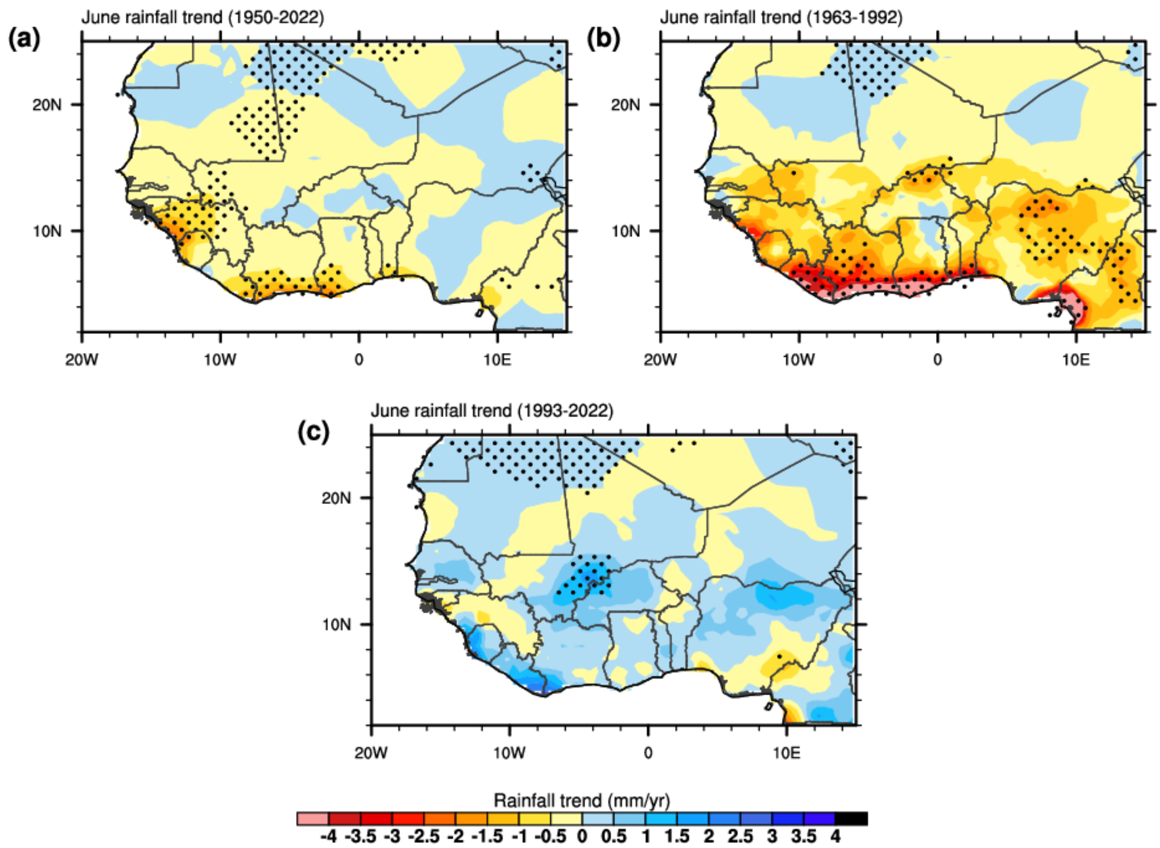

Fig. 5. Patterns of June rainfall trend over West Africa for a) 1950-2022, b)1963-1992, and c) 1993-2022

Fig. 6 illustrates the spatial patterns of July rainfall trends over West Africa for the three distinct periods. During the entire study period (Fig. 6a), the northern parts of West Africa, particularly northernmost part of Mali, some parts of Niger and southeastern Burkina Faso show significant increasing rainfall trends. Significant decreases are observed in southern Nigeria, the coast of Sierra Leone, southwestern Niger and most parts of Western Sahel. Furthermore, in Fig. 6b (1963-1992), slight increases occur in southeastern Nigeria and small parts of the Sahel, while widespread decreases are evident across the Guinea coast, including southern Guinea, Sierra Leone, and Liberia, and extends into parts of southern Mali and Burkina Faso.

From 1993 to 2022, significant trends are observed in central Nigeria, parts of southern Mali, and the western Sahel. Decreases are prominent along the Guinea coast, especially in southwestern Ghana and southeastern Nigeria, with additional declines in southwestern Mali.

Apparent differences and some consistent trends emerge when comparing the patterns across the three periods. The long-term period (1950-2022) reveals a mix of increasing and decreasing trends, with significant decreases along the coastal regions and some increases in the Sahel. 1963-1992 shows extensive decreases, particularly along the Guinea coast, reflecting the historical drought prevalent during this time. In contrast, the recent period (1993-2022) indicates a shift, with some areas in the Sahel and central Nigeria experiencing increases, while the Guinea coast continues to exhibit significant decreases. This suggests a possible recovery in specific regions juxtaposed with ongoing drying in others.

The observed rainfall patterns significantly affect water resource management, agriculture, and socio-economic stability in West Africa. Regions experiencing increasing rainfall, such as parts of the Sahel and central Nigeria, may face challenges related to flooding, soil erosion, and changes in agricultural practices. Conversely, areas with decreasing trends, particularly along the Guinea coast, must address water scarcity, drought resilience, and food security issues.

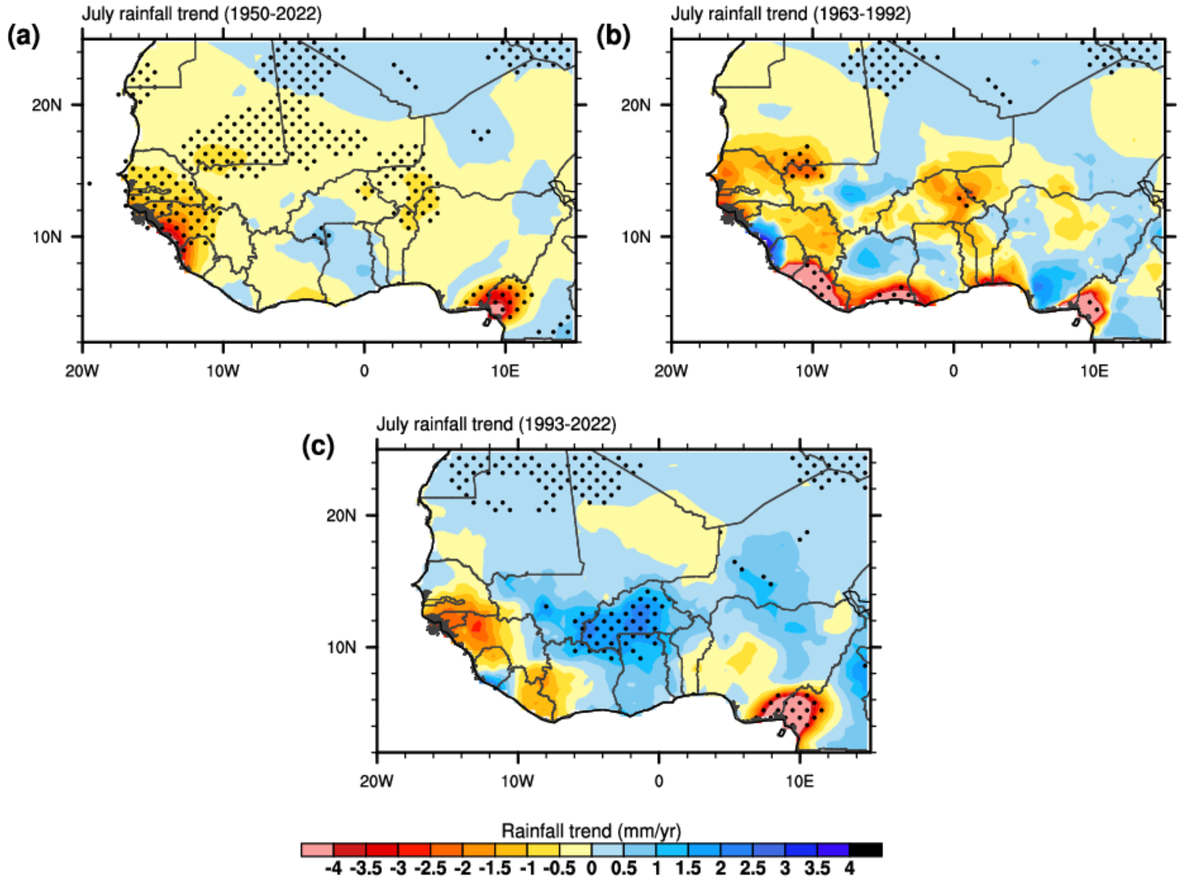

Fig. 6. Patterns of July rainfall trend over West Africa for a) 1950-2022, b)1963-1992, and c) 1993-2022

Fig. 7 presents the spatial patterns of August rainfall trends over West Africa. During 1950-2022 (Fig. 7a), increases in rainfall are observed in the Guinea coast region with significant areas including Liberia, central parts of Ghana, Togo, Benin and Nigeria. Most parts of the Sahel region show decreases in rainfall with significant areas including northwestern Niger, central Mali and northwestern Nigeria, with few isolated areas of substantial increase, mainly in the Sahel region. Rainfall decreases are observed along the Guinea coast (particularly between southwestern Nigeria and eastern Cote D'Ivoire), with a significant decline around the Adamawa axis of northeastern Nigeria. For the 1963 to 1992 period (Fig. 7b), extensive decreasing trends are evident across the Sahel and Guinea coast regions, with minimal areas showing an increasing trend. Significant decreasing areas are evident in northern Nigeria, Guinea, Mauritania, Mali, Burkina Faso, north of Cote d'Ivoire and Niger. However, Fig. 7c shows that most parts of the Sahel show an increase in rainfall, with significant areas observed around the eastern part of Niger extending to northeastern Nigeria and central Mali extending to northern Burkina Faso. The western part of Sierra Leone, central Ghana, up to Cameroun, shows decreases in rainfall in August, with slight insignificant increases along the coastal areas of western Nigeria up to Liberia.

Fig. 8 illustrates the spatial patterns of September rainfall trends over West Africa across three periods. From 1950 to 2022 (Fig. 8a), rainfall increased significantly in northern and eastern Mali and southwestern Nigeria, although most of the region shows non-significant increases and decreases. From 1963 to 1992 (Fig. 8b), extensive rainfall decreases are observed across the Sahel and Guinea coast regions, with only a few isolated areas showing increases. Significant decreasing trends are widespread, especially in western West Africa, the Sahel, and eastern Nigeria. In the recent period from 1993 to 2022 (Fig. 8c), there is a notable increase in rainfall in most parts of the Sahel and Guinea coast, with significant increases around the Sene-Gambia, northeastern Cote d'Ivoire, southern Ghana, and western Nigeria. However, significant decreases in rainfall are observed in Liberia and northeastern Mali.

The spatial pattern of the long-term analysis shows a mixed pattern of increasing and decreasing trends across West Africa. The western Sahel and part of central Nigeria exhibit increasing trends, indicating a general intensification of the monsoon rains in these areas. Conversely, the Guinea coast domain shows significant decreasing trends, highlighting the region's vulnerability to drying conditions over the long term. The period (1963-1992) is marked by widespread decreasing trends, especially over the Sahel region in all months, which aligns with the known historical drought periods that affected the Sahel and surrounding regions [1,20]. The recent period (1993-2022) continues mixed trends. While some regions, particularly central Nigeria and parts of the western Sahel, have experienced increasing rainfall, the Guinea coast shows significant decreasing trends [25].

Furthermore, interesting regional hotspots of increasing and decreasing rainfall are observed over West Africa for the different monsoon months. An increase in rainfall is consistently observed in parts of central Nigeria and the western Sahel, especially between eastern Mali and Burkina Faso, indicating regions where the monsoon rains have been strengthening, especially in recent periods. This corroborates the findings of Daramola et al., [41], Ndehedehe et al., [25] on the intensification of extreme rainfall events in West Africa. Also, decreasing rainfall dominates the Guinea coast domain, especially southern Guinea, Sierra Leone, and Liberia, where persistent drying trends are observed [42]. This mixed pattern of rainfall changes across different parts of West Africa raises severe concerns for water resource management and agricultural productivity in these regions.

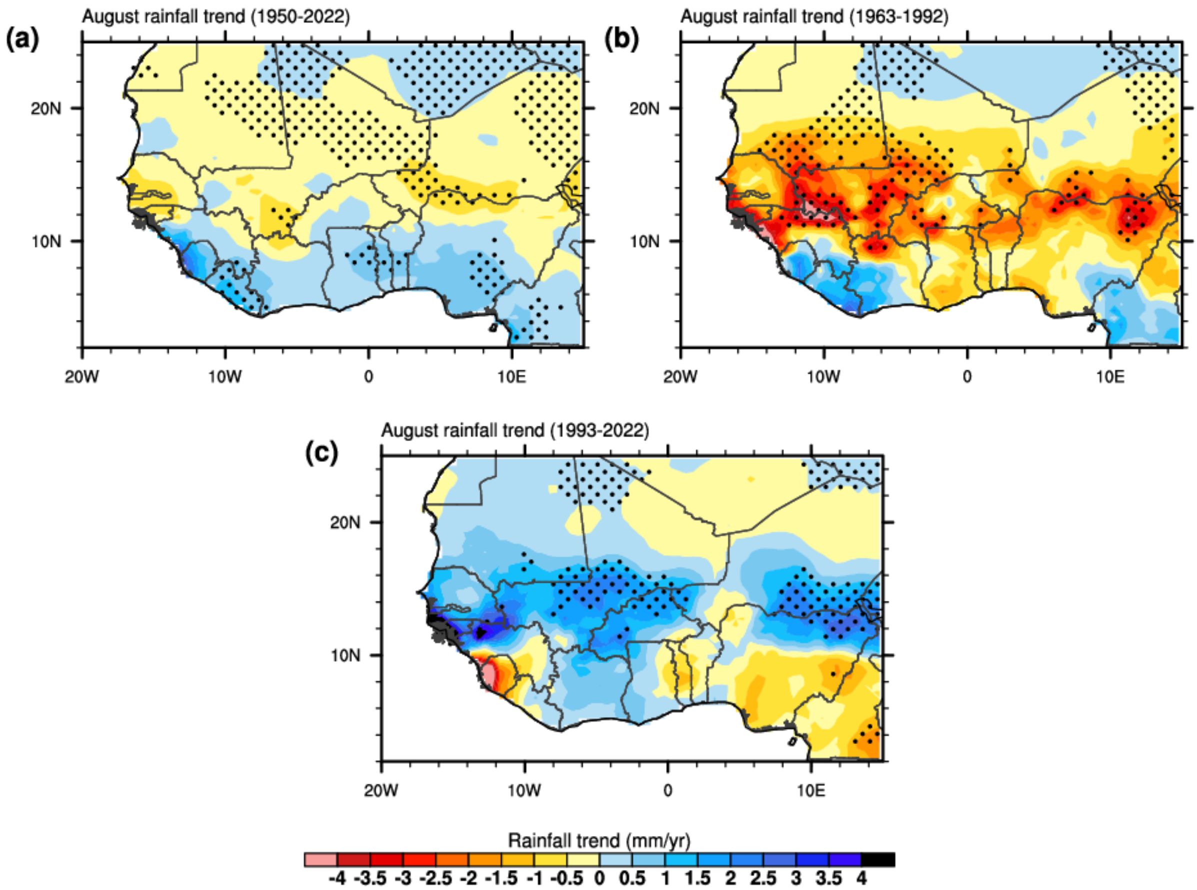

Fig. 7. Patterns of August rainfall trend over West Africa for a) 1950-2022, b)1963-1992, and c) 1993-2022

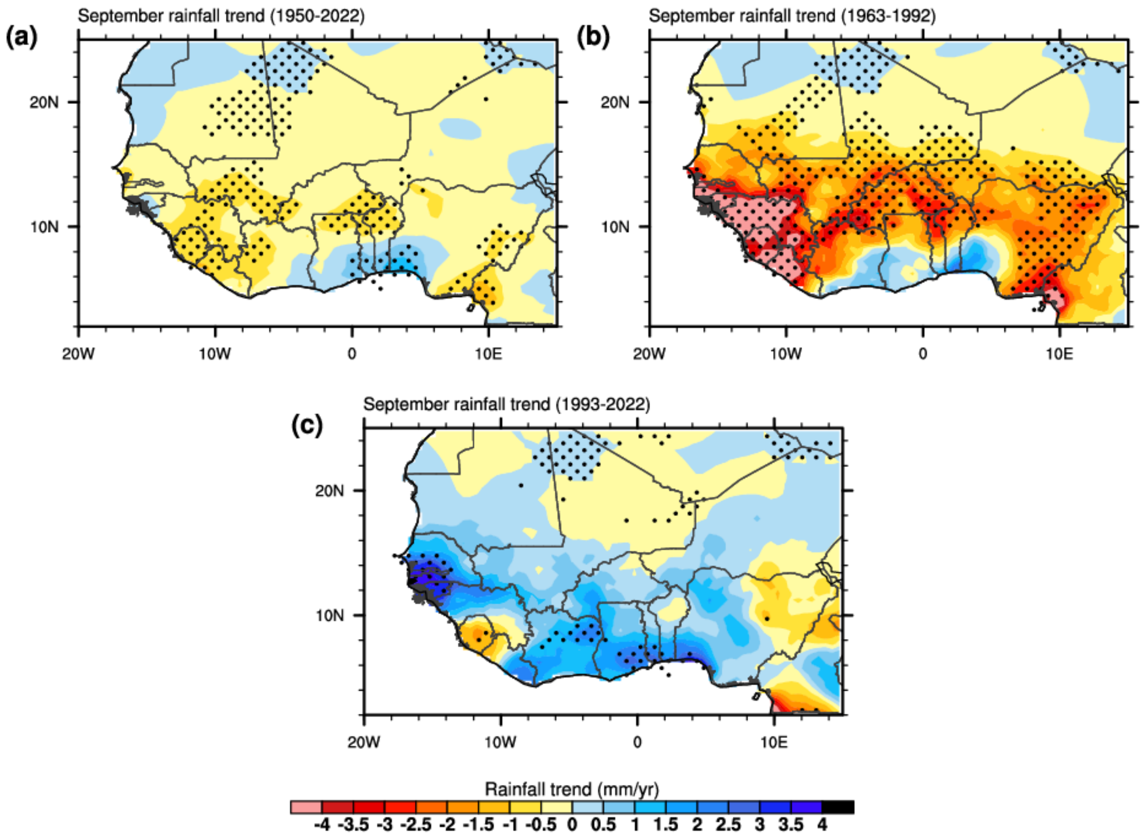

Fig. 8. Patterns of September rainfall trend over West Africa for a) 1950-2022, b)1963-1992, and c) 1993-2022

4. CONCLUSION

This study has analysed and updated the information on West African rainfall variability and trends during each monsoon month using monthly gridded rainfall data from 1950 to 2022. The findings reveal significant increases in rainfall, particularly in the western Sahel, during June and July. In contrast, August and September show mixed trends, with increases and decreases observed across different regions. The temporal analysis shows a significant decreasing trend in June, July and September rainfall, with significant changepoints in 1969,1974,1971,1971 for the four monsoon months, respectively. Rainfall in August is more persistent, with little changes relative to the other monsoon months.

Furthermore, the various changepoint detection methods show divergent results. Distinct spatial patterns and trends in monsoon rainfall variability were observed across the three periods and months analysed. The two sub-periods, 1963-1992, were marked by extensive drying across the Sahel, while 1993-2022 shows a more nuanced pattern, with some regions experiencing recovery and others continuing to dry. For the whole period (1950 to 2022), specific regions, such as the western Sahel, exhibit significant increases in rainfall, while others, like parts of the Guinea coast, show pronounced decreasing trends in Guinea and Sierra Leone coastal areas. The period (1963-1992), often associated with the prolonged Sahel drought, highlights widespread drying across much of the region in all months.

Conversely, the post-1993 period indicates a partial recovery in rainfall amounts in some areas, especially the Western Sahel (between eastern Mali and Burkina Faso) and significant drying in some parts of the Guinea coast. These findings underscore the necessity of continuously monitoring climatic variables' temporal and spatial patterns, especially rainfall in the region. While our results are robust, there may be limitations due to the possibility of inherent biases in the gridded dataset compared to in-situ-based data due to the region's limited number of meteorological stations. This study paves the way for future research that should focus on comparing the findings with insitu data especially over the hotspot areas. Also, it will be worthwhile to examine the underlying mechanisms driving these changes, including the role of sea surface temperature anomalies, land-use changes, and other climatic factors. This study contributes to the existing body of knowledge by providing a detailed and comprehensive analysis of rainfall variability over an extended period and for each monsoon month, which will enhance the development of effective mitigation and adaptation policies to address climate change and disaster risk impacts in the various hotspots and West Africa in general.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts. The paper's grammar structure was enhanced using Grammarly.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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