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CHARACTERISATION OF RAINFALL PATTERN IN NORTHERN NIGERIA

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ABSTRACT

In this work, attempt was made to characterise rainfall pattern in Northern Nigeria. Investigations were carried out by using rainfall data from selected gauging stations across the hydrological areas; Three statistical tests: (i) statistical moment (ii) Analytic studies of annual rainfall cycles and (iii) detection of drought signature via standardised anomaly were explored for this analysis. The results obtained indicated that most observed stations showed significant pattern in the series. For instance, rainfall statistical moment portrayed that HA 1 has a mean annual rainfall of 194cm with standard deviation of 16.79cm and HA 3 and HA 8 jostled for the less for example HA 3 had annual mean rainfall of 76.207cm and substantial standard deviation that stood at 21.598cm which is quit debilitating whereas HA 8 scored the least mean, that is 36.175cm and outrageous standard deviation of 24.700cm. In this context, incidence of rainfall seems to decreases with a sequential increment of latitudinal signatory. In addition, notable years of extreme dryness are 1976, 1978,1983,1984, 1986, 1987, 1972, 1973,1974 and 1976 and this probably informed the classification of the whole Northern Nigeria as a slightly dry region when considered in the period understudy. In addition, general pattern for the entire HAs shown that for the period under consideration the rainfall increasing at an average rate of 6.10% per annum for whole Northern Nigeria, a factors sufficient to sustain rain fed agriculture. Considering the results obtained, there is need to examine other hydrometeorology variables in addition to rainfall in order to have a thorough understanding of the time-space dependent behaviour of the hydro-meteorological processes and their correlating aggregate effects. It is pertinent therefore that several statistical approaches should be used to capture trend and mutations; as one approach may not truly give a snapshot of` hydrological variability in a particular basin; i.e., for purposes of drawing effective conclusions.

Keywords: Nigeria, Northern, Rainfall, Drought, Climate and Pattern

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INTRODUCTION

Considering the recent and potential future increases in global temperatures and changes to precipitation, it has been indicated that climate change may come with changes in the frequency and severity of extreme events such as drought and flood (Intergovernmental Panel on Climate Change (IPCC), 2007). Rainfall remains the most important of all the climatic variables such that the amount, intensity, duration, variability and its spatial and temporal distribution influence all economic activities especially in the tropical region where prevailing economic activity is simply agro-based (Emeribe *et al.,* 2017). Therefore, thorough insight into rainfall pattern is a sine qua non for healthy ecological detailing as well as a right step towards optimal managing of scarce water resources that was perceived under incessant stress in Northern Nigeria due to increased water demand, increase in population and economic development. As noted in the submission of Kipkorir (2002). Rainfall is the meteorological phenomenon that has the greatest impact on human activities and the most important environmental factor limiting the development of the semiarid and arid region (Kipkorir, 2002). Typically, in Nigeria the dominant attribute of rainfall is its seasonal behaviour. The rainfall supposedly known with a remarkable variability from year to year which is attributed to the fluctuation in the movement of the two different dominant air masses, the Inter Tropical Discontinuity (Ayoade, 1973). The variability of rainfall and the pattern of extreme high or low precipitation are very important for agriculture as well as the economy of the state. It is well established that the rainfall is changing on both the global and the regional scales due to global warming Hulme,1998). The knowledge of climate variability over the period of instrumental records and beyond on different temporal and spatial scale is important to understand the nature of different climate systems and their impact on the environment and society (Oguntunde *et al.,* 2012).

Despite, recent advances made in science and technology, farmers and their crops are still left at the mercy of rainfall especially in Sub-Saharan Africa, where the Northern region of Nigeria lies. In the light of the foregoing, it is pertinent to regularly characterise rainfall pattern in Northern Nigeria. Reviewed literature revealed dearth of literature that extensive characterised rainfall pattern in the concern region. For instance few related studies was Adefolalu (1986) that studied rainfall trends in Nigeria not northern Nigeria exclusively, it was a fragmental study though, with sole objective determining climatic signatory capable of transmitting drought pattern to Northern Nigeria, in the overall it lacked specific intent. However, failed to adequately appreciate the fact Nigeria is marked by admixture or heterogeneous climatic component and distinctive ecological system, as Sahel and Sudan may have seemingly similar hydro-climatic variability and slight graduation as move down the Guinea savannah and changes rapidly at verge rainforest. However, seemingly pattern observed in the Northern Nigeria will constituted a gap which this research will investigate thoroughly. Consequent on lack of century data, most of related studies were based on records that terminate in the late 1980s and the early 1990s (Ayoade, 1973; Hulme 1998 and Lamb 1983). Though, Mustapha et al. (2018) used monthly rainfall amount data of fourteen synoptic stations in some parts of Northern for the period of forty-two years (1971-2012), though still considered old and not enough in the face of swift climatic variability. The huge implication of this; that their submission may have lost touch with hydro-climatic reality, at such out of phrase with revolving climatic changes or global warming. Emeribe *et al.* (2017) performs a fragmented studies of inter-decadal nature of rainfall character specifically for Sokoto-rima river basin, Northwestern Nigeria but do not factor in implication of transboundaries as station and city at the fringes often shares similar hydro-climatic relation therefore, concluded result may show remarkable deviate in face fringe stations. Hence, there is need to look at rainfall characterisation through spectral of basins via designated hydrological areas (HAs) for the whole Northern Nigeria. Suffice to note, that the central theme of this research is characterised rainfall pattern in Northern Nigeria, on the basis of HAs.

MATERIALS AND METHODS

Study Location and Data Assembly

The study location Northern Nigeria is located between 10^{o}N - 14^{o}N and 4^{o}E - 7^{o}5̓E. It belongs to arid and semi-arid region of the country, precisely of a predominantly Sudan vegetation. It is characterised by a distinct bi-seasonal weather pattern; i.e., wet and dry. The wet season starts in April and ends in October, while the dry season starts in November and ends in March (Sombroek and Zonneveld, 1971). **Figure 1** shows the map of HAs in Northern Nigeria. For this study, historical rainfall time series of over 50years (1971-2021) from the region was used. To do this, mean monthly rain gauge rainfall values (i.e., point rainfall) for substantial decadal time period were collected from NIMET and River Basin Development Authority Zonal offices across the catchment States of Katsina, Kano, Minna and Sokoto respectively.

Figure 1: Hydrological areas in Northern Nigeria

Method

Microsoft excel statistical software package and Statistical R programming language were used for the analysis. The data were subjected to statistical analysis using measures of central tendency such as mean, mean deviation and median; measures of dispersion such as range, variance and standard deviation as well as a measure of relationship (coefficient of variance).

Mean = $\frac{\sum_{i=1}^{n} X_i}{n}$

Variance = $\frac{\sum_{i=1}^{n}(x-x_i)^2}{n-1}$

Coefficient of Variation(CV) = $\frac{SD}{\bar{X}}$X100 Where:

SD is standard deviation = $\sqrt{\frac{\sum_{i=1}^{n}(x-x_i)^2}{n-1}}$

RESULTS AND DISCUSSION

Evaluation of General Stochastic Characteristics of the Rainfall Moments

Table 1 shows the values of statistical moments for annual total series for the hydrological areas (HAs). The values indicate significant dispersion or deviation from normality over the entire HAs, but more staggering value were obtained in HA 8 and 3; predominant in Sahelian region, known for sporadic occurrence of hydrological phenomena. Whereas, slightly dispersion was observed in HA 1. For example the average kurtosis and standard deviation values of HAs,1, 3, 4 and 8 were relatively high connoting substantial peakness and extreme deviation from the mean respectively, Inference from Table 1 showed that HAs, 1, 2, 3, 4 and 8 had coefficient of variation (CV) of 56%, 18.7%, 48.12%, 17.18% and 53.01% respectively of the total data length considered. According to Hara (2023**),** CV was used to classify the degree of variability of rainfall events as less (CV < 20), moderate (20<CV<30), and high (CV>30). Based on this, it suffices to note, rainfall is highly variable at HA 1, 3,4 and 8 which covered 80% of the Northern Nigeria. The findings from Table 1 further indicated that significant increase or decrease in precipitation, may distort statistical properties of candidate distribution, for example rainfall maximum of 253.275cm of HA 1 birthed increased skewness and kurtosis of annual precipitation of the surmised distribution. In a similar routine, a reduction of rainfall markedly intensified the interaction of the skewness and the kurtosis, while the skewness–kurtosis interaction weakened with decreased maximum rainfall in stations across the HA Hara (2003) affirmed that. Moreover, it was observed that the effect of extreme precipitation on the skewness–kurtosis interaction was stronger in arid or Sahel and Sudan of Northern Nigeria (NN). As pointed out by Odekunle (2004), the rainfall pattern could be influenced by the dynamics of continental air and maritime air masses which meet along a slanting surface called Inter-Tropical Discontinuity

(ITD). There is notable varying degrees of convective activity and precipitation that occur at the south of ITD while little or no cloud development or precipitation occur in the Northern part of ITD (Odekunle, 2004).

Table 1: A Statistical Summary of Annual Precipitation of Northern Nigeria

Hydrological Area (HA)	Station	Statistics						
		Min	**Max**	**CV**	**Skewness**	**Kurtosis**	**Mean**	**Standard Deviation**
1	Goronyo	0.000	264.300	15.340	1.700	0.05	96.971	18.760
	Gusau	0.000	455.000	84.800	1.200	-0.494	120.23	23.122
	Katsina	0.000	368.800	1.560	1.790	-0.777	119.754	19.756
	Sokoto	32.340	95.980	29.170	0.940	-0.679	656.324	16.908
	Tatamafara	0.000	265.000	98.080	1.370	4.969	141.387	18.316
	Jibyia	1.970	4.850	19.820	-0.070	0.449	60.482	0.590
	Zobe	67.73	319.000	78.980	1.620	-0.204	163.735	20.109
Regional Average		***14.577***	***253.275***	***4.821***	***1.221***	***0.473***	***194.126***	***16.794***
2	Kaduna	68.200	136.000	14.090	1.220	-0.145	101.586	7.997
	Zaira	71.930	111.680	0.140	-0.240	-0.185	95.554	9.150
	Minna	68.200	136.000	14.650	-0.080	0.047	100.012	4.130
	Bida	83.500	130.190	12.870	0.360	0.033	104.925	3.981
	Abuja	143.400	231.580	22.950	0.040	-0.838	178.33	5.521
	Ilorin	66.2300	212.720	24.770	2.030	6.849	104.476	6.190
	Lokoja	53.8100	134.760	23.140	-0.270	2.904	8.856	1.660
Regional Average		***79.924***	***156.132***	***16.087***	***0.437***	***1.237***	***99.105***	***5.518***
3	Yola	0.460	154.500	98.010	0.470	-0.296	67.596	23.981
	Bauchi	41.980	166.630	27.110	0.860	1.285	73.091	24.904
	Gombe	55.260	90.360	14.700	-1.580	-0.067	87.935	15.9110
Regional Average		***32.567***	***137.163***	***4.606***	***-0.083***	***0.562***	***76.207***	***21.598***
4	Jos	67.900	120.350	11.480	-0.280	1.329	104.936	11.950
	Lafia	55.2500	106.040	15.450	-1.340	-0.244	130.525	10.140
	Makurdi	17.28	134.76	17.320	0.120	-0.04	98.126	8.289
Regional Average		***46.81***	***120.383***	***14.750***	***-0.500***	***0.542***	***111.195***	***10.126***
8	Kano	21.3	141.06	30.510	1.060	-0.145	8.466	21.300
	Maiduguri	0	254.47	89.090	1.260	-0.171	5.393	38.610
	Ibi	20.73	130.38	26.250	-0.190	1.587	77.516	26.260
	Portiskum	12.63	88.99	21.390	1.230	0.067	53.325	12.630
Regional Average		***43.605***	***123.785***	***45.577***	***0.840***	***0.334***	***36.175***	***24.700***

Spatio-temporal Variability on an Annual Cycle

Figure 2 shows the rainfall pattern for selected stations typically exhibited stochastic or random characteristics. Thus, traceable to random oscillation or seasonality due to the periodicity of the weather and climatic variabilities. May arise probably due to seasonal variations in precipitation volume well as the rate of excessive evapotranspiration without corresponding precipitation input. The anticipated phenomenon translates into variable stochastic characteristics which is within an annual cycle. In addition, Figure 3 revealed spatial distribution of rainfall across the region; it showed decreases in average rainfall days across the region, with only Abuja, Lafia, Minna and Lokoja having above average rainfall days; which accounted for only 22 % of the stations under discourse. This is in agreement with the finding of Burn and Elnur (2002**).** Hence, it indicates that the occurrence of a significant variation in rainfall pattern and can be used as a criterion to characterise Northern Nigeria into sub-regions based on susceptibility to abrupt climatic fluctuations. In this context, incidence of rainfall seems to decreases with a sequential increment of latitudinal signatory. For instance, Lokoja (7.8023°N, 6.73334oE) experienced prolong rainfall days exceeding hundred (100) days which approximately climaxed to five (5) months against Maiduguri of (11.8311° N, 13.1510oE) that had sparing rainfall days. Similarly, the findings here are in accord with the report of Aondover (2000); that is there is a seeming decreasing in rainfall pattern from the Sahel, Sudan to the Guinea Savanna accordingly.

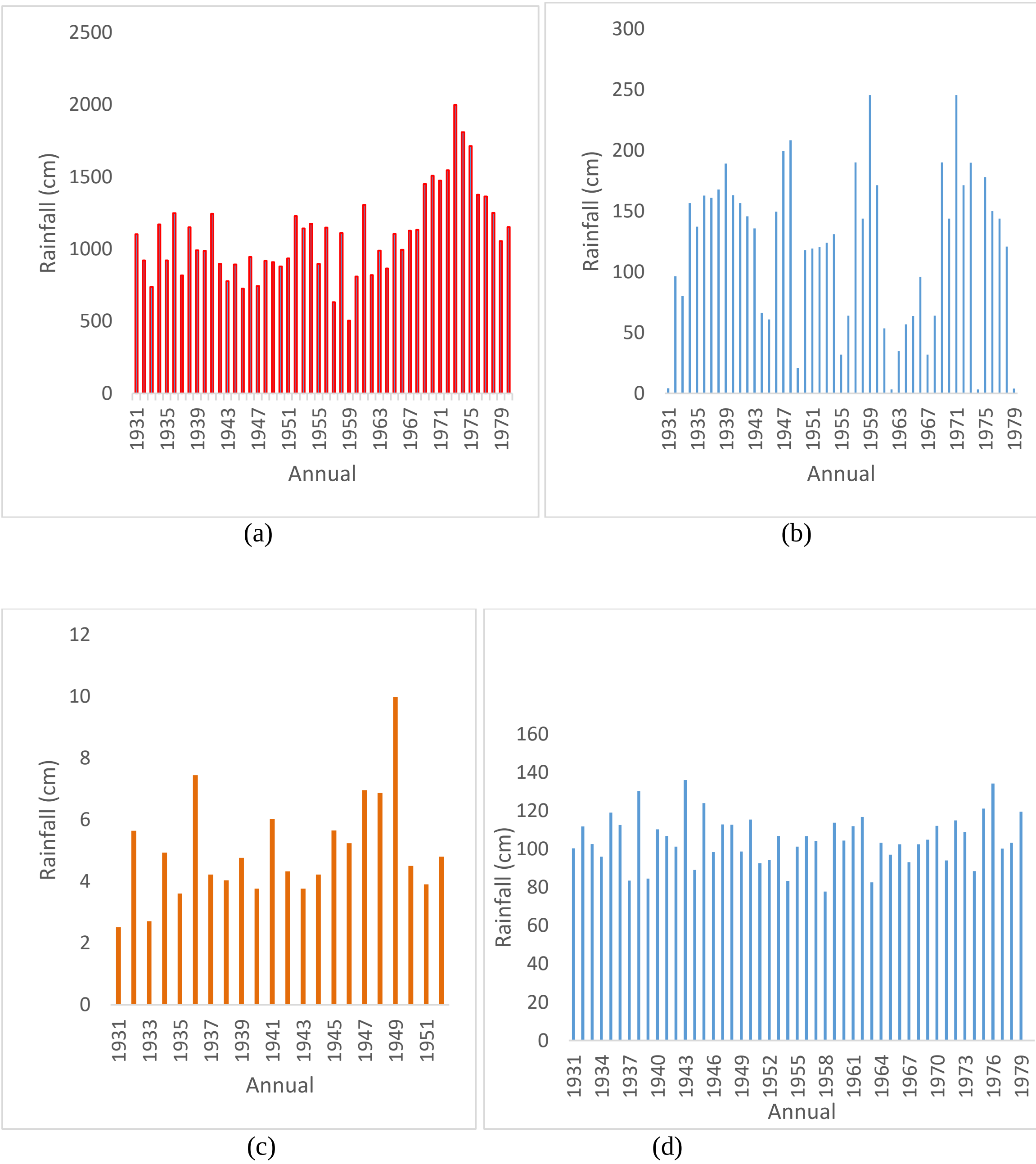

Figure 2: Annual hydrograph for (a) Ilorin (b) Katsina (c)Maiduguri(d) Bida

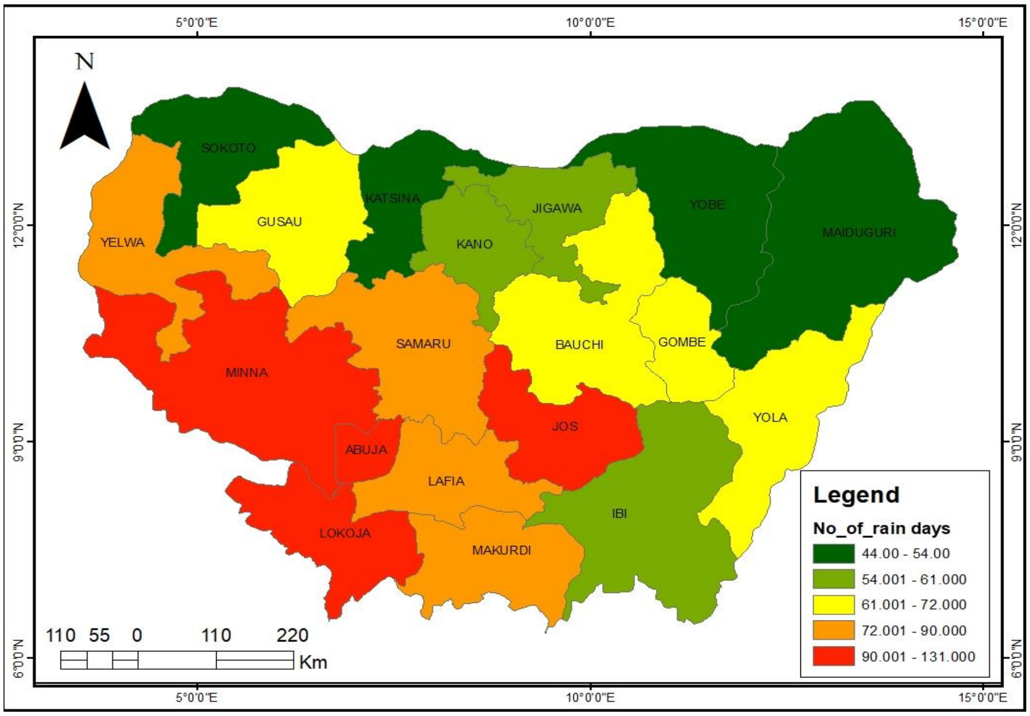

Figure 3: Spatial distribution of Rainfall Pattern from 1971-2021 in Northern Nigeria.

Detection of Potential drought signature

Standardised rainfall anomaly

Table 2 and Table 3 shows the rainfall distribution across the HAs are not uniform over the entire region as further illustrated by Figure 4. However, during the period understudied (Table 2) gave thorough breakdown of average number of wet season in increasing order of 13.500, 19.667, 25.428, 26.000, 31.285 of HAs, 8, 3,1, 4 and 2 respectively. In this regard, high average standardised anomaly were observed in HAs 1 and 3 as -0.961 and -0.388 respectively (Table 3) which signifies acute rainfall shortage. Figure 4 depicted HAs 8,3 and 1 as a region most susceptible to drought occurrence. Hence, as it steadily experiencing below normal rainfall, taking into consideration mean rainfall of 89.900, 150.120, 99.811, 135.401 and 78.981cm of HAs 1, 2, 3, 4 and 8 respectively. Similarly HA 3 has the highest contribution to the anomaly (15.013) as explained by the R2. Related instance, was detected in Bauchi (Figure 4d) in earlier 1950s to later 1983s, that accounted for 33 consecutive years rainfall shortage as average anomaly stood at -2.00, similar in cases were discerned in katsina (Figure 4a) and Maiduguri (Figure 4c) whereas Lokoja (Figure 4b) reflected strongly the characteristic of Guinea ecologic zone, were evapotranspiration rate tends to counterbalance rainfall correspondingly as wet and dry period were evenly distributed. In addition, Lokoja (Figure 4b) scored second highest peak wet period which occurred at 1973.

However, Figure 4.10 gives a vivid snapshot of spatio rainfall distribution as a function of the computed anomaly, the displayed severe stations was tilted to HA 1, HA 3 and HA 8, which accounted about 78% of area coverage in NN. Surmised to conclude that the deficit in rainfall in HAs 1, 3 and 8 overshadowed rainfall surplus in HA 2 and 4. Notable years of extreme dryness are 1976, 1978,1983,1984, 1986, 1987, 1972, 1973,1974 and 1976 and this probably informed the classification of the whole Northern Nigeria as a slightly dry region when considered in the period understudy. The general trend pattern for the entire HAs shows that for the period under consideration the rainfall increasing at an average rate of 6.10% per annum for whole Northern Nigeria which was not substantial enough to adequately support rain-fed agriculture. However, it is important to note that the simplicity of the rainfall anomaly concept greatly undermines it practical adoption in real-time. For instance, a drought initiation time is usually identified at the point when the cumulative anomaly begins a substantial decline which is determined subjectively. As noted in Keyantash and Dracup (2002), the instant at which a drought begins is of great importance but this approach does not really capture that.

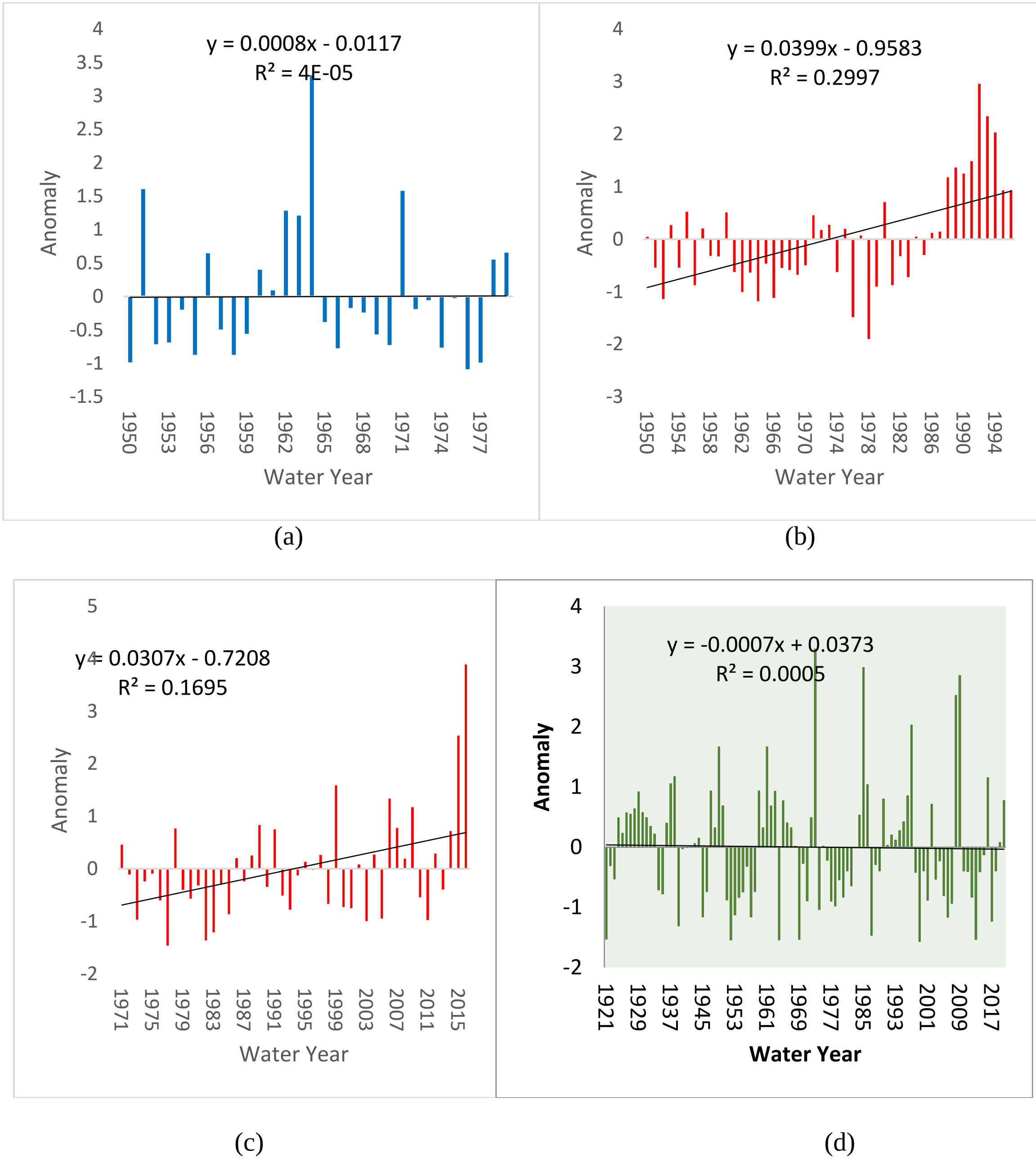

Figure 4: Standardised rainfall anomalies for (a) Katsina (b) Lokoja (c) Maiduguri (d)Bauchi

Table 2: Summary of the wet years and standardised rainfall anomalies

Hydrological Areas (HAs)	Station	Number of Wet Years	Average Standardisd Anomalies	*R*squared %
	Goronyo	18.000	0.713	0.450
	Gusau	28.000	0.644	14.000
	Katsina	32.000	0.701	0.050
1	Sokoto	57.000	0.867	0.620
	Tatamafara	23.000	0.790	4.100
	Jibyia	18.000	0.739	2.200
	Zobe	20.000	0.589	0.710
Regional Average		***25.428***	***0.702***	***3.161***
	Kaduna	33.000	0.477	0.000
	Zaira	18.000	0.625	13.600
	Minna	30.000	0.517	0.380
2	Bida	28.000	0.703	15.010
	Abuja	40.000	0.973	0.091
	Ilorin	29.000	0.784	12.590
	Lokoja	41.000	1.095	16.950
Regional Average		***31.285***	***0.739***	***8.374***
	Yola	27.000	0.758	14.090
3	Bauch	17.000	0.457	29.970
	Gombe	15.000	0.488	0.980
Regional Average		***19.667***	***0.568***	***15.013***
	Jos	27.000	0.902	0.149
4	Lafia	25.000	0.537	17.090
	Makurdi	26.000	0.827	2.500
Regional Average		***26.000***	***0.755***	***3.980***
	Kano	27.000	0.903	15.000
8	Maiduguri	10.000	0.465	0.000
	Ibi	6.000	0.459	3.000
	Portiskum	11.000	0.385	0.000
Regional Average		***13.500***	***0.553***	***4.500***

Table 3: Summary of the dry years and standardised rainfall anomalies

Hydrological Area (HA)	Station	Number of Dry Years	Average Standardisd Anomalies	*R*squared %
	Goronyo	32.000	-0.658	0.450
	Gusau	32.000	-0.967	14.000
	Katsina	28.000	-0.098	0.050
1	Sokoto	38.000	-0.233	0.620
	Tatamafara	27.000	-0.514	4.100
	Jibyia	32.000	-0.139	2.200
	Zobe	27.000	0.589	0.710
Regional Average		***30.857***	***-0.288***	***3.161***
	Kaduna	35.000	-0.71	0.000
	Zaira	32.000	-0.638	13.600
	Minna	20.000	-0.47	0.380
2	Bida	28.000	0.702	15.010
	Abuja	10.000	-0.259	0.091
	Ilorin	21.000	0.784	12.590
	Lokoja	10.000	-0.202	16.950
Regional Average		***22.285***	***-0.311***	***8.374***
	Yola	23.000	-0.384	14.090
3	Bauch	33.000	-1.61	29.970
	Gombe	35.000	-0.888	0.980
Regional Average		***30.333***	***-0.961***	***15.013***
	Jos	33.000	-0.946	0.149
4	Lafia	25.000	-0.751	17.090
	Makurdi	24.000	-0.125	2.500
	Average	27.333	-0.607	3.980
	Kano	31.000	0.902	15.000
8	Maiduguri	20.000	-0.567	0.000
	Ibi	36.000	-0.617	3.000
	Portiskum	25.000	-0.989	0.000
Regional Average		***28.000***	***-0.318***	***4.500***

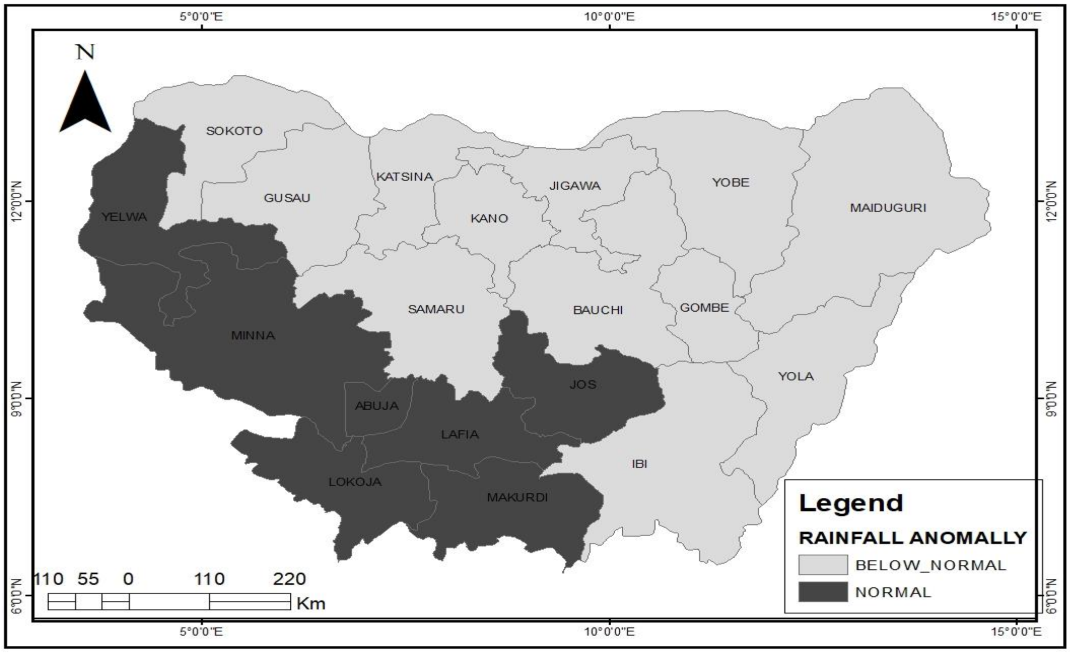

Figure 4: Rainfall Anomaly across Northern Nigeria from 1971-2021

CONCLUSION

This study provides valuable insight into various degrees of rainfall as well as variability over the study area. The results of rainfall pattern and Standardised anomaly are important for policy makers, especially for water resources management and agriculture. It was observed that most of the stations showed significant pattern in the series. For instance, rainfall statistical moment portrayed that HA 1 has a mean annual rainfall of 194cm with standard deviation of 16.79cm and HA 3 and HA 8 jostled for the less for example HA 3 had annual mean rainfall of 76.207cm and substantial standard deviation that stood at 21.598cm which is quit debilitating whereas HA 8 scored the least mean, that is 36.175cm and outrageous standard deviation of 24.700cm. It was inferred further that the occurrence of a significant variation in rainfall pattern and can be used as a criterion to characterise Northern Nigeria into sub-regions based on susceptibility to abrupt climatic fluctuations. In this context, incidence of rainfall seems to decreases with a sequential increment of latitudinal signatory. In addition, notable years of extreme dryness are 1976, 1978,1983,1984, 1986, 1987, 1972, 1973,1974 and 1976 and this probably informed the classification of the whole Northern Nigeria as a slightly dry region when considered in the period understudy. The general pattern for the entire HAs shown that for the period under consideration the rainfall increasing at an average rate of 6.10% per annum for whole Northern.

Generally, it can be inferred that, there is evidence of significant pattern in rainfall regime in the entire HAs for 73.3 % of the years. This varying degree in the pattern across the HAs has the potential of leading to extreme hydro-meteorological conditions of drought. Significant rainfall fluctuation observed in the region can largely be attributed to global warming caused by anthropogenic emission of greenhouse gasses and the gradual expansion of the tropics during the last 30 years. Based on the results, for effective generalisation in the long-term, it is strongly recommended that extensive data should be employed for analysis. In the same context, a plurality of analytical approaches should be deployed in the assessment while considering admixture of hydro-meteorological variables in the context of the aggregate effects of the interactions of same on the variability evolution of the associated extremes.

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