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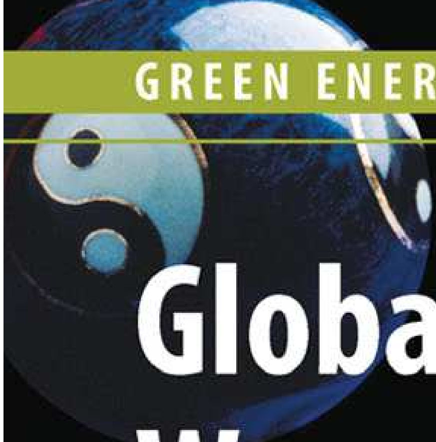

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Temperature Variations and Their Effects on Rainfall in Nigeria

Osita Ibe and E.F. Nymphas

38.1 Introduction

Nigeria is located between Latitude 4° and 14°N and Longitude 2°45′ and 14°30′E. To the north, the country is bounded by the Republics of Niger and Chad, in the west by the Republic of Benin, in the east by the Republic of Cameroon, and to the south by the Atlantic Ocean. Approximately 13,000 km^2 of the land is covered by water (1.4%) and the remaining 98.6% of the land cover ranges from thick mangrove forests and dense rain forests in the south to a near-desert condition in the northeastern corner of the country. The country takes its name from its most prominent river, the Niger. Nigeria has a land area of about 910,770 km^2 (Adeyinka et al., 2005); a north–south length of about 1,450 km and a west–east breadth of about 800 km. Its total land boundary is 4,047 km while the coastline is 853 km.

Nigeria is located primarily within the lowland humid tropics just north of the equator and is generally characterized by a high–temperature regime almost through the year. In the far south, mean maximum temperature is about 32°C while in the north it is 41°C. However, the mean minimum temperature is 21°C in the south and under 13°C in the north which has a much higher annual range. The mean temperature for the country is 27°C, in the absence of altitudinal modifications. Over the last few decades, there has been a general increase in temperature throughout Nigeria (UNFCC, 2003).

Nigeria, by virtue of its location, experiences a warm tropical climate with two seasons – the rainy or wet season that lasts from mid-March to November in the south and from May to October in the north; and the dry season occupies the rest of the year (Oyenuga, 1967).

The Nigerian climate varies from tropical in the coastal area to sub-tropical up north. There are two regimes of climate: a dry season and a wet season. The seasonal pattern of climatic conditions over Nigeria gives rise to four seasons in

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the south and two in the north. This is the result of annual total rainfall occurrence and distribution, which is more predominant in the south than in the north. The mean annual rainfall along the coast in the southeast is 4000 mm while it is only 500 mm in the northeast.

Southern Nigeria: The four observed seasons are

- The long rainy season: This starts in February/March and lasts to the end of July, with a peak period in June over most parts of southern Nigeria. It is a period of thick clouds and is excessively wet particularly in the Niger Delta region and the coastal lowlands.
- The short dry season: This is experienced in August for 2–3 weeks known as 'August break.'
- The short rainy season: This brief wet period follows immediately after the 'August break' from early September to mid-October, with a peak period at the end of September. The rains are not usually as heavy as those in the long rainy season, although the spatial coverage over southern Nigeria is similar. The two periods of rainfall intensity give the double maxima phenomenon of the rainy season characteristic of southern Nigeria.
- The long dry season: This period starts from late October and lasts till early March with peak dry conditions between early December and late February. The period witnesses the prevailing influences of the dry and dusty northeast winds, as well as the 'harmattan' conditions.

Nigeria can, thus, be broadly divided into the following climatic regions:
(a) the humid sub-equatorial, in the southern lowlands
(b) the hot tropical continental, in the far north
(c) the moderated sub-temperate in the high plateaus and mountains
(d) the hot, wet tropical, in the hinterland (the middle belt) (Online Nigeria, 2002).

In general there are fewer dry season in the extreme southern tip of the country, the wet season often does not exceed 5 months in the northeastern part. Similarly annual rainfall totals range from 2,500 mm in the south to less than 400 mm in parts of the extreme north (FMEN, 2001).

38.2 Methodology

38.2.1 Data used

The data used for the study cover an average of 30 years and it was collected from the Nigerian Institute of Meteorological Agency (NimetAg). It includes daily maximum and minimum temperatures, rainfall, and relative humidity of the affected localities. The study area covers the six geo-political zones of the country viz, southwest (SW), northwest (NW), southeast (SE), northeast (NE), south–south (SS), and north central (NC).

A total of 16 states of the Nigerian federation were covered in the study. The duration of study was 30 years on the average. Table 38.1 gives the summary of the analogy. The discrepancy in the duration of the data as against the period of coverage specified is informed by the missing data of some years. Figure 38.1

is the current map of Nigeria, showing some of the locations covered by the study in thick circles.

Table 38.1 Study area locations, population, and duration.

S/N	Study areas	Geographical location	Latitude (°N)	Longitude (°E)	Population	Duration of study (Years)	Missing data (%)
1	Benin	South–south	6.33	5.63	3,218,332	1971–2002 (32)	0.0
2	Ibadan	Southwest	7.38	3.90	5,591,589	1971–2003 (33)	0.0
3	Lokoja	North central	7.80	6.73	3,278,487	1971–2002 (31)	3.1
4	Oshogbo	Southwest	7.83	4.58	3,423,535	1971–2003 (33)	0.0
5	Bauchi	Northeast	10.31	9.84	4,676,465	1971–2002 (24)	25.0
6	Maiduguri	Northeast	11.85	13.16	4,151,193	1971–2000(30)	0.0
7	Nguru (Yobe)	Northeast	12.88	10.45	2,321,591	1971–2002 (28)	12.5
8	Warri	South–south	5.52	5.75	4,098,391	1971–2003 (33)	0.0
9	Ikeja	Southwest	6.45	3.47	9,013,534	1971–2002 (30)	6.3
10	Port Harcourt	South–south	4.78	7.00	5,185,400	1971–2002 (28)	12.5
11	Sokoto	Northwest	13.07	5.24	3,696,999	1971–2003 (33)	0.0
12	Owerri	Southeast	5.50	7.02	3,934,899	1974–2003 (28)	6.7
13	Calabar	South–south	4.96	8.3 1	2,888,966	1971–2002 (31)	3.1
14	Kano	northwest	12.00	8.52	9,383,682	1971–2000 (27)	10.0
15	Jos	North Central	9.93	8.89	3,178,712	1971–2000 (30)	0.0
16	Yola	northeast	10.6	7.22	3,168,101	1971–2000 (29)	3.3
	Average	-	-	-	-	1971–2003(30)	

38.2.2 Data analysis

Since the data represented a daily minimum and maximum temperature as well as daily rainfall in the localities of interest, it was reduced into the monthly and yearly average. The monthly average for the temperature situation was calculated with the relation below:

$$T_{avg} = (\sum \text{Daily Temperatures})/\text{Number of days of the month} \quad (38.1)$$

Since rainfall is not a daily event, the relation below was employed in the calculation of monthly rainfall situation:

$$R_{\text{toal}} = \sum \text{Daily precipitation} \qquad (38.2)$$

The average for all the years studied at the different localities and the cumulative average for all the localities altogether were computed.

Fig. 38.1 Map of Nigeria showing some of the stations covered by the study.

Since the maximum and minimum daily temperature situation was taken at each location, formula below was employed in computing the annual temperature average

$$T_{\text{avg}} = \frac{T_{\max} + T_{\min}}{2} \qquad (38.3)$$

Equation (38.4) is used for the computation of the annual rainfall average

$$R_{avg} = (\text{Total rainfall})/\text{Duration} \quad (38.4)$$

Also, the monthly averages of temperature and rainfall were equally deduced for all the years. In a bid to establish the relationship between the variables, the average temperature and rainfall against the months of the years of study were plotted for all the stations.

38.2.3 Trend analysis

Various trend-detection studies have been carried out in different parts of the world, mostly for the identification of climatic change, if any. Some of these cases have shown significant trend components, especially during the last 40 years (Karl et al., 1993). Different techniques, such as parametric and non-parametric tests, are used for testing whether there have been statistically significant trends. However, the physical interpretation has related, at times, to the greenhouse effect, global warming, urban heat islands, and to aerosols that exert cooling effects on our climate (Balling, 1992). The data are analyzed in order to identify meaningful long-term trends by making use of the sequential version of the Mann–Kendall rank statistics, the effective application of which includes the following steps in sequence:

(i) The values of x_i of the original series are replaced by their ranks y_i, arranged in ascending order.

(ii) The magnitudes of y_i (i = 1,…,N) are compared with y_j (j = 1,…,i−1). At each comparison, the number of cases $y_i > y_j$ is counted and denoted by n_i.

(iii) A statistic t_i is, therefore, defined as follows:

$$T_i = \sum_{1}^{i} ni \quad (38.5)$$

(iv) The distribution of the test statistic t_i has a mean and a variance as

$$E(t_i) = \frac{i(i-1)}{4} \quad (38.6)$$

and

$$\text{Var } t_i = \frac{i(i-1)(2i+5)}{72} \quad (38.7)$$

(v) The sequential statistic $U(t_i)$ is then computed as follows:

$$U(t_i) = \frac{[t_i - E(t_i)]}{\sqrt{\text{var}\, t_i}} \tag{38.8}$$

Herein, $U(t_i)$ is a standardized variable that has zero mean and unit standard deviation. Therefore, its sequential behavior fluctuates around zero level. Furthermore, $U(t_i)$ is a Gaussian normal variate.

(vi) Similarly, the values of $U'(t_i)$ are computed backward starting from the end of the series.

Although, the Mann–Kendall test can successfully locate the trends, it is not able to provide a measure of the amount of change involved during a defined period. However, the linear changes are estimated by the least squares regression analysis (Kadioglu, 1997).

38.2.4 Least squares regression analysis

The name 'least square' comes from the process of defining a trendline
The least squares line method uses a *straight line*

$$y = a + bx \tag{38.9}$$

to approximate the given set of data, (x_1, y_1), (x_2, y_2),..., (x_n, y_n), where $n \geq 2$, Where 'a' stands for the intercept and 'b' stands for the slope. The slope is equivalent to variation in temperature (or rainfall) per year (Kadioglu, 1997).

38.2.5 Correlation analysis

In probability theory and statistics, correlation also called correlation coefficient indicates the strength and direction of a linear relationship between two random variables.

Correlation is a measure of association between two variables. The variables are not designated as dependent or independent.

The value of a correlation coefficient can vary from minus one to plus one. A minus one indicates a perfect negative correlation, while a plus one indicates a perfect positive correlation. A correlation of zero means there is no relationship between the two variables. When there is a negative correlation between two variables, as the value of one variable increases, the value of the other variable decreases, and vice versa. In other words, for a negative correlation, the variables work opposite each other. When there is a positive correlation between two variables, as the value of one variable increases, the value of the other variable also increases. The variables move together.

38.3 Results and Discussion

Extensive work has been carried out on the rainfall and temperature situations in Nigeria but research work on the possible fallout of the interplay between rainfall and temperature in Nigeria appears scanty.

Seasonal variations of rainy days of different categories in Nigeria, changing pattern or rainy days in Nigeria (Olaniran, 1990), regional variations in fluctuations of seasonal rainfall over Nigeria, variation of surface temperature with solar activity are few of the many researches that have been carried out on temperature and rainfall. Adedoyin (1989) carried out a research on the global scale sea–surface temperature anomalies and rainfall characteristics but with emphasis on northern Nigeria. The present work covers the entire country and the results are presented according to the geographical regions of the country. The least squares regression plots for all the zones are as shown in Figures 38.2a,b,c,d,e,f.

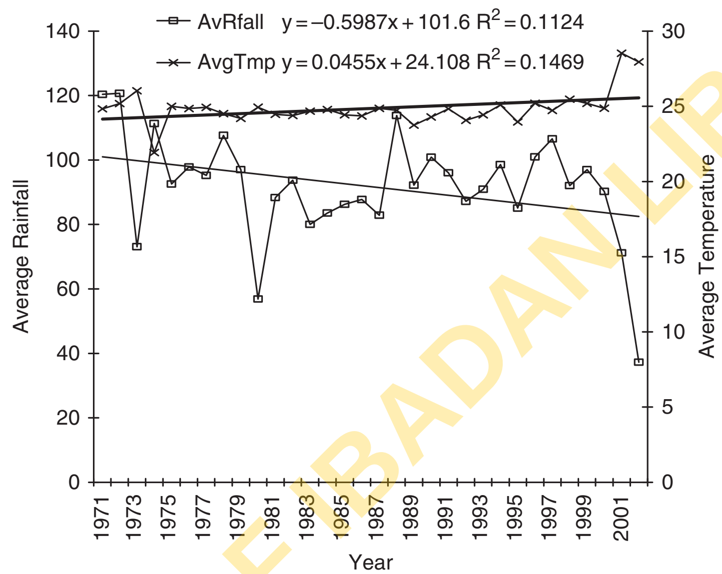

Fig. 38.2.a Least squares regression plots for the north central zone.

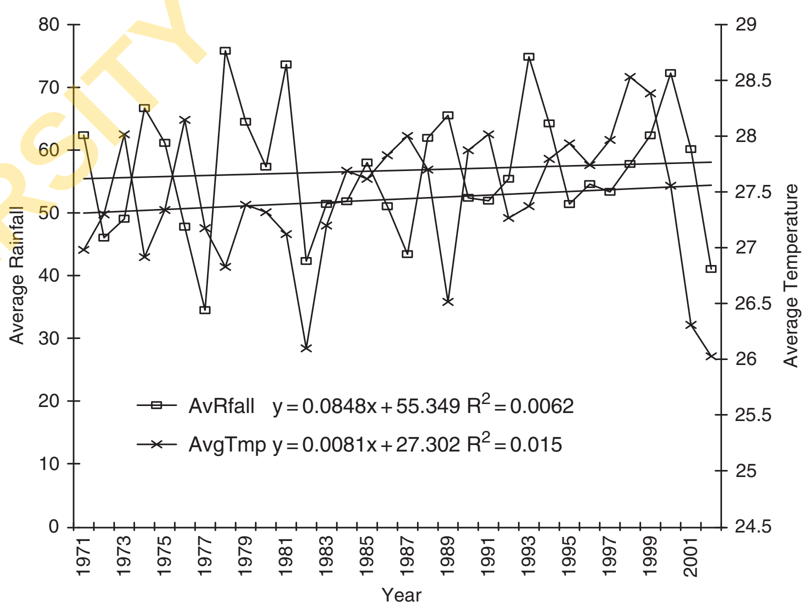

Fig. 38.2.b Least squares regression plots for the northeast zone.

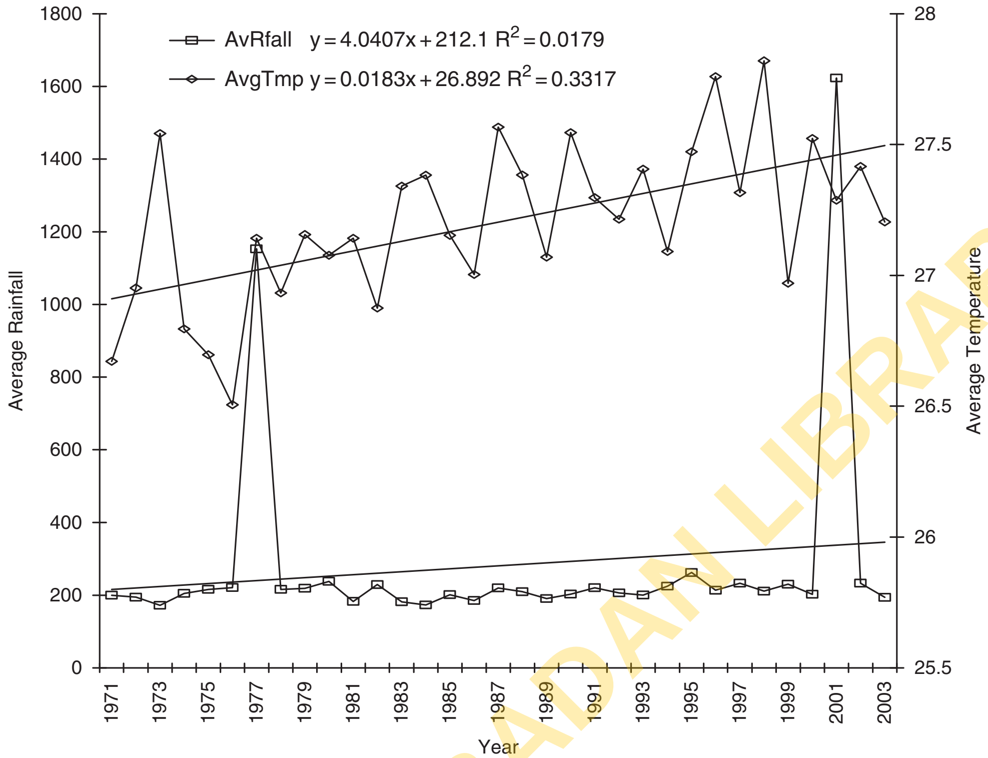

Fig. 38.2.c Least squares regression plots for the south–south zone.

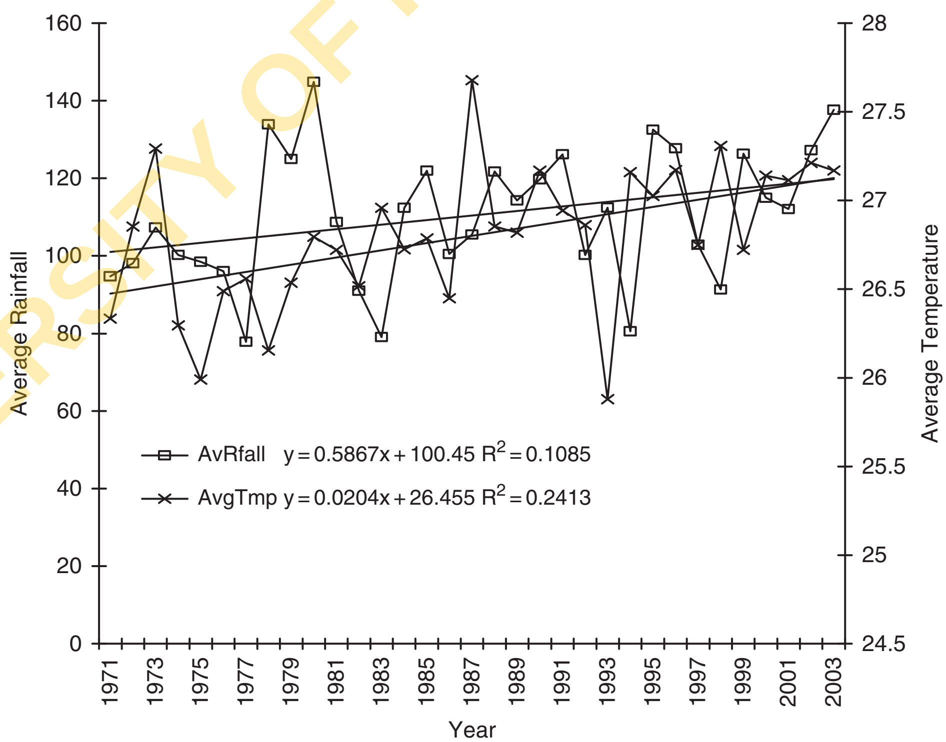

Fig. 38.2.d Least squares regression plots for the southwest zone.

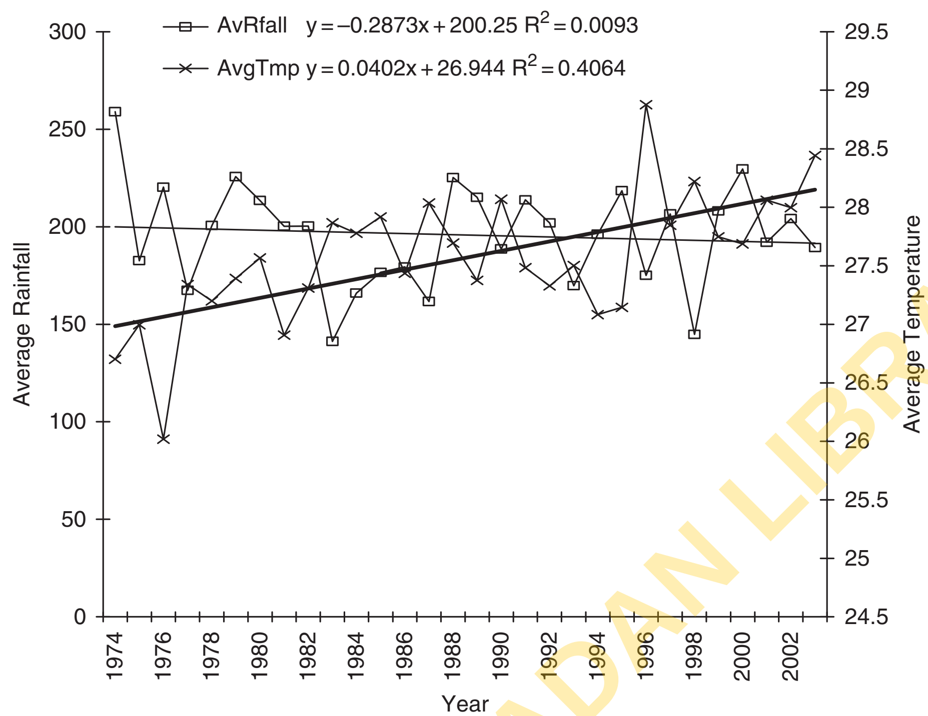

Fig. 38.2.e Least squares regression plots for the southeast zone.

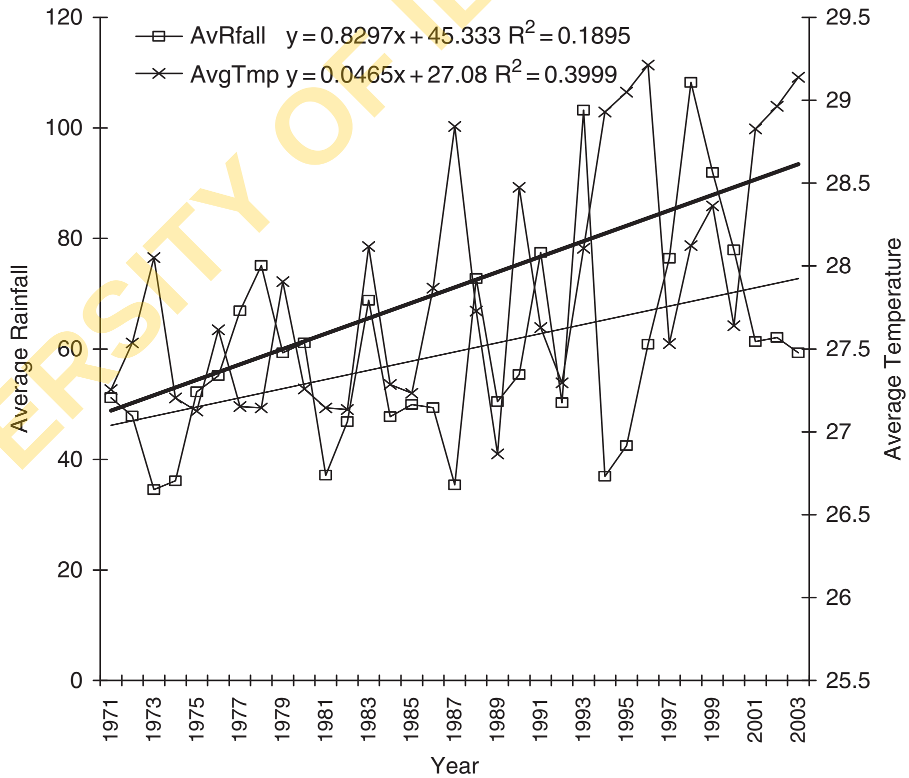

Fig. 38.2.f Least squares regression plots for the northwest zone.

Table 38.2 below is the tabular representation of the least square regression analysis of the rainfall/temperature variations at six geopolitical zones of the country.

Table 38.2 Regression analysis results of the rainfall/temperature variations.

S/N	Zone	Rainfall variation/ annum(mm)	Temperature variation/ annum (^{o}C)
1	North central	−0.5987	0.0455
2	Northeast	0.0848	0.0081
3	Northwest	0.8297	0.0465
4	Southeast	−0.2873	0.0402
5	South–South	4.0407	0.0183
6	Southwest	0.5867	0.0204

From Table 38.2 above, the North Central and South East geopolitical zones witnessed negative regression in the rainfall trend while all other zones witnessed a positive trend; The temperature variations in all the zones regressed positively. In effect, only the North Central and South East geopolitical zones witnessed a decrease in the rainfall pattern; all other geopolitical zones experienced some increase. The temperature situation in all the geopolitical zones was of increasing trend.

38.3.1 Analysis of rainfall and temperature trends

By the use of the Mann–Kendall non-parametric tests, the trends represented by Figs. 38.3.a and 38.3.b were generated.

38.3.2 Correlation analysis of temperature and rainfall

When the rainfall was correlated against the temperature on the basis of the six geo-political zones (refer to Table 38.3), the results of the correlation coefficients are as presented in Table 38.4.

Table 38.3 Summary of average rainfall and temperature variations in Nigeria (1971–2003).

Year	AVRfall	AvMxTp	AvMnTp	AvTP
1971	105.6816	32.24316	20.58701	26.41508
1972	101.4489	32.58167	20.94658	26.76413
1973	87.23662	33.33338	21.4432	27.38829
1974	129.6859	31.54399	20.40155	25.97277
1975	117.2148	32.08727	20.96188	26.52458
1976	123.0084	31.82155	21.38619	26.60387
1977	265.827	32.17625	21.25547	26.71586
1978	134.8733	31.80759	21.11623	26.46191
1979	131.7137	32.08383	21.43744	26.76063
1980	128.6203	32.13945	21.5118	26.82562
1981	115.1485	31.96624	21.20101	26.58363
1982	117.2709	31.63429	21.13824	26.38626
1983	100.4001	32.30803	21.74502	27.02653
1984	105.8013	32.37619	21.50636	26.94128
1985	115.6764	32.08798	21.62686	26.85742
1986	108.9178	32.07368	21.57288	26.82328
1987	108.117	32.99266	22.00327	27.49797
1988	134.1874	32.16349	21.86823	27.01586
1989	121.391	31.87779	20.9181	26.39795

1990	120.0189	32.53531	21.93756	27.23644
1991	130.9435	32.08429	21.98338	27.03384
1992	116.8451	31.96757	21.37686	26.67221
1993	125.2546	31.9999	21.56633	26.78312
1994	116.9129	32.59916	21.78698	27.19307
1995	132.0527	32.56329	21.6333	27.09829
1996	122.0929	33.10353	22.21658	27.66006
1997	129.8261	32.46584	21.57914	27.02249
1998	117.5948	33.04568	22.11288	27.57928
1999	135.9347	32.5367	21.92083	27.22876
2000	131.2478	32.45771	21.68301	27.07036
2001	353.2994	32.97443	22.40049	27.68746
2002	117.5228	32.9501	22.2391	27.5946
2003	145.0544	32.83385	23.14399	27.98892
Average	131.7219	32.34594	21.58205	26.96399

Table 38.4 Correlation results of the average rainfall against temperature for the geo-political zones.

Geo-political zones	Correlation coefficient
North central	−0.408
Northeast	−0.039
Northwest	0.055
Southeast	−0.481
South–South	0.018
Southwest	0.116

The correlation analysis across the six geo-political zones, which represent the whole of the Nigerian federation (please refer to Table 38.3), yielded a value of 0.199.

38.4 Conclusion

From the foregoing research work, the following can be deduced:

- Throughout the period of study, the country witnessed an average of 131.72 mm rainfall and the average temperature was 26.96ºC.
- The trend analysis of the country-wide variation indicates that there is a general increase in rainfall and temperature over the years. The 0.756ºC increase over the years appears to fall within 0.6±0.2 range predicted by the Inter-Governmental Panel on Climate Change (IPCC, 2001).
- The correlated value of 0.199 throughout the country and the maximum value of 4.0407 mm rainfall variation per annum in the coastal areas suggest that the country is at the brink of global warming and the coastal areas are the worst hit.
- The gradual drying up of Lake Chad and the creeping down of the Sahara Desert are danger signals of the possible negative impacts of the temperature increase. An evidence of regional climate change in Nigeria is the current southward drift of the Sahara Desert which has been estimated to be about 5 km/year (Madueme, 1994). This incidence of increased drought is bound to impact negatively on agriculture and food supply.

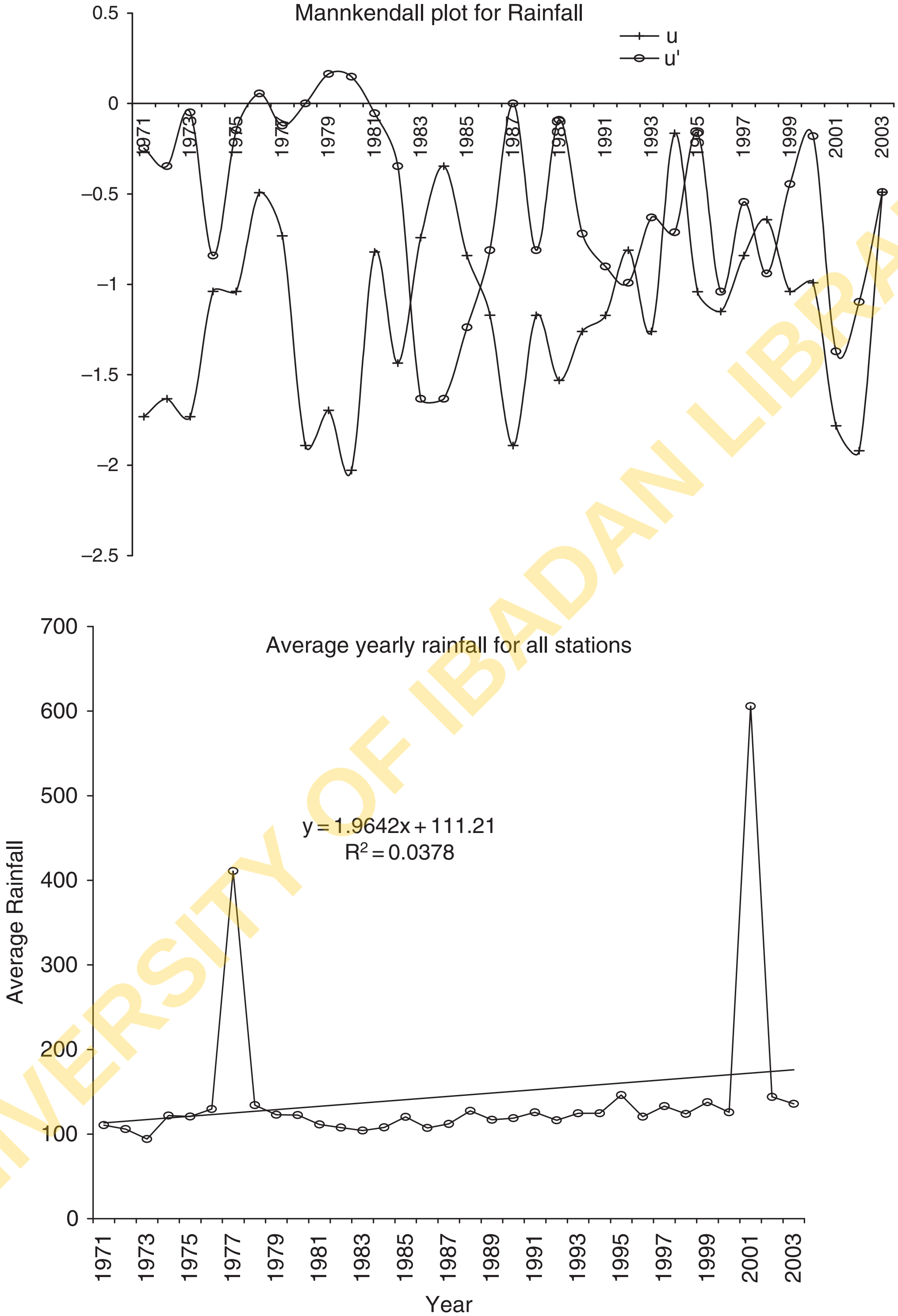

Fig. 38.3.a Time series of average rainfall and the sequential version of the Mann–Kendall tests for the period 1971–2003.

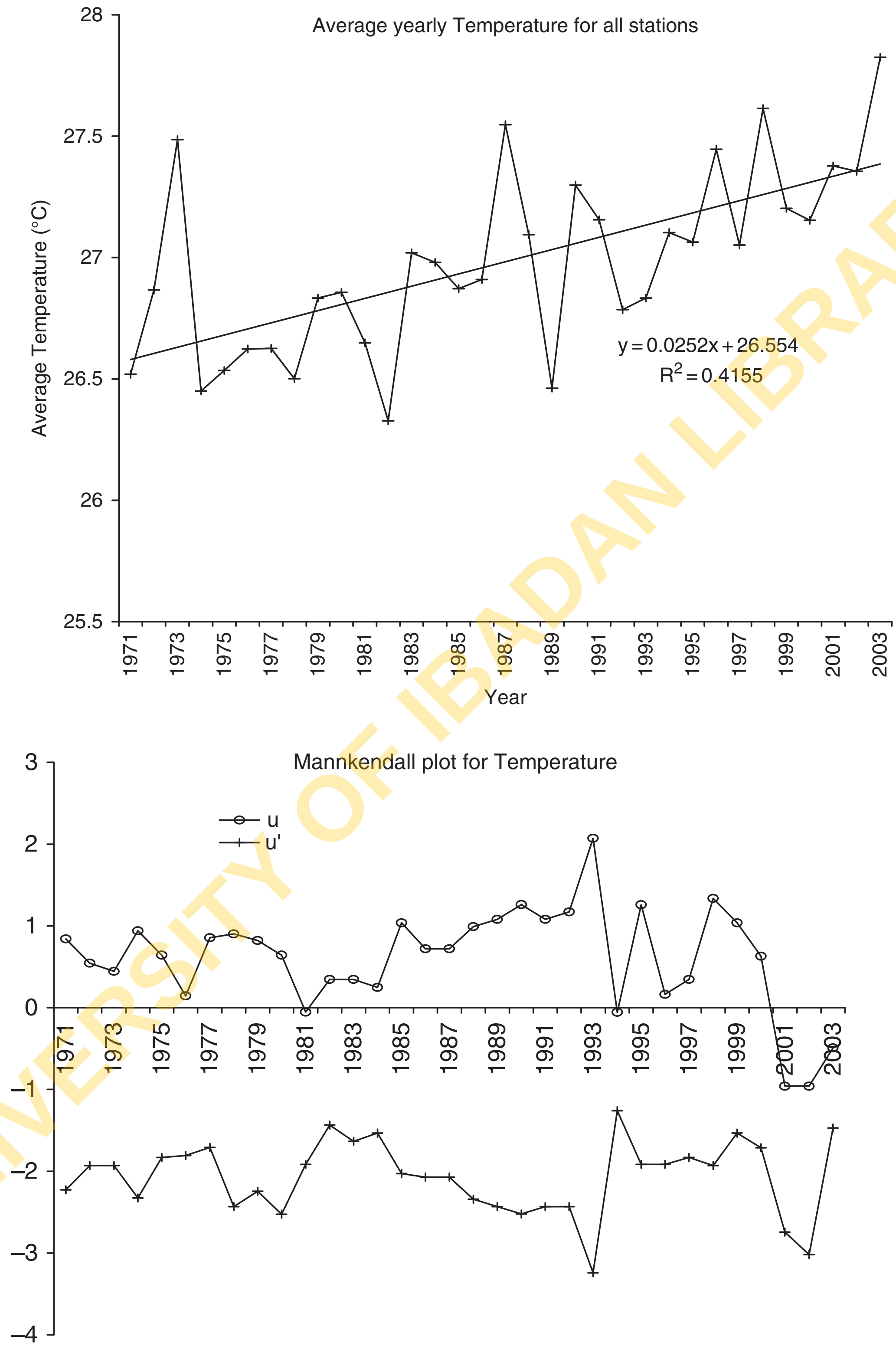

Fig. 38.3.b Time series of average temperature and the sequential version of the Mann–Kendall tests for the period 1971–2003 for all stations.