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Analysing the characteristic-sequence of rainfall amounts in Ibadan, Nigeria

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Abstract: *Rainfall varies from year to year and over decades, and changes in rainfall amounts affect the environment and society. Steady moderate rains penetrate into the soil and benefit plants, while the same amounts of rainfall in a short period of time may cause local flooding and runoff. Ibadan has been experiencing yearly severe flooding within and around the metropolis with substantial costs. Despite research endeavours by numerous researchers, there is limited studies on the analysis of the characteristics of rainfall. This study, therefore analysed the sequence of rainfall amounts in Ibadan. Rainfall data from 1989 to 2018 were retrieved from the archive of the Nigeria Meteorological Agency and Forest Research Institute of Nigeria meteorological station, Ibadan to examine the dynamics of rainfall amounts. The data were analysed using descriptive and inferential statistics, at $p \leq 0.05$. The result showed that there was no significant relationship between the annual rainfall totals and time in years (-0.119). The study also revealed that there was no significant difference in the mean rainfall amounts between the Nimet and the FRIN stations, with the calculated T-value of 0.89, which was less than the T-critical value of 2.04 at 0.05 confidence level. This indicates that the difference in the mean annual rainfall at the two stations is not significant. The result showed that the Nimet station is not significantly wetter than FRIN station. The results will be used in establishing guidelines for the use of rainwater in agriculture, and the prevention of flooding, runoff and soil erosion in Ibadan.*

Keywords: *Temporal pattern, Variability, Amount, Decadal rainfall, Period*

INTRODUCTION

Nigeria receives rainfall from the southwesterlies which invade the country from the Gulf of Guinea coast, that is, the Tropical Atlantic. This moist airstream is overlain by the northeast trades which originate from above the Sahara and are thereby dry and dust laden. The zone of contact of the two air masses at the surface is a zone of moisture discontinuity and it is known as the Inter Tropical Discontinuity (ITD) zone. The ITD advances inland as far as 22 – 25^{0}N in August at the margin of the Sahara i.e. considerably beyond Nigeria's northern border (Adejokun 1978; Adedokun, 1985) while it does not retreat equatorward beyond 4^{0}N latitude during the 'Harmattan' dry season (Adefolalu, 1983). Five weather zones are associated with the ITD (Figure 1). Zone A to the north of the ITD is rainless as well as Zone B to the immediate south because they do not contain rain-producing clouds. Rainfall in the ITD occurs in Zone C and D where conditions favour the development of clouds of great vertical extent. Thunderstorms and squall lines are associated with Zones C weather and monsoon rains with Zone D weather. Consequently, rainfall is spatially discontinuous when Zone C weather prevails. On the other hand, the monsoon system gives continuous rains which may last 12 hours or more (Olaniran, 1995). Overall, rainfall occurs at a distance of about 500 km south of the surface location of the ITD, 4–6 weeks behind it in its annual cycle. When the fifth weather type associated with the ITD i.e. Zone E, prevails over an area, light rainfall usually results because Zone E weather is dominated by layered stratiform clouds.

The position of the ITD fluctuates seasonally and the different ITD zones affect different areas of the country at various times (Figure 1). Between January/February and August, the ITD migrates northward and there is a corresponding shift northward of the area of rainfall activity, and from the end of August when the ITD begins its north – south retreat, the zones of rainfall activity similarly shift southward. In July – August, when the ITD is at its most northerly position, Zone E weather migrates a short distance inland causing a period of reduced rainfall in the coaster area, a phenomenon known as the 'little dry season' or the 'July/August break.'

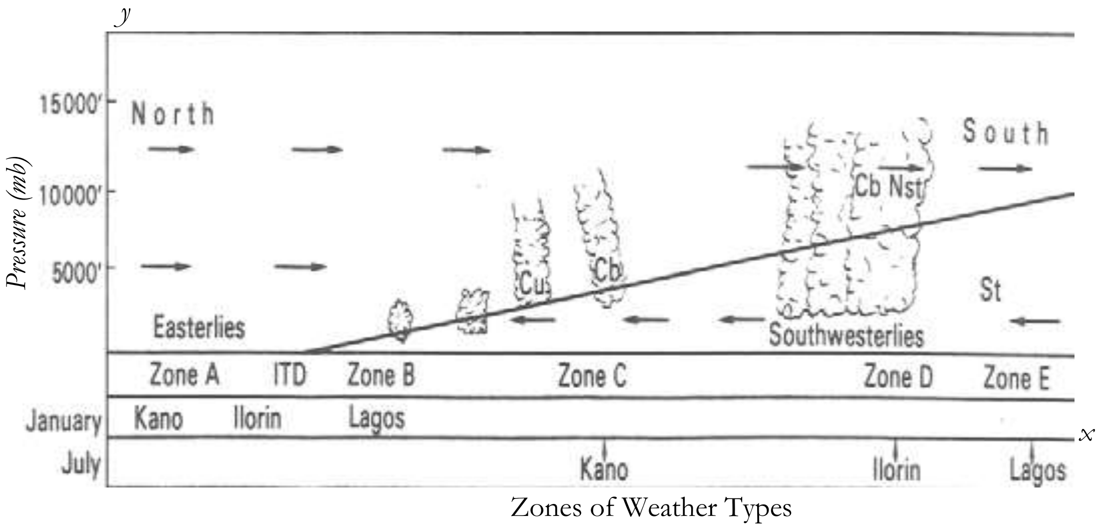

Figure 1: The I.T.D and the Weather Zones in an Idealized Atmospheric Cross- Section from South to North over Nigeria (Ojo, 1977)

During this period the southwesterlies become deflected into westerlies which bring little or no rain. This causes rainfall to increase eastward over southern Nigeria during the July – August period (Olaniran, 1988a, b). This explains why the onset of the rains over the country is more gradual than the retreat.

The account of the rainfall – producing systems presented above for Nigeria, depicts rainfall activity over the country as a function of the migration pattern of the ITD (Ayoade, 1970; Kowal and Knabe, 1972; Olaniran, 1995; 1988 a; 1988 b; Sekoni, 1992 and Adediran, 2017; 2020). Accordingly, droughts in Nigeria, and indeed over West Africa, are associated with a restricted northward advance of the ITD. On the other hand, wet years result from a considerable northward advance of the ITD. Different from this simplistic picture, the ITD itself is erratic in its south–north retreat. It moves in a series of surges, retreats and stagnations. Data presented by Walter (1967) showed that along longitude 3^{0}E in that year the ITD advanced up to 11^{0}N latitude in January but retreated southward to 6^{0}N latitude in normally experienced, although in occasional years there may be brief spells of the steady monsoonal rain of zone E. In other words, practically all the rainfall in the southern parts of the country is due to the isolated rainstorms, disturbance lines and monsoon rain. The former are experienced in the south only at the beginning and at the end of the February i.e. the following month, a retreat of 500 km. Oguntoyinbo and Richards (1977) also reported a similar situation for southern Nigeria during 1972/73. Such irregular movements of the ITD have implications for the location of the area of rainfall activity over the country. Often, they cause a false start of the rainy season i.e. early onset of rainfall at a location which is subsequently followed by a prolonged dry spell.

The position of the ITD in Nigeria is very important, not because there is any particular weather activity at this boundary, but because it serves as a reference line for the normal weather system and structure associated with the two-dimensional boundary between the Harmattan and the Monsoon (Clarckson, 1957). Figure 1 shows a cross section of the atmosphere along the longitude of Ibadan in August when the ITD is usually at its northernmost position. It is clear from the diagram that the weather types of zones B, C, and D are only experienced in the southern parts of the country. In the latitude of Ibadan, only three of the five weather types are

rainy season whereas the latter are experienced in the south at the peak of the rainy season.

In general, several authors have worked on rainfall pattern such as rainfall intensity, duration and amount, and their implications on human welfare (Walter, 1967; Ayoade, 1970; Jackson, 1977; Walsh and Lawler, 1981; Oguntoyinbo, 1982; Oguntoyinbo and Akintola, 1983, Ayoade and Akintola, 1986; Sumner, 1988; Sekoni, 1992; Adefolalu, 2001; Indrani, 2009; Kundzewicz, 2012; Ayoade, 2012; Audu et al., 2013; Keggenhoff et al., 2014; Zhihe et al., 2015; Ivana et al., 2016 and Adediran, 2017; 2020). However, none of these studies considered the statistical analysis of rainfall amounts. Hence, the need for a detailed understanding of rainfall dynamics, formed the basis for this study. Through an understanding of distributional patterns of rainfall, proper physical planning can take place in order to sustain physical life and ensure continued comfort. This paper was aimed at analysing- the dynamics of rainfall in Ibadan, between 1989 and 2018.

MATERIALS AND METHODS

The Study Area

Ibadan (7° 15' and 7° 30' N, 3° 50' and 4° 00' E) (Figure 2) has a tropical grassland of Savanna climate (Koppen's Aw) with distinct wet and dry seasons. The onset of the wet season is estimated at 15 March within a two week variation period and 15 November as the tentative end of the wet season with the same level of variation (Oguntoyinbo and Akintola, 1983; Ayode, 2012, Adediran, 2017; 2019; 2020). The area also experiences the double maxima rainfall regime with the characteristic break in August known as the "little dry season" (Ayoade and Akintola, 1986; Ayoade, 2012; Adediran, 2017; 2019; 2020). The mean annual rainfall over the study area is about 1500 mm. The mean monthly temperature is about 27°C. Hottest months coincide roughly with the movement of overhead sun. The first hottest months occur between March-April, while the second is between November-December (Ayoade and Akintola, 1986).

The climate can also be described as dry humid using Thornthwaite's moisture index. The wet and dry seasons are associated respectively with the prevalence of the moist maritime southwesterly monsoon from the Atlantic Ocean and the dry continental northeasterly Harmattan from the Sahara desert (Garnier, 1967; Ayoade, 1974; Sekoni, 1992 and Adediran, 2017; 2019; 2020). The fluctuating boundary zone between these two air masses has been called various names of which the Inter-tropical Discontinuity (ITD) appears to be the least ambiguous. As in other parts of Nigeria, the sequence of weather types experienced in Ibadan during a given year is determined largely by its location relative to the fluctuating surface position of the ITD (Garnier, 1967; Ayoade, 1974; Sekoni, 1992 and Adediran, 2017; 2019; 2020).

Data Base and Analysis

The data used for this study was extracted from daily weather registers kept by the Nigeria meteorological (Nimet) Agency, Airport, Alakia and Forest Research Institute of Nigeria (FRIN) meteorological station, Jericho, Ibadan. Daily rainfall data were processed for two autographic rain gauge stations over a 30 year period (1989 to 2018) and expressed in millimetre (Ayoade, 2008 and Adediran, 2017; 2019; 2020). The data collected for the period of the study were aggregated, examined and analysed using descriptive and inferential statistics such as percentage, mean, standard deviation, and Pearson Product Moment Correlation analysis and paired samples *t*-test statistics, respectively, at $p \leq 0.05$. The paired samples *t*-test statistics, is expressed as:

$$t = \frac{|\bar{a} - \bar{b}|}{\sqrt{\frac{\sigma a^2}{n_a} + \frac{\sigma b^2}{n_b}}} \quad \ldots \quad (1)$$

where (a) is mean of the amount of rainfall during the peak period of the rainy season, (b) represents mean of the amount of rainfall during the late rainy season, (σ) is standard deviation, (n) represents number of observations.

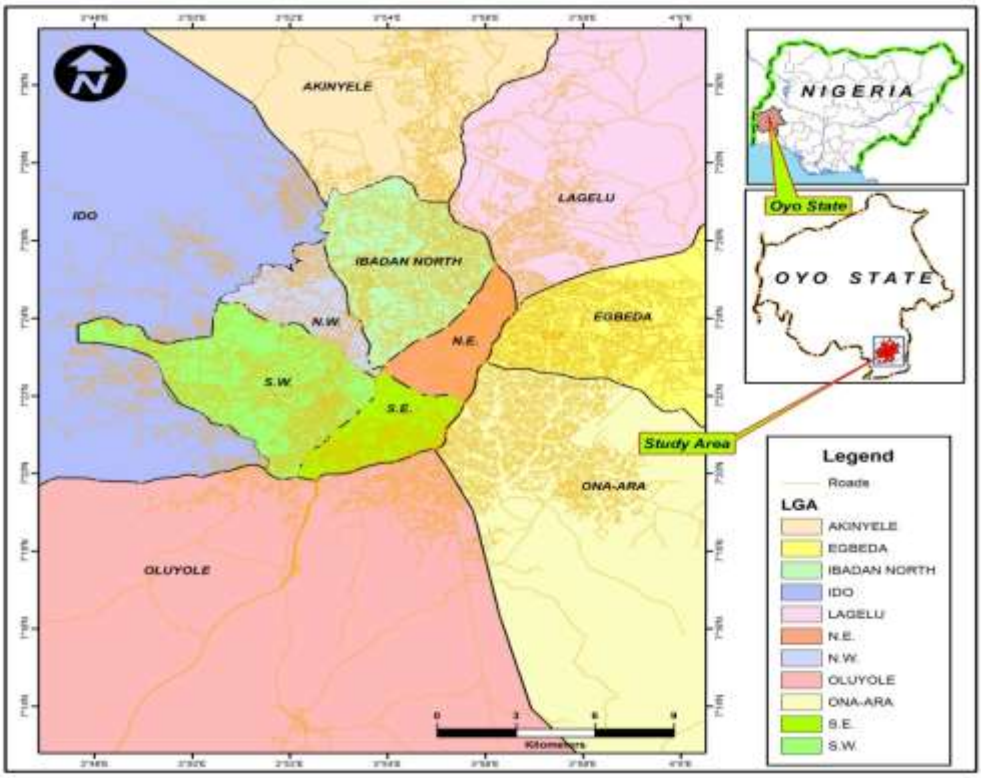

Figure 2: The Study Area

RESULTS AND DISCUSSION

Temporal Pattern of Rainfall Amounts in Ibadan

Rainfall Variability

The rainfall amounts varied rather widely from one year to another. Over the period 1989- - 2018, the highest annual rainfall was 2647.5 mm and the lowest was 1036.2 mm given an absolute range of 611. The coefficient of variation of the annual rainfall over the 30 years period was 19.9%, thus making monthly rainfall totals more variable. About 15% of the monthly rainfall totals have amounts with 20 mm or less, 7% with 40 mm or less, 6% with 60 mm or less, 10% with 80 mm or less, and 62% with 100 mm and above (Figure 3). The variability of rainfall is relevant to any consideration of the agricultural potentialities of an area.

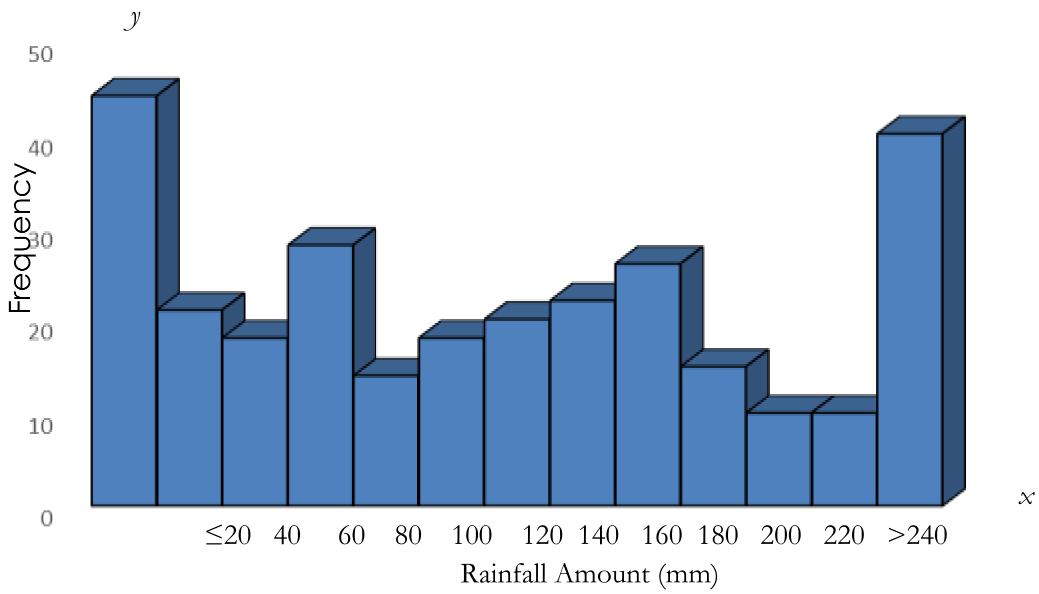

Figure 3: Rainfall Class Distributions in Ibadan

Annual Rainfall Fluctuations and Trends

The mean annual rainfall amount for the years as shown in Table 2, had an average rainfall amount of about 1407.5 mm per year, with a standard deviation value of 304.

Table 2: Mean Annual Rainfall at Ibadan, 1989-2018

Years	Mean annual rainfall (mm)(NMetS)	Mean annual rainfall mm(FRIN)	Mean annual Rainfall for the two stations (mm)	Percentage (%)
1989	1344	1567.7	1456.1	3.6
1990	1284	1363.6	1323.8	3.2
1991	1369	1396.3	1382.8	3.4
1992	1073	1155.6	1114.2	2.7
1993	1257	1574.8	1416.1	3.5
1994	1003	1915.9	1049.3	2.6
1995	1535	1473.1	1504	3.7
1996	1648	1506.2	1577.1	3.9
1997	1195	1360	1277.7	3.1
1998	921	1151.7	1036.2	2.5
1999	1851	1640.5	1727.7	4.2
2000	1198	1178.4	1188.1	2.9
2001	1290	1133.6	1211.7	3.0
2002	1515	1196.4	1355.9	3.3
2003	1469	1304	1386.7	3.3
2004	1327	1006.6	1167	2.9
2005	1226	1314	1270.1	3.1
2006	1447	1198.5	1322.8	3.2
2007	1247	1079.3	1163.4	2.8
2008	1765	1435.8	1600.4	3.9
2009	1916	1504.1	1710.3	4.2
2010	1520	1702.5	1611.3	3.9
2011	1586	1433.6	1509.9	3.7
2012	1377	1537.7	1457.5	3.6
2013	1156	1548.9	1352.5	3.3
2014	1234	1148.1	1191	2.9
2015	1058	1028.7	1043.5	2.6
2016	1481	1349.7	1415.4	3.5
2017	1620	1362.5	1491.5	3.6
2018	1785	1389.6	1587.3	3.9

Source: Nimet and FRIN Meteorological Station, Ibadan

The wettest year during this period was 1990 which had a rainfall of 2647 mm. The driest year, 1998, received a rainfall total of only 1036 mm (Figure 4). These extreme rainfall annual total in Ibadan represent a range of deviation of from 164% to 64% by comparison with the mean for the period 1989 – 2018. The year to year variability of mean rainfall totals in Ibadan is shown in Figure 4. This annual rainfall series is characterised by periodicity by more visual inspection of the graph. The graph distribution is skewed towards ten year interval. The variations in the series were of various wavelengths and fluctuations of the values.

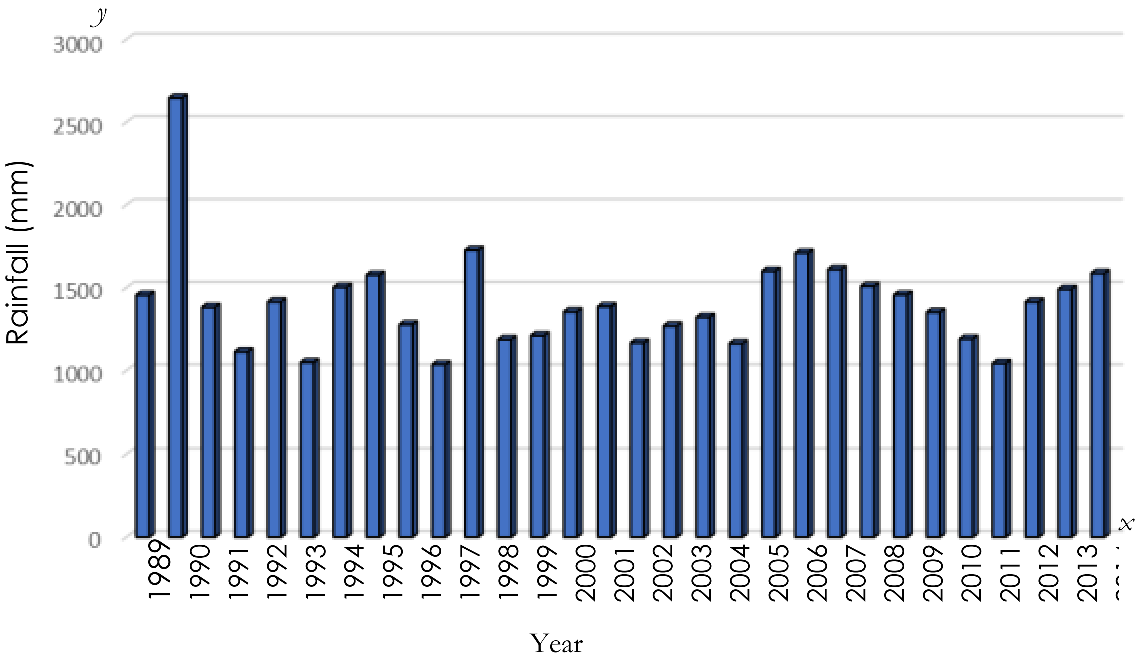

Figure 4: Mean Annual Variability of Rainfall at Ibadan (1989–2018)

The correlation coefficient between the annual rainfall totals and time in years is -0.119 which is insignificant at the 5% probability level. The apparent downward trend in the annual rainfall totals in Ibadan from 1989 – 2018 might have been due to chance or sampling variations, and does not necessarily reflect a long–term trend.

Decadal Cumulative Rainfall in Ibadan

Rainfall amount recorded in the first decade (1989-1997) ranged between 1036 mm and 2647 mm, which formed the lowest and highest amounts, respectively (Figure 5a). The cumulative rainfall for the year 1990 was the highest. This decadal rainfall had an impressive spread and coverage going by the graph only three years (1992, 1994 and 1998) were below 1200 mm. However, it was observed that six years in this decade were above the standardized rainfall of 1311 mm (Koppen Geiger climate classification). The implication of this trend is that there would be frequent annual flood and soil erosion which would have adverse effect on agricultural potentialities.

Figure 5b shows the second decadal rainfall. There was a significant departure from the first decadal rainfall. Five years of annual rainfall were above the standardized rainfall of 1311 mm. These were 1999, 2002, 2003, 2006 and 2008 with cumulative annual amount of 1727 mm, 1355 mm, 1386 mm, 1322 mm and 1600 mm, respectively. However, between the beginning and climax of the decade, annual rainfall hovered from 1163 mm to 1727 mm. It is therefore, observed that five years in this decade were below the climate normal of 1311 mm. This departure from the normal could have mixed implication for agriculture. For crops that require increased moisture (vegetables and cereals) this could mean poor yield and harvest especially during the drier months of November to March in this years. However, this trend could result in less incidents of inundation of farmland by floodwater, and soil erosion. This significant change from the rainfall benchmark could be attributed to increase in anthropogenic activities such as deforestation.

The third decade showed a remarkable increase as most of the annual cumulative rainfall rose above the climate normal except in 2014 and 2015 with the values of 1191 mm and 2015 1043 mm, respectively. This decade also recorded an unprecedented rainfall amount of 1710 mm in 2009. This was the second highest peak in the 30 years under review. Eight years in this decade were above the normal (Figure 5c). By implication, this trend would contribute immensely to agricultural potentialities in the study area. It is also an indication that the next decade would experience more rainfall above the standardized value.

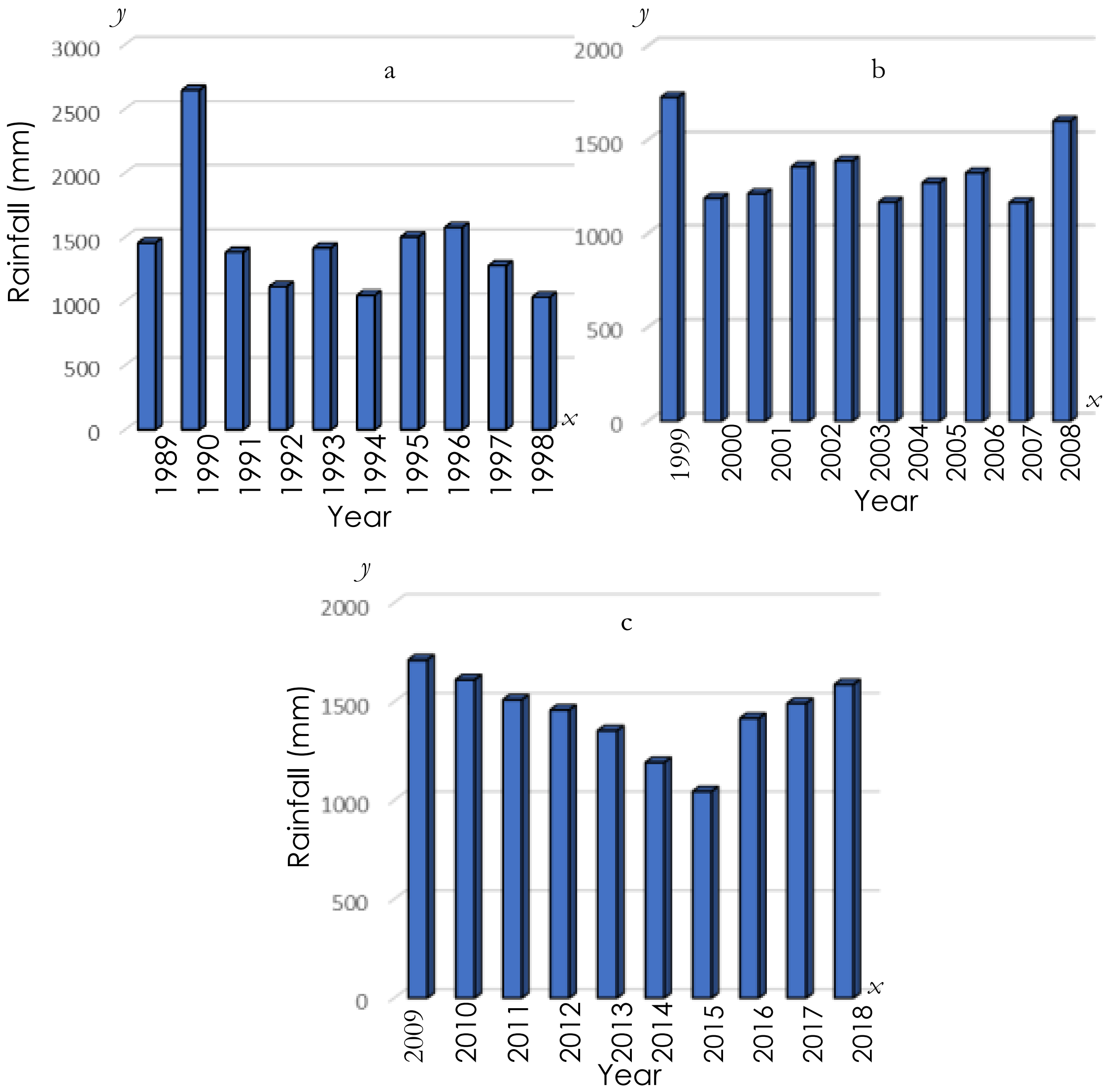

Figure 5: Decadal Cumulative Rainfall at different Periods (a–c)

The decadal annual rainfall amount in relation to the standardized average for Ibadan is shown in Figure 6. From the findings, three years (1992, 1997 and 1998) with the values of 1114 mm, 1049 mm and 1036 mm, respectively, were below the normal. The highest amount recorded for this decade was in year 1990 with a value of 2647 mm, which was above the normal (Figure 6a). It is apparent that the study area fall within the tropical rainforest region of Nigeria which experiences high amount of annual rain as indicated by seven years. This trend is favorable to agricultural potentialities.

The rainfall pattern for the second decade revealed that five years of annual rainfall fell above the standardized average while the remaining five years fell below (Figure 6b). The year 2005 recorded highest annual rainfall amount with a value of 1270 mm while the year 2007 had the lowest amount of 1163 mm. This is a clear departure from the first decade. This rainfall amount was quite unusual for the area and could portend drought in some places thereby, impacting negatively on agricultural activities.

A clear observation from Figure 6c, showed that the cumulative annual rainfall for two years (2014 and 2015) were below the climate normal on the one hand, eight years of rainfall were above the normal with the highest annual rainfall amount recorded in 2009 with a value of 1710 mm on the other hand. This clearly portend floods as the amount was above the normal.

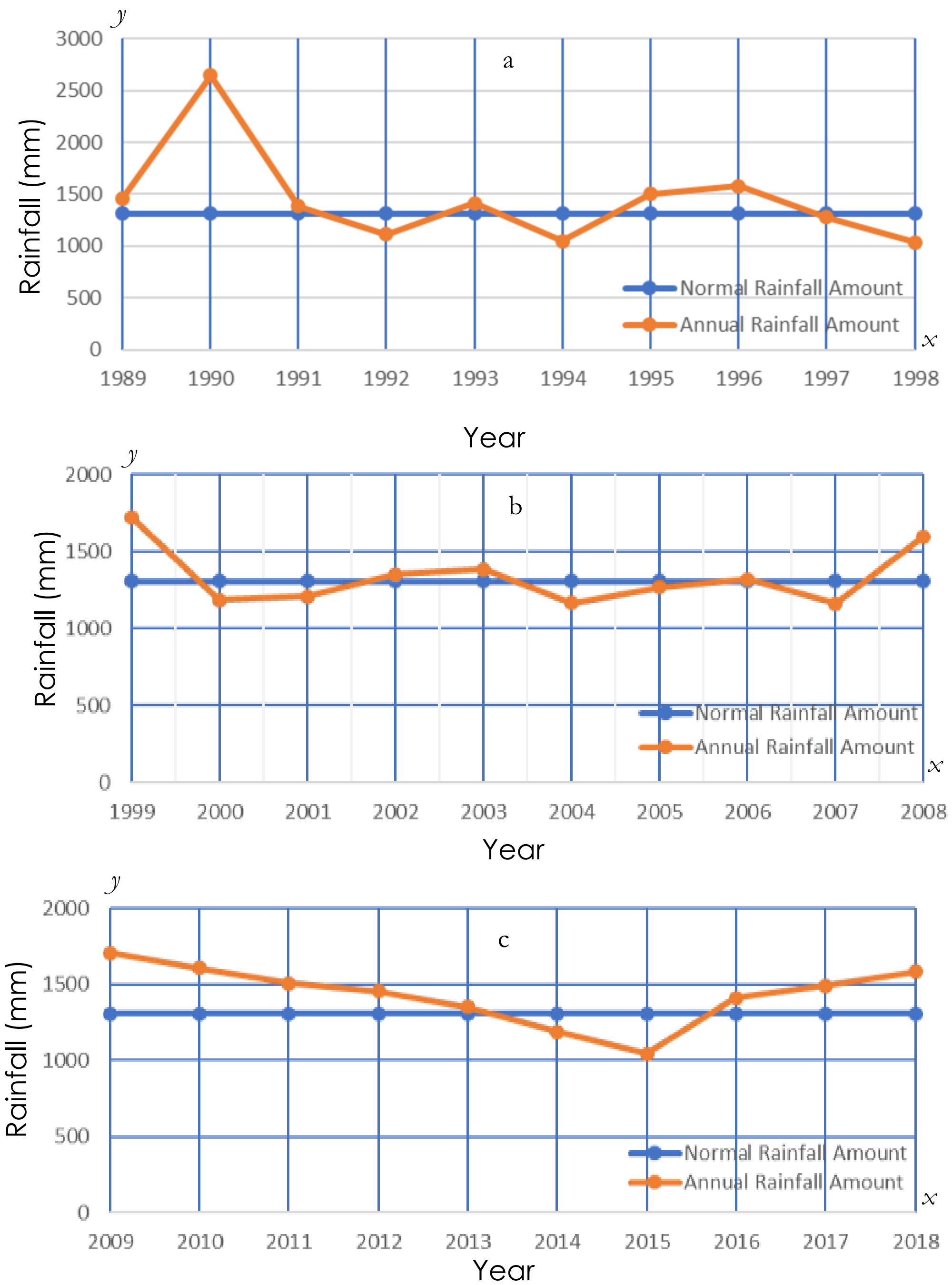

Figure 6: Decadal Rainfall Amount in Relation to the Standardized Average for Ibadan at different Periods (a–c)

Comparison of the Amounts of Rainfall between the Nimet and the FRIN Stations in Ibadan

The analysis of two-independent sample comparison of mean rainfall amounts between the Nimet and the FRIN stations was done using paired sample t-test method. The summary of the result is shown in Table 3. The results of the analysis of the differences between the mean rainfall amounts between the two stations revealed that there was no significant difference in the mean rainfall amounts between the Nimet and the FRIN stations, with the calculated T-value of 0.89, which was less than the T-critical value of 2.04 at 0.05 confidence level. This indicates that the difference in the mean annual rainfall at the two stations is not significant i.e. that station Nimet is not significantly wetter than FRIN station.

Table 3: Summary of the Analysis of T-Test for Two-Independent-Sample Comparison of the Amounts of Rainfall between the Nimet and the FRIN Stations

Stations	T-cal	T-critical	Level of significance
Nimet and FRIN	0.89	2.04	Not significant at 0.05 level

CONCLUSION

The findings of the study showed that the rainfall amounts varied from one month to another, so also from year to another, over the period of the study. The correlation coefficient between the annual rainfall totals and time in years was -0.119 which was insignificant at the 5% probability level, showed the negative relationship in the annual rainfall totals and time in years in Ibadan. The first and second decadal rainfall periods had an impressive spread and coverage, only three years were below and above 1311 mm, respectively. However, the third decade showed a remarkable increase as most of the annual cumulative rainfall rose above the climate normal. Results of seasonal variation of rainfall amounts over Ibadan showed that there had been a decline in total rainfall amount received especially from 2011 till date. There was a deviation in the observed peak period in the years under investigation. However, there was no significant difference in the mean amounts of rainfall between the Nimet and the FRIN stations in Ibadan.

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