Analysis of Rainfall Distribution Over Enugu During the Little Dry Season (1990-2005)

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Abstract
Rainfall is highly variable in both time and space, particularly in sub-humid tropical regions like West-Africa. This paper examines the variations in rainfall distributions over Enugu metropolis during the "little dry season" from 1990-2005 for the months of June, July, August and September. Statistical techniques like Time Series charts with Trend line analysis and standard deviation were used to depict the temporal distribution of rainfall in Enugu urban. The results show that the temporal variations in rainfall for the months under consideration were not significant enough to regard it as a true little dry season. The mean annual rainfall for the period of study over Enugu urban area was found to be 4687.59mm with a standard deviation of+/-18.11 and a coefficient of variation of 6% approximately. The study further shows that 1997 was the wettest year, while 1994 was revealed to be the most rainfall deficit year. In analyzing the four months under consideration for the period of the study, a rainfall total of 3822.4mm was recorded with 1998 recording the lowest monthly rainfall value in August of 96.2mm.The month of August recorded the lowest total monthly rainfall value for the entire period of study. The total number of dry spell days in Enugu urban area for the period of study is 810 days. 1996 recorded the highest number of dry spell days while the lowest number of dry spell days was recorded in 1991 with 43 days.

Background of the Study

Rainfall over Nigeria is of two regimes: a bi-modal maximum south of 100N and a single maximum north of this latitude. This distribution is partly as a result of the seasonal oscillations of the inter-tropical discontinuity (ITD). Moisture from the tropical Atlantic via low-level southwesterly, flow across the southern coast and penetrates, at the surface, beyond the country up to the southern fringes of the Sahara desert near 200N. This southwesterly air stream is overlain by the hotter and drier north-easterly air stream emanating from the Sahara. The discontinuity between these two air masses is what is known as the inter-tropical discontinuity (ITD).

Five (5) weather zones are recognized in Nigeria, namely zones A, B, C1, C2 and D. These weather zones are latitudinal in pattern and result from the seasonal fluctuation of the ITD. Along the coast these zones are experienced during a year while inland, as many as six or seven may be experienced in a particular location. Zone D, the most southerly and penetrating only a relatively short distance inland in July and August when the ITD has been displaced north beyond Nigeria, it appears is responsible for this short dry season over southern Nigeria. Stratus clouds with a base of 200 – 300m are common, with little sunshine. Relatively stable conditions, sometimes with a temperature inversion are prevalent above this level, inhibiting upward movement and consequently rainfall occurrence. (Olaniran, 1988).

This July – August period is considered to be an anomaly in the rainfall climatology of Nigeria when rainfall is reduced over southern Nigeria despite the great depth and humidity of the tropical maritime (mT) air near the coast. It is a period of reduced rainfall separating two main rainy seasons and can last up to six weeks (Ojo, 1977). Terms like "little dry season" (Ireland, 1962), "July – August break" or 'midsummer drought' have been used by different authors to describe this weather period. It is regarded as part of the 'rainfall anomaly' of the West African region, because this break in the rainy season is experienced near the coast of southern Nigeria at a time of the year when the very humid tropical maritime (mT) air mass is deepest with high atmospheric water vapour content over the area (Ojo, 2001).

Earlier researchers have postulated that this phenomena does not extend beyond the northern and eastern limits of 90 N and 70 E (Ireland, 1962; Adefolalu, 1972; Adekoya, 1979) implying a decrease in intensity of the 'little dry' season towards the east. They considered it merely a rainfall occurrence minimum instead of a true little dry season. This paper examines their assertion by looking at the characteristics of rainfall over Enugu Metropolis to determine whether there is a decline in rainfall amounts for the period. This is because this phenomenon can have mixed economic implications for beneficiaries like the Agriculture and the Oil & Gas sectors. The aim of this work is to statistically determine through quantitative analyses of rainfall amounts and "dry spell" frequency if there was a significant variation of rainfall in Enugu during the little dry season for a period of 16 years from 1990 to 2005.T

The following objectives were employed in this work to achieve this aim: To statistically examine rainfall amounts for the months of June to August for the period, 1990 to 2005.) To examine the relationship between the variations in the number of dry spell days and the length and frequency of dry spells during the July-August period. To examine the interannual variability for the period of 16 years from 1990 to 2005 over the metropolis.

Scope of the Study

This study examines rainfall characteristics like intensity and frequency during the months of June, July, August and September (possible months of "dry spell" occurrence) for the period of sixteen (16) years from 1990 – 2005 over Enugu Metropolis. It looks closely at rainfall occurrence duration, frequency amount and rainfall amount on monthly and yearly basis over Enugu Metropolis.

The Study Area

The study area, Enugu urban area, is the capital of Enugu State and was once the capital of the former eastern region. It was famous for producing half of the world's total output of palm kernels. The study area lies approximately within Latitude 6^0 20"N and 6^0 30"N and Longitude 7^0 20"E and 7^0 30"E and is bounded by several other states; in the North by both Benue and Kogi States, in the South by Abia and Imo States while in the west and east by Anambra and Ebonyi state. The Official population figure of Enugu urban area from the 2006 population census stands at

722,664(NPC,2007).

Settlement in towns is usually laid out in distinct camps and residential quarters. In Enugu urban centre, for example, residences are delineated into the Government Residential Area (GRA), the Ogui, Asata, Uwani, New Haven, Awkunanaw, Garki, Abakpa Nike and OguiNike Areas, the Independence Layout, the Colliery Camps, China Town and the Railway Artisan Quarters.

The climate is tropical hinterland in nature and is comparatively congenial. These are characterized by high temperature, high humidity and substantial rainfall. The mean monthly temperature in the hottest period of February to April is about 33°C. The rain is entirely seasonal, most of it falling between May and October. Humidity is highest between the months of May and October and low between the months of December and February. The weather associated with the study area, during the period of the study (June to September) is generally characterized by lower temperature. Cloudiness with stratus clouds and light showers/drizzles are more prominent in the area.

The relief of the study area is dominated by a prominent landform unit in the West of the town in the Enugu escarpment. This is part of the Udi-hills, which carries the false-bedded sandstones of the Asali formation and contains some isolated gravels domes. This gradually merges into shale undulating flood plains of the Manu-Adada River complex. The high land region extends from Otukpo junction through Nsukka Udi, Afikpo and Okigwe areas. The western escarpment is heavily dissected by run-off and streams producing fully erosion-prone surfaces in the study area. This yields the isolated steep sided topped hills, which form part of the Nsukka – Okigwe Plateau. These relief features gave rise to the dendrite characteristic drainage pattern governed by two main river system – the Nyaba and Ekulu river system. These two rivers and their tributaries flow in the general direction of South East to the Cross- River plain.

Methodology

Data Need/Sources: The data required for this work was daily rainfall values over Enugu for the months of June, July, August and September from 1990 to 2005. The data collected covers daily rainfall amounts, annual rainfall amounts, monthly rainfall amounts and “dry spell” days. The data covers a period of 16 years (1990 – 2005). The data for this study was obtained mainly through secondary sources from the Records, Investigations and Network Section of the Nigerian Meteorological Agency, Oshodi, Lagos for Enugu urban area.

Method of Data Collection

Rainfall observation and collection was done every six (6) hours by the Meteorological Observers at the Akanu Ibiam International Airport, Enugu. The measurement of rainfall is done by removing the funnel and emptying the collected rain in the bottle/ container into a graduated cylinder with a 3.8cm (1.5 inches) diameter. The reading is done at eye-level to an accuracy of 0.25mm (0.01 inch).

Method of Data Analysis

Statistical and graphical tools in Microsoft Office Excel were primarily employed in the analysis and presentation of this study. These consist of the following:

- Pictorial diagrams such as Histograms and Bar Charts.
- Time Series with Trend line analysis of the seasonal rainfall values to illustrate the trend pattern in rainfall behaviour.
- Standardized Anomaly charts.
- Descriptive statistical analysis:

(i) Mean $(\bar{X}) = \left(\frac{\sum x}{N}\right)$

Where x is the variable
N is the number of years

(ii) Standard Deviation, S $= \sqrt{\frac{\sum (x-\bar{x})^2}{N}}$

Where x is the variable $\bar{x}$ is the mean
N is the number of years

Data Presentation

Table 4.1 shows the monthly mean rainfall values for the years 1990 – 2005. While table 4.2 shows monthly mean rainfall amounts for June, July, August and September extracted from table 4.1 and from which dry spell days are plotted.

Table 4.1 Monthly Mean Rainfall Values in (MM)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1990	0.5	0.5	0	181.5	89.7	279.4	508.3	359.1	317.5	318.8	2.3	25.8
1991	0	37.6	62.4	198.7	346.4	244.8	319.2	264.3	230.5	253.5	2.5	0.7
1992	0	0	111.5	200.9	192.4	354	313	149.3	249.7	105.3	28.8	0
1993	0	5.1	61.7	148.9	109.9	263.7	186.7	390	243.5	72.9	82.9	11.6
1994	33.8	0	9.7	144.5	211.2	140	216	187.2	331.9	181.6	0	0
1995	1.6	0	90.2	194.1	263.7	356.7	340.2	432.1	192.4	261.7	35	0
1996	0	26.7	48.6	160.9	277.2	289.6	368.3	268.4	176.3	303.4	0	0
1997	0	0	111.6	261.3	376.1	344.9	226.8	235	392.3	242.2	68.1	4.1
1998	0	6.1	25.8	161.1	188.7	285.9	259.2	96.2	256.6	217.4	0	0
1999	18.2	15.7	30	103.6	223.5	316.8	206.4	100.2	195.1	313.4	24.3	0
2000	32.4	0	32.3	202	357.5	206.1	298.5	331.8	339.7	226.5	0	0
2001	0	28	72.5	305.5	273.8	188.8	152	130.6	407.9	118.1	0	0
2002	0	46.5	10.4	159.1	219.7	296.4	263.3	121.9	270.9	332.5	0	0
2003	0	0	2.9	74.6	234.3	286.9	400.4	290.2	334.4	227.4	39.8	0
2004	0	6.4	4.8	186.8	305.5	222.3	284.7	174.1	292.3	258.1	22.1	33.1
2005	0	26.9	20.8	115.6	170	258.3	277.6	292	283.6	228.5	24.1	0

Source: Nigerian Meteorological Agency, Lagos

Table 4.2 Monthly Mean Rainfall Amounts in (MM) for June, July, August and September.

	JUN	JUL	AUG	SEP
1990	279.4	508.3	359.1	317.5
1991	244.8	319.2	264.3	230.5
1992	354	313	149.3	249.7
1993	263.7	186.7	390	243.5
1994	140	216	187.2	331.9
1995	356.7	340.2	432.1	192.4
1996	289.6	368.3	268.4	176.3
1997	344.9	226.8	235	392.3
1998	285.9	259.2	96.2	256.6
1999	316.8	206.4	100.2	195.1
2000	206.1	298.5	331.8	339.7
2001	188.8	152	130.6	407.9
2002	296.4	263.3	121.9	270.9
2003	286.9	400.4	290.2	334.4
2004	222.3	284.7	174.1	292.3
2005	258.3	277.6	292	283.6

Source:Nigeria meteorological Agence (2007)

Table 4.3 illustrates the computed rainfall deviation and anomalies within the years under consideration (1990 – 2005).

Table 4.3 Annual Mean Rainfall Amounts and Standardized Anomaly.

Years	Rainfall (mm)	Anomalies $(x-\overline{x})/STD$
1990	313.3385	1.08889
1991	303.9692	0.587916
1992	284.3769	-0.45969
1993	274.6077	-0.98205
1994	265.3769	-1.47562
1995	320.2077	1.456189
1996	301.1846	0.439023
1997	327.6462	1.853925
1998	268.8462	-1.29012
1999	272.7846	-1.07953
2000	309.7538	0.897221
2001	282.9385	-0.5366
2002	286.3615	-0.35357
2003	299.5308	0.350591
2004	291.8615	-0.05948
2005	284.8	-0.43706

Source: Author (2007)

Table 4.4 Dry Spell Days For June, July, August And September Over Enugu From 1990 – 2005.

Years	June	July	Aug	Sept	TOTAL
1990	13	10	14	10	47
1991	15	9	7	12	43
1992	15	10	14	9	48
1993	11	13	8	15	47
1994	20	14	9	11	54
1995	15	13	6	12	46
1996	17	17	11	15	60
1997	13	16	14	11	54
1998	15	15	16	10	56
1999	17	12	14	11	54
2000	9	11	9	13	42
2001	16	16	14	8	54
2002	11	12	12	11	46
2003	9	14	16	12	51
2004	18	12	16	9	55
2005	15	8	18	12	53

Source: Nigeria Meteorological Agency (2007)

Data Analysis.

Time series analysis and histogram charts were employed in the analysis of rainfall data and dry spell days for the years (1990 – 2005). In computing the deviation score, standard deviation and the standardized anomaly we use the following formulae

Deviation Score X = $x - \bar{x}$

Where x = rainfall value (monthly or annual value)

$\bar{x} =$ mean rainfall value

Standard Deviation, S = $\sqrt{\frac{\sum(x-\bar{x})^2}{N}}$

Where S = Standard Deviation

$\sum(x-\bar{x})^2$ = sum of the squared deviation from the mean

N = Number of years

Standardized Anomaly = $\frac{(x-\bar{x})}{STD}$

Where $(x-\bar{x})$ = Deviation Score

STD = Standard Deviation

Mean, $\bar{x} = \frac{\sum x}{N} = \frac{4687.585}{16} = 292.97$

Table 4.5: Standard Deviation For Annual Rainfall

S/N	Year	Rainfall Amount (mm)	$x-\bar{x}$	$(x-\bar{x})^2$
1	1990	313.34	20.37	414.94
2	1991	303.97	11	121
3	1992	284.38	-8.59	73.79
4	1993	274.61	-18.36	337.09
5	1994	265.38	-27.59	761.21
6	1995	320.21	27.24	742.02
7	1996	301.19	8.22	67.57
8	1997	327.65	34.68	1202.71
9	1998	268.85	-24.12	581.78
10	1999	272.79	-20.18	407.23
11	2000	309.75	16.78	281.57
12	2001	282.94	-10.03	100.6
13	2002	286.36	-6.61	43.69
14	2003	299.53	6.56	43.03
15	2004	291.86	-1.11	1.23
16	2005	284.8	-8.17	66.75
		4687.59		5246.19

Source:Nigeria Meteorological Agency (2007)

Standard Deviation, S = $\sqrt{\dfrac{5246.19}{16}} = 18.11$

The chart results are shown below in figures 4.1 to 4.7.

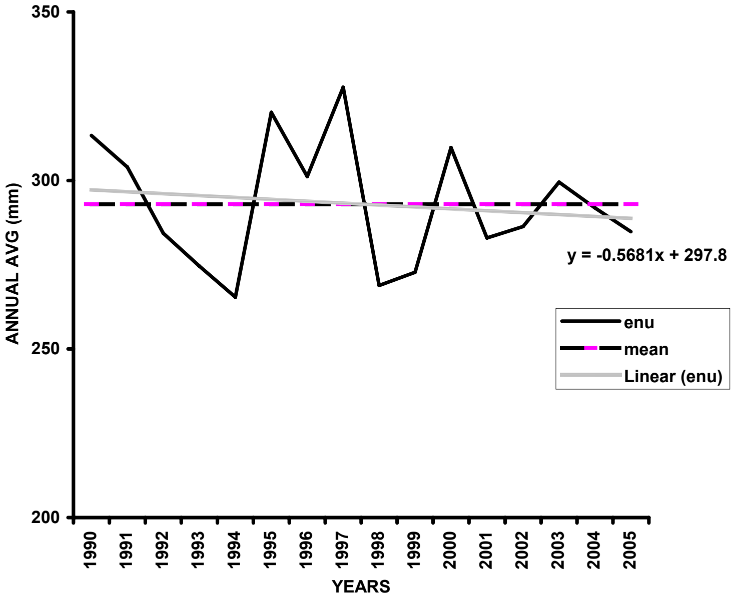

Fig 4.1 Annual Mean Rainfall For Enugu From 1990 – 2005.

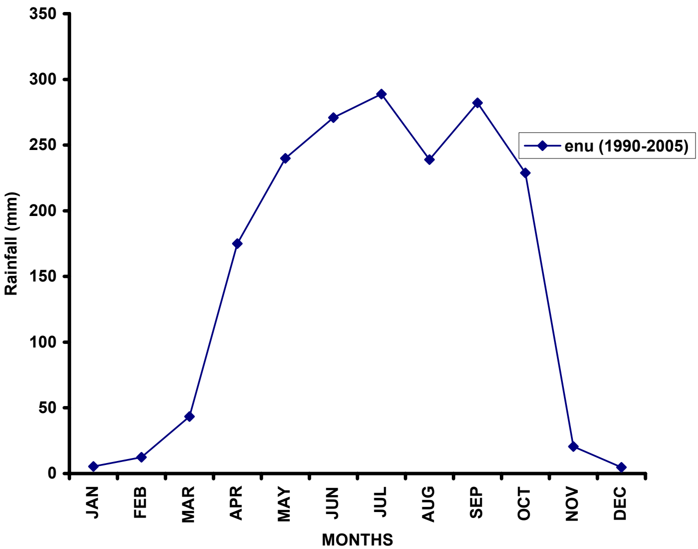

Fig4.2 Monthly Mean Rainfall For Enugu (1990-2005)

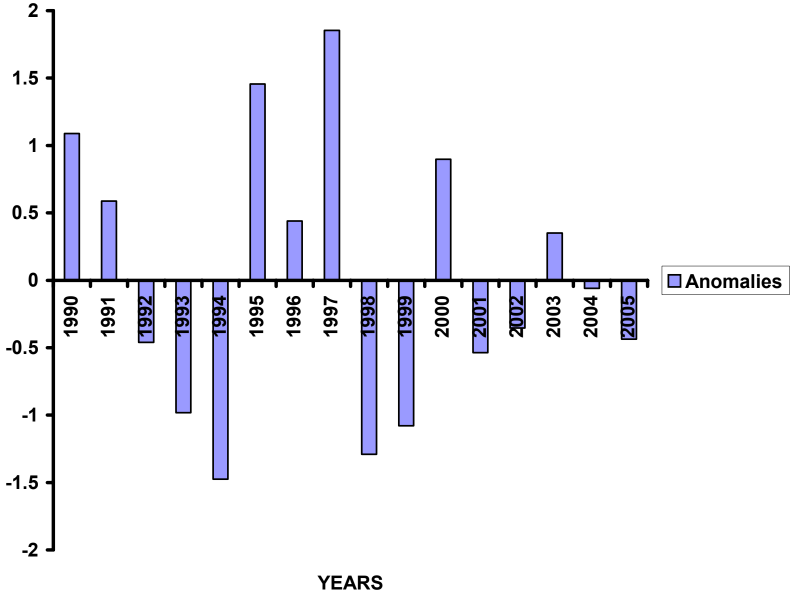

Fig 4.3: Standardized Rainfall Anomaly over Enugu for the period (1990-2005)

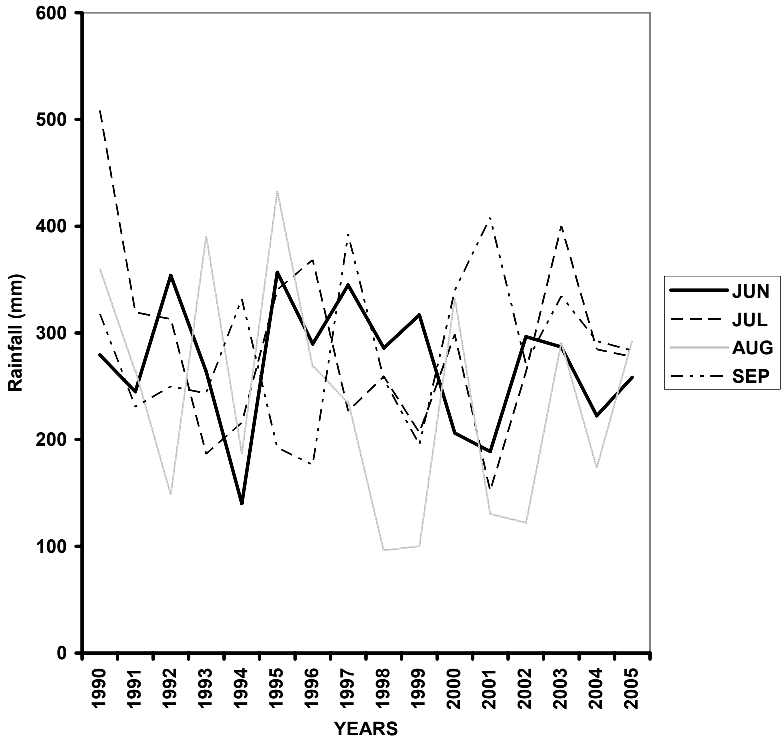

Fig 4.4: Inter-Annual Variability Of Rainfall Over Enugu For The Months Of June To September (1990-2005)

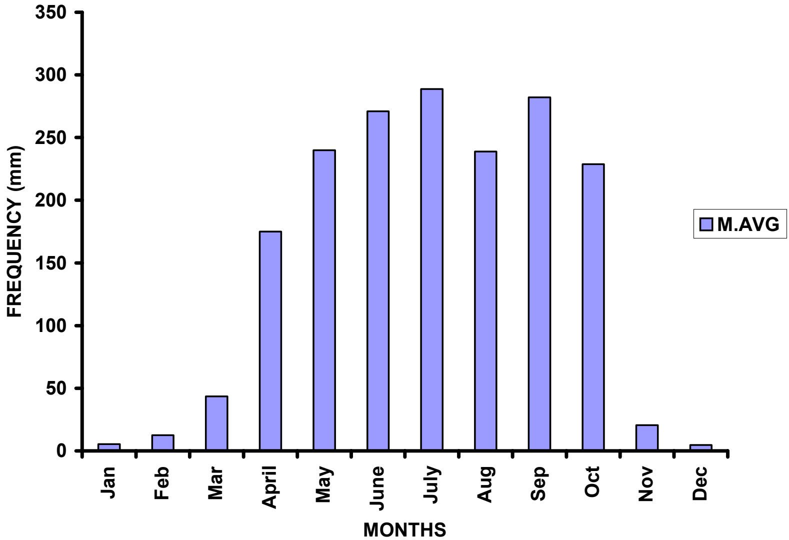

Fig 4.5: Monthly Rainfall Averages over Enugu from 1990 -2005

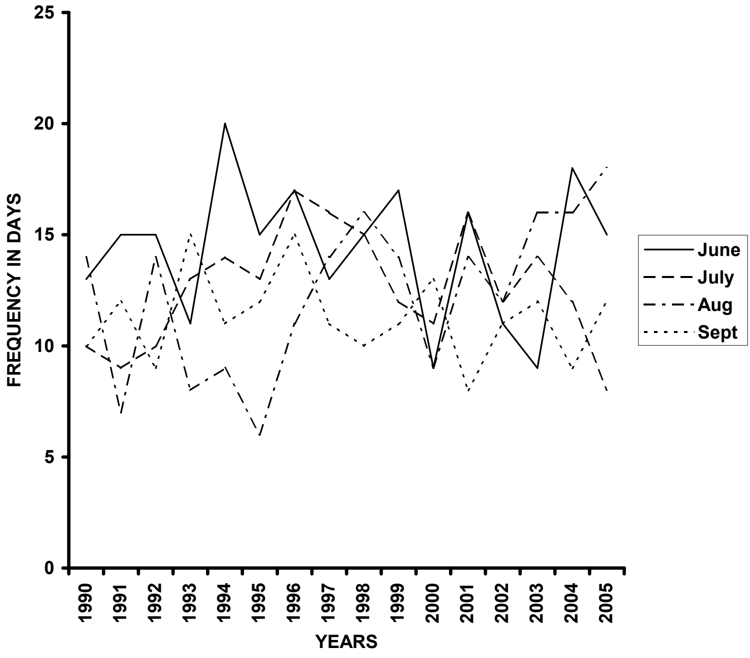

Fig 4.7: Monthly Dry Spell Over Enugu from 1990 – 2005

Findings

Figure 4.1 shows the inter-annual variability over Enugu metropolis for the years under consideration, the trend suggests a general decline in rainfall values in recent times. Rainfall values for the years under consideration suggest values between 265.37mm and 320.21mm. The inter-annual variability suggests a downward trend in the pattern when a trend line is fitted. Rainfall values over the study area for the years under consideration show that there is a slight but noticeable dip in rainfall for the month of August as shown in figure 4.2. This seems to support the bi-modal maxima of rainfall over southern Nigeria. Inter-annual variability for the months under consideration which are June, July, August and September, show a significant decline in rainfall values in 1998 and 1999 for August and also in 2001 and 2002 (figure 4.4). Rainfall values for August, 1998 and August, 1999 suggest values of 96.2mm and 100.2mm.

In figure 4.3, annual total rainfall for Enugu was standardized and these standardized rainfall deviations were averaged for the period (1990 – 2005). 1990, 1991, 1995, 1996, 1997, 2000 and 2003 are years with above average rainfall with 1997 showing the highest positive deviation from the normal of approximately 12%. While 1992, 1993, 1994, 1998, 1999, 2001, 2002, 2004 and 2005 are years with rainfall below normal with 1994 recording the highest negative departure of approximately 9%. Figure 4.3 suggests an even distribution of the departures in annual rainfall from the mean with seven (7) anomalous situations on one side and eight (8) anomalous situations on the other side.

Figure 4.5 shows the monthly frequency of rainfall for the period under consideration. July suggests the highest rainfall value of 288.79mm with August having a value of 238.9mm, again depicting the bi-modal maxima.

Figure 4.6 shows the frequency of occurrence of "dry spell" days over Enugu for the period under consideration. 1996 suggests the highest occurrence of dry spell days with a value of 60 days while 2000 has the lowest dry spell occurrence of 42 days. 1998 also shows the second highest occurrence of dry spells with a value of 56 days. Figure 4.7 shows the inter-annual variability of the dry spell days for the months under consideration. June, 1994 records the highest dry spell occurrence of 20 days with August, 1995 recording the lowest dry spell occurrence of 60 days.

Recommendation

Timely observations and forecasts of rainfall onset, duration (length of rainy season) and cessation are useful in addressing the persistent problem of dwindling water resources. This paper, therefore recommend an integrated water-resources management as well as sustainable agriculture especially during the 'little dry season'

Conclusion

This present study has enabled us to understand the temporal variations in daily, annual, monthly and seasonal rainfall amounts over Enugu urban area. The driest and the wettest year and month in Enugu urban area for the period of study has been identified and the sequence documented for future reference on the probability of droughts and floods.

The study revealed a significantly high value of mean annual rainfall over Enugu urban area within the period of study (1990 – 2005) of 4687.59mm which is good for agriculture and water resource planning. The study also showed a decline in trend pattern of mean annual rainfall over the study area for the period of study and significant daily variations for the months under consideration when analyzed in Julian days. The anomalous departures from the mean were observed to be very small with the highest positive departure from the mean of approximately 11% in 1997. This seems to support early research that the Little Dry Season decreases in intensity towards the southeast and hence is considered merely a rainfall occurrence minimum instead of a true "Little Dry Season".

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