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Climatological Review of Enugu Rainfall from 1916 - 2012 and its Implications

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Keywords: climate change and fluctuation, rainfall parameters, seasonality index of rainfall, wet and dry season, enugu.

I. Introduction

The understanding of climate involves adequate knowledge of climatic variables or elements. These elements are temperature, precipitation, sunshine duration, wind, cloud cover, humidity and pressure. The fluctuation of these elements can affect the climate of an area for good or for bad.

The examination of these variables in a single paper or study is difficult; therefore researchers tend to study single or few variables, knowing that variation in one will also affect the others and indeed the climate.

In the tropics, it has been observed that the most unreliable variable is rainfall; besides the effect of rainfall (form of precipitation in the tropics) on the environment is multidimensional in nature. Note: rainfall is almost, if noteverything in the tropics.

Climate is a summary of mean weather conditions over a period of time, usually based on 25-30 years record. Climate are largely determined by location with respect to land and seamasses, to large scale patterns in the general circulation of the atmosphere, latitude, altitude, and to local geographical features (Alexander, 2012; Bradshaw and Weaver in 1995; Mayhew, 2004; Ajayi, 1998. and Iwena, 2008).

The study of climate is vital all over the globe. The importance of climate is summarized by Hardly (2004) he stated that almost every aspect of human life's are affected by weather and climate. Were we live, what we wear, eat and drink, and our work and leisure pursuit. It imposes cost on us but also bestows benefit. Storm and flood causes damage and sometimes loss of lives, but the day to day variations contributed to the rich variety of flora and fauna which add so much to the quality of life.

Rainfall is a form of atmospheric precipitation that is composed of large drops of liquid water it consist of water droplets ranging from 1 - 5mm in diameter (Alexander, 2012). The types of rain produce reflect the circumstances in which it is form (Mayhew, 2004).

Rainfall is one element that influences, the tropical ways of life, it dictates the agricultural calendar, impact on hydrologic circle, social life and even food distribution and transportation.

Most scholars within and outside Nigeria agrees that the climate is changing; there is now scientific consensus that the global climate is changing (Kandji, et al, 2006). Abaje, et al (2012) stated that observations show that as climate changes, changes are also occurring in the amount, intensity, frequency, and types of precipitation.

Ayoade,(2003) and Akinsanola and Ogunjobi, (2014) also pointed out that the global climate has change rapidly, with the global mean temperature

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increasing by 0.7 within the last century. However, the rate of change has significant different among region (IPCC, 2007).

Climate change is a product of natural factors or anthropogenic factors or both. It may result from factor such as change in orbital elements (eccentricity, obliquity of the ecliptic precession of equinoxes), natural internal processes of the climate such as the El Nino-Southern Oscillation (ENSO) or anthropogenic forcing (for example increasing atmospheric concentration of carbon dioxide and other greenhouse gases (GHGS), the effects of deforestation, urbanization and interference or limited infiltration due to tilling, pavement and inter logging of surface (Buba, 2004; Pobeni, 2004; Deneerdt, 2007; Agbola and ojeleye,2007; Odjugo,2010; Alexander, 2012, Bates et al, 2008; NOAA,2007).

Many factors are responsible for the changes in distribution and characteristics of rainfall in Nigeria, and indeed all over the globe. These include the aforementioned. However the general dispersions of climatic variables are just variations (being primary characteristics of natural system),but as a steadily and slow changes due to human inadvertent incursion into nature by ways of social-economic activities that result to developmental initiatives, population growth, agricultural activities as well as growth in science and technology.

The gaseous and material injections that the above activities inject into the atmosphere, the continuous clearing of green vegetal cover and other land use purposes practically inhabits transpiration and evaporation from land and vegetal surfaces. The stage is thus set for a change in the rainfall of such vicinity after decade or decades, centuries of such human intervention(Goldie,1980;Gribbinand Kelly, 1996; Sorte, 1999; Afangideh and Ekanem, 2005; Odjugo, 2007). This dynamic and natural variation occurs on seasonal, decadal, centennial and even longer time scales. Each "up and down" fluctuation can lead to conditions which are warmer or colder, wetter or drier, more stormy or quiescent (NOAA, 2007, Abaje et al, 2010).

Most of the available works are on trends for instance, Abaje et al, 2010; Ifabiyi and Ojoye, 2013; Abaje et al, 2012; Imo and Ekpenyong, 2011, all discussed trend. Rainfall trend gives pictureof rainfall pattern annually. It is important in the study of hydrologic cycle. However it is not very important for agriculture. It does not also explain the fact on drought and flooding. It is actually an illusion to true distribution of rainfall.

Other scholars such as(Srivastava, 1975 and Akinyemi et al, 2013) worked on seasonality of rainfall. Seasonal rainfall is vital in the field of agriculture and even monitoring of drought and flood incidences, however most of the works did not use results for predictions. It is also observed that seasonal rainfall on its own cannot explain much and therefore will be usefully limited. It is like a sort of fluctuation or monthly variations.

This work tends to review Rainfall (RF) characteristics over Enugu using annual records to study if climate was actually changing or not. Finally the work tends to investigate climate using the onset, cessation and duration of rainfall. Most of the previous works are limited to short period of time except when the element under investigation is temperature. This work will use a longer record 1916 – 2012.

Unfortunately many researchers around the world tend to portray climate change as evil. This work is in distance position or deviant. It tend to observe if there is such change in the first place, if there is, is it to human advantage or not. Such vision will help in further research on how to enhance climate change to human's benefit.

II. Study Area

Enugu is an old city that came to prominence as a result of coal mining in and around it. The name Enugu means hilltop. However the city is on the foot of the hills. Presently Enugu is divided into three local government areas, Enugu East, Enugu North and Enugu South. Enugu is the headquarters of Enugu State, and former capital of old East Central State of Nigeria.

Enugu is located within the geographical coordinate of latitude 06° 26' 0'' N and longitude 07^{0}29' 0''E. the city of Enugu occupied 113km^2 area of land; with a population of 722,664 persons. It has an approximate population destiny of 6,400 persons per km^2(http//en.wikipedia.org/wiki/enugu, 7-8-2015; NPC, 2006.) Enugu is in between the northern edge of tropical rain forest and southern guinea savanna belt. In terms of climate Enugu enjoy the tropical wet climate. This implies that it has moderate rainfall of about 1500mm-2500mm (Iwena(36)2010).

Rainfall occurs within6-7 months followed with a dry period of about5-6 months. The southern part record more rainfall that the northern parts. Enugu has a double maxima pattern of rainfall. There is always a dry spell in between two peaks.

The temperature is moderate, a mean temperature of 27^{oc}, with a range of 5^{oc}–7^{oc}. The major soil type is the farraginous soil which falls within the interior zone of laterite soil. Major crops produce includes maize, cassava and palm fruit.

Mineral resources like Coal, Lead and Zinc are mined within and around Enugu.

Enugu is home to Enugu State University of Science and Technology, Enugu State Institute of Management studies and Akanu Ibiam International Airport (http://www.enugustate.gov.ng,7-8-15). Figure 1 shows the study area. The time zone is WAT (UTC+I). It is known in Nigeria as the coal city. She has one of the oldest football clubs in Nigeria, the Enugu Rangers.

Figure 1 : Map of Enugu, the study area

III. Methodology

Rainfall data of Enugu were retrieved from Nigeria Metrological Agency archive (NIMET)Oshidi, Lagos for a period of 1916-2012 (97 years). Five (5) of the years had no record, these include, 1922, 1966, 1967, 1968 and 1970. Records for these months were generated using the result of five years running mean. In isolated case, three years from before and two from after the year was taken or used in generating record for the missing months and years.

The data were grouped into 25 years(exclusive) and the last of the four has 22 years. Relationship between the four groups was sorted by observing first, the differences in the mean of the groups. Secondly, the groups were collapse into two to find the significance in relationship using Pearson Product Moment Correlation. Note student't' test and coefficient of determination shall be used to test the result.

Pearson Product Moment Correlation(r) = Σxy - nσ e /nσxσy---------- (1)

Each of the group mean ± the sample size depending on whether the GP σ > or < than the Gn σ. If GP σ >Gn σ minus sample size from the group mean. Then subtract the Gn σ from the result. If GP σ < Gn σ then adds sample size to GP σ and subtract Gn σ

Seasonality index of RF (SIR) which refers to the tendency for a place to have more RF in certain months than in others is also calculated. Markham's vector method of calculation is used. The SIR is obtained in percentage (%) with values ranging from 0 – 100.

SIR = VR * 100/MAR ..... (2)

Where SIR is the Seasonality Index of RF, VR is the Vector Resultant converted in term of the amount of RF. Note, vector lengths correspond to mean monthly rainfall. A circle proportionately divided into 12 sectors representing the twelve months of the year, the amount of RF is represented as a VR. MAR is the Mean Annual Rainfall. Srivastava (1975) and Markham (1970) used this method in their works.

Graphs of the group data where plotted using Microsoft Excel. The result shows the trend in rainfall distribution over the study period.

The seasonal, analysis will be carried out using graphs from the results of the four groups (1916-1940; 1941-1965; 1966-1990 and 1991-2012). The seasonal pattern will be achieved using Group σ /General σ * 100, which is the percentage of seasonal contributions.

Finally the onset, cessation and duration will be used to check for actual changes in climate, if there is any. Any trend develops tell the real rainfall pattern as it affects the climate and the economy.
Walter (1967) formula was adopted.

$$\text{Onset} = \text{NDM}\frac{(51-PAR)}{ARM} \quad (3)$$

Where NDM is the number of days in the month, 51 is constant the amounts at which it was assumed that rainfall has started. Onset therefore is when the rainfall is = or > than 51mm.

ARM therefore is the actual rainfall as at the onset.

Same formula appose to cessation.

PAR, mean the previous accumulated rainfall before the 51 target was achieved. ARM is the amount of rainfall within the month that the target was achieved.

$$\text{Duration of rainfall} = \text{Cessation} - \text{Onset} \quad (4)$$

IV. Results and Dicussion

a) Annual Rainfall

The highest rainfall (RF) occurred during 1991-2012, and the least was recorded during 1961-1990. Table 2 shows the mean, standard deviation, and coefficient of variation of Enugu RF during the study period.

Table 1 : Enugu RF statistical data over the study periods

PERIOD	1916-1940	1941-1965	1966-1990	1991-2012
TOTAL	45281.01	44156.55	42547.44	40091.3
MEAN	1811.241	1740.02	1701.9	1822.333
STD	302.691	272.0619	243.535	213.067
CV	16.71	15.636	16.72	11.69

Annual rainfall analysis shows that the four (4) Enugu rainfall groups has close mean over the study period. The fluctuation or changes in the mean is not directional, which implies that the difference in group mean rainfall is by chance.

The groups are 1916-1940, 1941-1965, 1966-1990, and 1991-2012. 1916-1940 has a mean rainfall distribution of 1811.24mm, 1941-1965 recorded 1740.02mm of rainfall, 1966-1990 had mean rainfall of 1701.9mm during the study period, and 1991-2012 had a mean rainfall occurrence of 1822.33mm for the 22 years of study.

Figure 2 shows the graph of the groups mean rainfall (RF) distribution during the study periods.

The coefficients of variation (CV) of the above groups are very close. It shows a slow shift from the normal RF of Enugu. The study shows that 1916-1940 has the lowest CV of 16.71%, 1941-1965 recorded 15.64%. The highest CV was recorded during 1966-1990 (16.72%) and 1966-010 had a CV of 11.69%. Note this explains the annual rainfall condition of Enugu and not the pattern or characteristics of Enugu RF. The highest CV was recorded during 1966-1990 with 16.72%, and the lowest CV was recorded during 1991-2012 with 15.64% this implies that the RF varies less with lower CV and more with higher CV.

Further analysis using the groups data, we apply the following rule, when the GP σ > Gn σ then, GP σ – sample size –Gn σ gives the require RF indicator. The result may be positive or negative or zero. If GP $\sigma \leq$ Gn σ then adds sample size to GP σ and subtract Gn σ, the result could also be positive or negative. Positive result is an indication that rainfall pattern (i.e. onset will delay, cessation will be earlier and duration will reduce) will reduce, if negative it shows wetter condition (i.e. onset earlier, cessation late and delayed duration) an indication of increase RF. A scale of –15 to 15 shows the level of climate shift from the normal.

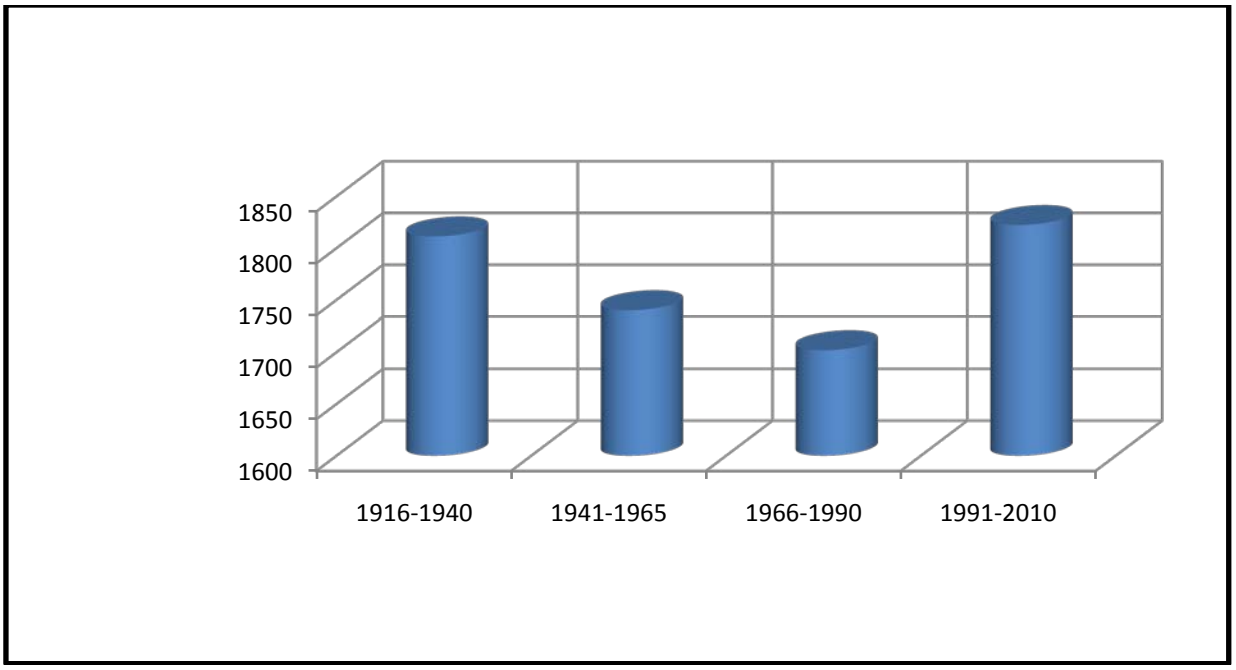

Figure 2 : Groups Mean RF Contribution during the study period

The group analysis shows a +0.01 result an indication of a very mild shift. Any increase in RF could be elusive, if the pattern continued for ¼ of a climate cycle (i.e. ¼*30yrs). The condition will trigger a reduction or drop in RF over Enugu and it's environ.

Statistical analysis using PPMC (Pearson Product Moment Correlation) shows a very negligible relationship between the climate groups during the study period. It was observed that r = -0.084, an indication of very mild reduction of RF distribution, this agrees with the trend line in figure 3. The coefficient of determination = 0.7%, this implies that the climate shift is explain by just 0.7% fluctuation in RF, this again in insignificant. The student's' test = 0.86 meaning that the result is not a product of chance.

The RF occurrence over the years is shown in figure 3. The highest RF was recorded in 1920 and the least in 1983.

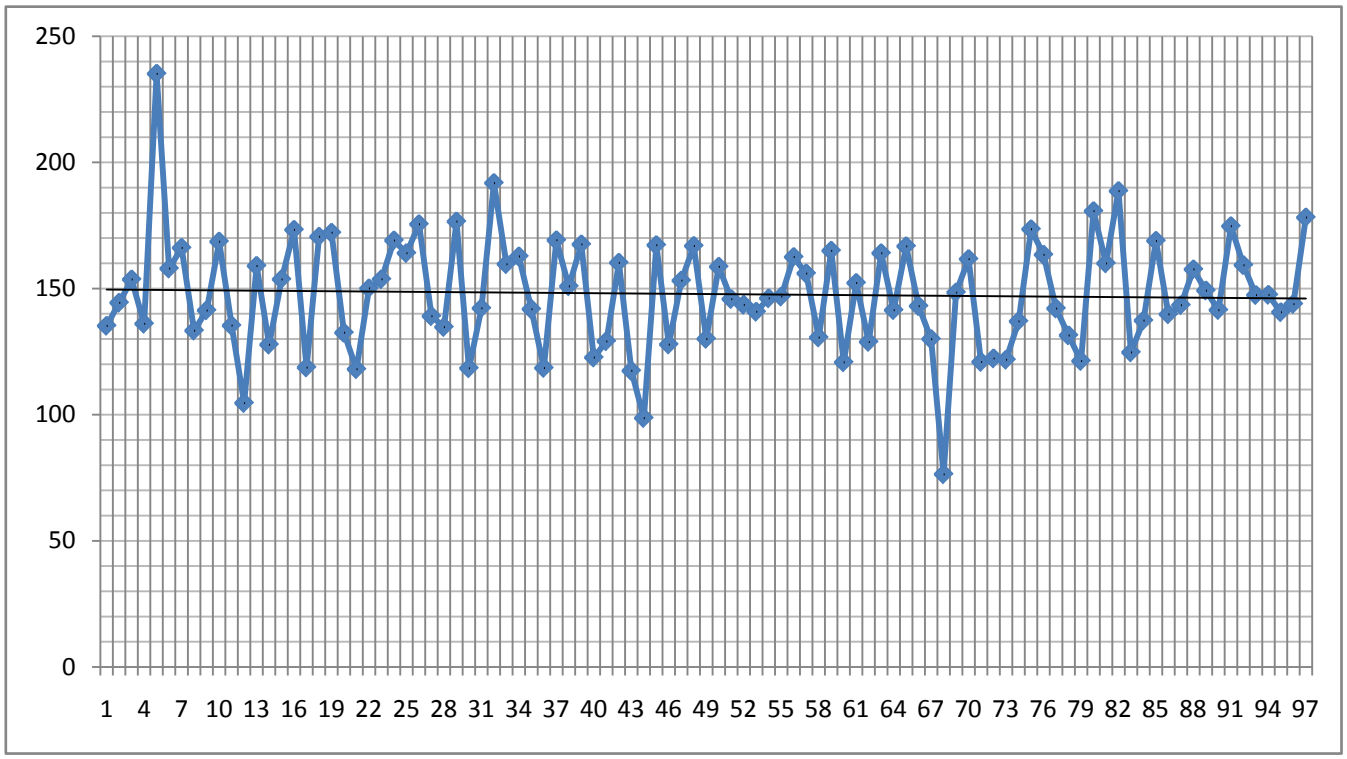

Figure 3 : Enugu Mean Rainfall Distribution (1916-2012)

To establish further trend in the study over the 96 years period under consideration, 5 years running mean was used. The result is shown in figure 4 as RF trend over Enugu.

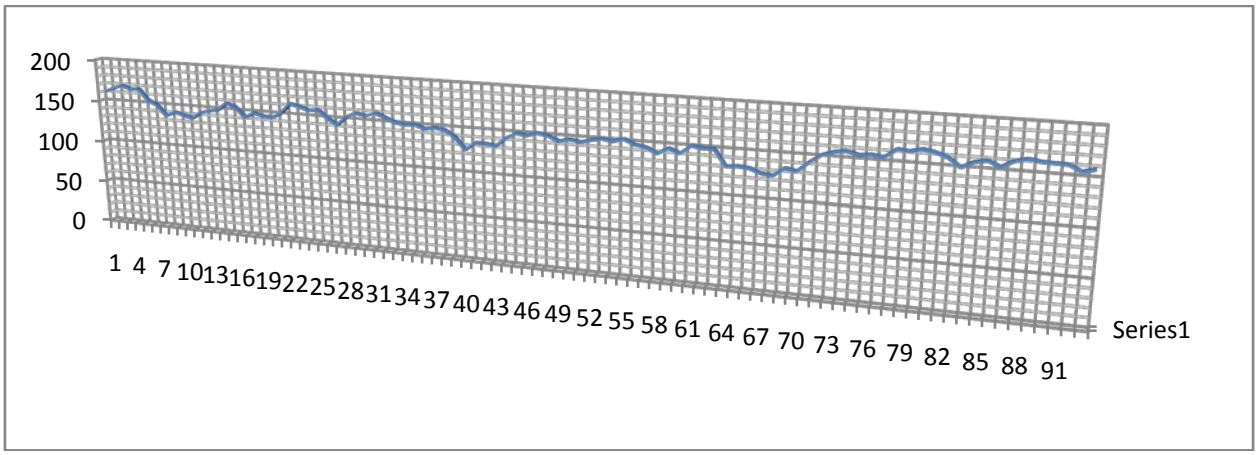

Figure 4 : Rainfall Trend over Enugu (1916 – 2012)

b) Seasonal Rainfall

The month of January and December had the lowest RF in the 97 years of study, while the highest RF was recorded in June and September. From figure 4 it was discovered that Enugu has double maxima type of RF pattern. In general sense of it, the break (dry spell) is longer than in the coastal areas of Nigeria.

The rainy (wet) season months of April through October accounted for 83.3% of RF during the study period (1916-2012), while the dry season months of November through March contributed just 16.7% (28841.95) of the total RF during the study period. This implies an average of 297.34mm of RF very year.

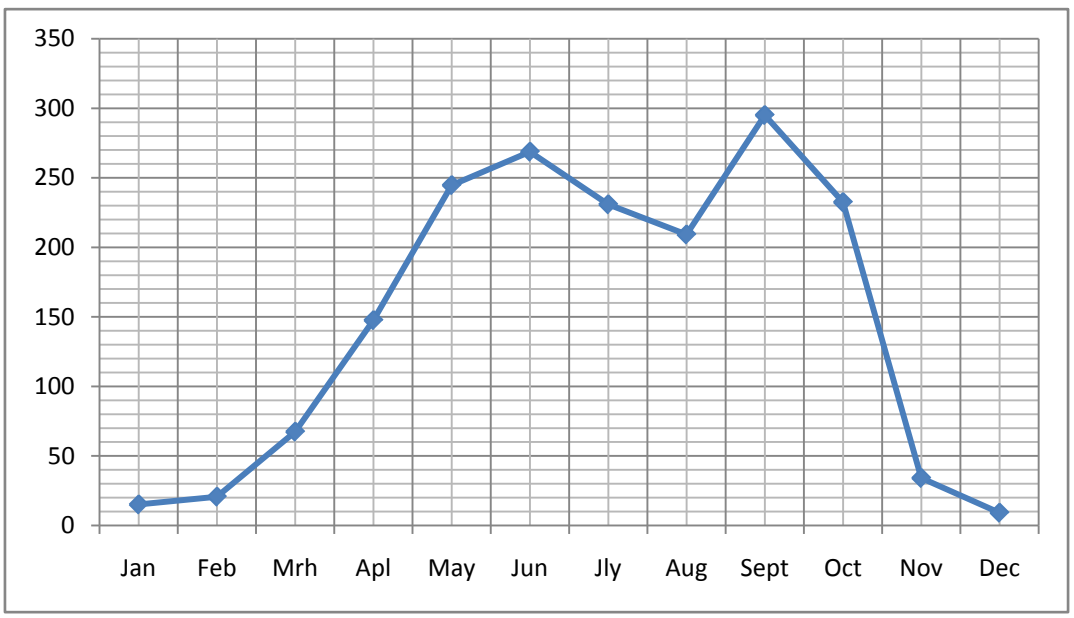

Figure 5 : Enugu mean seasonal RF distribution RF (1916-2012)

Table 2 shows the total, mean, standard deviation (σ), and coefficient of variation (CV) of the various periods of study of Enugu RF.

Table 2(a-d)

Month	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC
Σ	647.17	591.59	1859.6	3978.98	6060.57	6167.36	5425.51	4511.6	6743.64	6610.9	1229.69	329.94
б	25.887	23.664	74.384	159.159	242.423	246.694	217.020	180.464	269.746	264.436	49.188	13.198
σ	31.934	27.798	56.110	71.564	68.453	77.919	88.366	101.633	86.370	120.465	42.869	23.403
cv	123.359	117.470	75.433	44.963	28.237	31.585	40.718	56.318	32.019	45.555	87.153	177.322

Table 2a (1916-1940).

The drier months has the highest CV, this implies that RF are very much unreliable during the dry season and more reliable during wet seasons.

Table 2b (1941- 1965)

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Σ	358.4	673.66	1942.89	3571.4	6524.963	7268.31	4660.79	4666.26	7858.15	6112.4	1291.03	352.76
б	14.336	26.946	77.716	142.856	260.999	290.732	186.432	186.650	314.326	244.496	51.641	14.110
σ	24.178	24.626	45.412	72.396	98.367	98.501	78.294	126.958	92.132	82.358	39.206	17.258
CV	168.62	91.39	58.43	50.68	37.69	33.88	41.99	68.02	29.31	33.69	75.93	122.32

Table 2c (1966-1990)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Σ	257.02	470.56	1753.38	3194.74	5421.35	6572.37	6006.61	5819.78	7550.16	4941.65	413.33	146.49
б	10.2808	18.8224	70.1352	127.79	216.854	262.895	240.264	232.791	302.006	197.666	16.5332	5.8596
σ	15.3537	25.7165	48.5039	56.0727	60.2441	88.7839	83.3844	103.081	86.3484	75.5455	21.9448	12.0235
C.V	168.65	91.39	58.43	50.68	37.69	33.89	41.99	68.02	29.31	33.68	76.26	122.3

Table 2d (1991-2012)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TOTAL	221.4	296	1045.5	3535.2	5687.9	6043.5	6158.2	5213	6474.2	4913.3	423.4	79.7
MEAN	10.064	13.455	47.523	160.691	258.541	274.705	279.918	236.955	294.282	223.331	19.246	3.623
STD	16.876	16.217	37.287	54.420	71.830	63.75	70.515	87.700	75.773	76.429	25.663	9.222
CV	167.793	120.505	78.472	33.867	27.783	23.207	25.191	37.011	25.748	34.222	157.965	254.540

The study shows that RF varies within months, years and seasons, the variation or fluctuation is natural, however, it was observed that dry months total RF is decreasing over the years. This is an indication that RF duration is reducing, therefore more of RF in and around Enugu may occur within very short period. This could be inimical to agriculture, water resources, soil conservation and transport industries. Short duration of heavy RF triggers flash flood, soil erosion and water logging which accentuates crop rotten and witting.

Enugu RF shows close resemblance in climate pattern during the 97 years period of study. For instance the CV of the various time scale of study falls within certain % for both annual and seasonal distribution. The annual CV is lower than the seasonal CV. This implies that the annual RF is more reliable and predictable than the seasonal RF in Enugu. The annual (climatic) CV for the various study periods shows that, 1916-1940 recorded 16.71%, 1941 – 1965had 15.64%, 1961-1990 had 16.72% and 1991-2012 recorded 11.69%. The seasonal CV for 1916 – 1940 was 83.42%, 1941 – 1965 had 80.49%, 1966 – 1990 recorded 85.67%, and 1991 – 2012 accounted for 84.76%. Note the seasonal variation is higher than the annual variation because the differences between the wet season and dry season are compared in seasonal CV, while the differences between years are considered in annual CV calculation.

The Seasonality Index of RF (SIR) summarized by each group mean record shows a slight variation. The period 1916 – 1940 had a SIR of 19.89% (approximately 0.2), 1941 – 1965 had a SIR of 20.38% (~ 0.2), 1966 - 1990 SIR is 21.15% (~ 0.21), and 1991 – 2012 had SIR of 19.77 (approximately 0 .2). The mean SIR for Enugu over the different time or climatic period was 20.30% (~ 0.2). This implies that the seasonality index of rainfall varies very slightly.

c) Onset, Cessation, and Duration of Rainfall

Using the onset of RF for analysis, it was observe that the mean (б) RF onset for 1916 – 1940 is 12th March (71) day of the year. From 1941 – 1964 the б onset is 18th March (77) day of the year. The result for

1961 – 1990 ϭ onset is 18th March (77) day of the year, and finally the ϭ onset of RF from 1991 – 2012 is 27th March (86) day of the year. The result shows a gradual but consistent shift in onset of RF in Enugu. The Onset of RF in Enugu over the study period shows a delay of about two weeks. This gradual shift can hardly be noticed by local people and farmers and thus may affect agricultural yield. The ϭ Onset of RF during the study period is the 19th day of March (78) day of the year. The best onset period target would be 78± a week. The implication is that RF could start a week to or after the 78th day of the year.

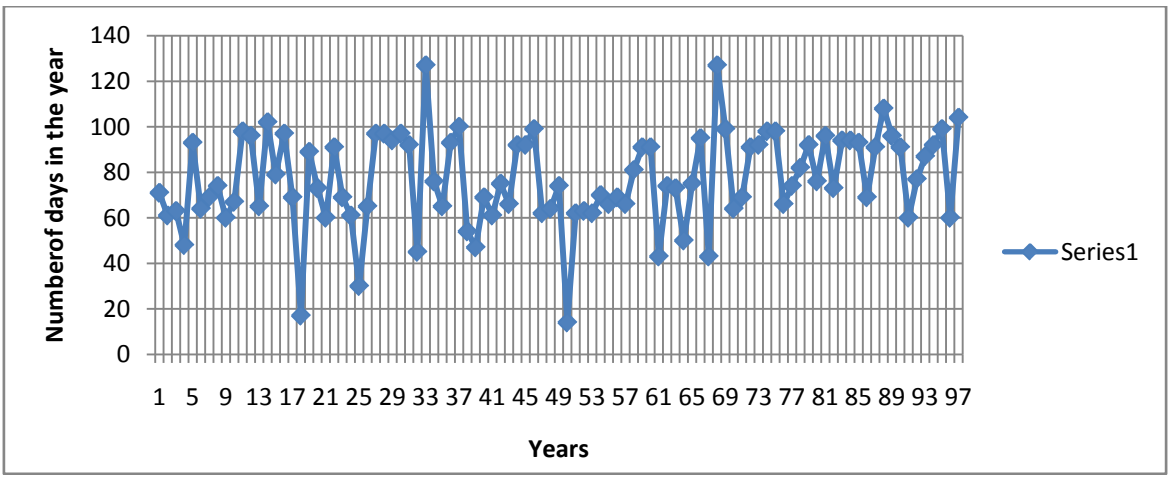

Figure 6a : Onset of RF over Enugu

Cessation or End of RF is analyzed, and it is discovered that the period 1916-1940 had a ϭ RF cessation date of 21st October (294) day of the year. The period 1941 – 1965 recorded a ϭ cessation date of 26th October (299) day of the year. Similarly the period from 1961- 1990 had a cessation ϭ date of 12th October (285) day of the year. Finally, the periods between, 1991 – 2012 was analyzed and it was observed that the ϭ cessation date was 10th of October (283) day of the year. The ϭ cessation date for the study area during the study period is the 17th day of October (290) day of the year. The analysis shows a decrease in or an early cessation from 1941 to 2012. This implies that RF will cease earlier than expected, an indication or warning that late for late planting. There is need for water to be conserve which can be used after RF cessation.

The two analyses gave a clear picture of RF condition or situation as it affects agriculture in Enugu. The annual RF distributions above show an increase in amount of RF over the study periods. This increase could be as a result of flash storm for few days, weeks or a month.

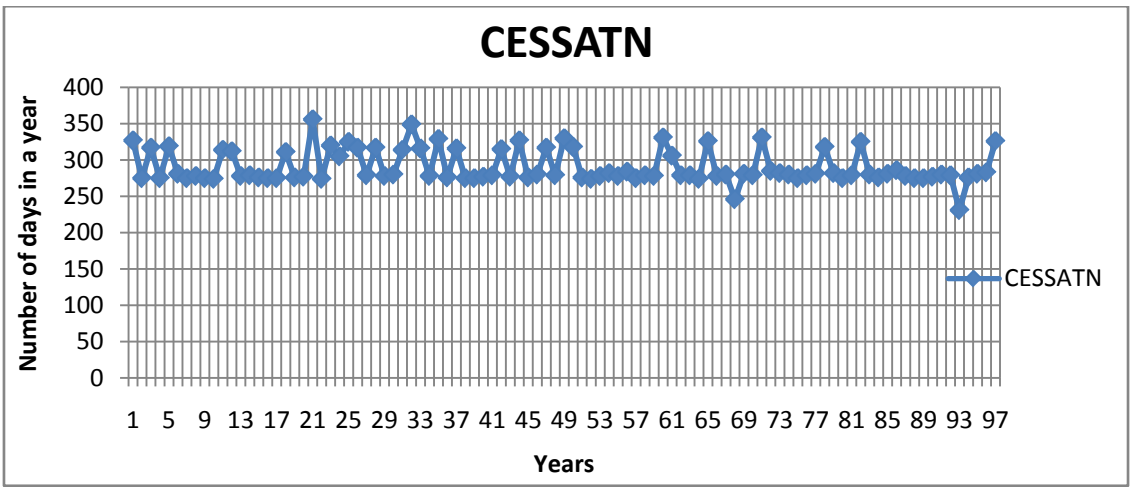

Figure 6b : Cessation of RF over Enugu

Finally Duration of RF was analyzed using the group data. It was discovered that from1916 – 1940, the ϭ duration of RF was 223 days. Note, there is 365 days in a year, therefore 223 of 365 represents 61.10%. 1941-1965 has ϭ RF duration of 222 days, representing about 61.07% of the year. The periods 1966 – 1990 recorded a

б RF duration of 208days representing 57% of the total years of study. Finally, 1991 – 2012 had б RF duration of 198 days, representing 54.3% of the years under consideration. These show a gradual but steady decrease in duration of RF over the study period. Note, the drop in RF duration from about 61% to about 54% is a clear indication that RF characteristics over Enugu is changing. The б RF duration from 1916 – 2012 is about 213 days which represents about 58.36% of the years under review. The seven (7) rainy months of Enugu represents also about 58.33% of the months of the year.

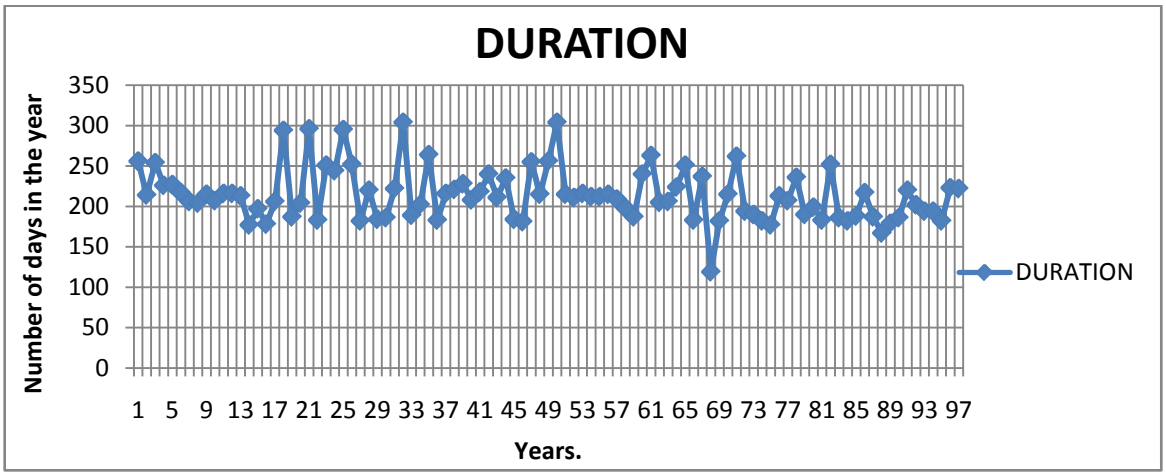

Figure 6c : Duration of RF over Enugu.

The analyses so far shows that Onset of RF is late, the cessation or end is early, these are responsible for the reduction in RF duration over the study area and period. The climate of Enugu is gradually shifting, because alteration of existing RF pattern will also affect other climatic variables. This is a sign for more food, because the climate is shifting to that of the zone known as food basket of Nigeria. The climate has about five months of dry season or relative low RF, new crops like beans; soya bean can now be cultivated in and around Enugu.

The RF condition of Enugu shows that policy makers, farmers, and developers need to consider the Onset of RF and End in their plan. For instance, in road construction especially the local roads, work should start about a week after End of RF.

V. Recommendations and Conclusion

The study observed a steady but gradual shift in RF characteristics/pattern over Enugu during the study periods, which suggest a likely change in climate in the future. Therefore adjustments should be made to accommodate changes observed.

The work shows that annual RF cannot actually explain the RF condition of an area, not even the drought incidence especially agricultural drought. Because a heavy RF outside the target period will give a high annual RF which in actual sense cannot stop agricultural or climatological drought. Similarly, flood can occur even when there is low annual RF or drought within the same year. So, this study suggests that data on RF pattern be consulted before outdoor plans are carried out, especially on agriculture which is the mainstay of the people. Furthermore we call on policy makers; Agriculture and Environment Ministry, and Water resources managers to dully consult related RF and take into account the benefits and otherwise associated with decrease in duration of RF and increase amount of annual RF over Enugu.

A fluctuation in annual RF occurrence is not characteristics of a climate change, besides climate change is not a threat to life and life style of the people of Enugu. Climate change (CC) portends threat or otherwise depending on the location and the environment. For people in the southern Guinea Savanna and Forest Vegetation of Nigeria CC will mean more time to work out door.

This work will not relay on available literature in making speculation, because most of it discusses annual and seasonal RF, and fluctuation and trends in RF distribution over Northern part of Nigeria. However, food productions in Enugu have not been under threaten in anyway or has its food production diminished as a resulted of climate change with regard to RF.

Enugu Ministry of Agriculture and Environment, should introduce crops that required less water and shorter period of maturity.

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