International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 15 (2015) pp 35045-35049

Influence Of Escarpment On Rainfall Pattern: A Case Study Of Udi-South Eastern Nigeria

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ABSTRACT
The presence of escarpment plays an important role in the distribution of rainfall. Its role was studied and was put together in this paper. Various parameter were studied and they included: amount of rainfall, elevation, latitude and the distance from the sea. In this research, frequency analysis was performed on the parameters and the log-pearson type III was considered the most suitable distribution method. Also, principal component analysis was used to determine that two components best estimates the variables with close correlation to be rainfall, elevation, latitude and distance from the sea as component 1 and distance to nearest neighbour and longitude as component 2. With regional coefficient of variation of 22%, the area has low variability indicative of high rainfall values with good consistency. Annual average rainfall of South Eastern Nigeria is at 1744mm with bi-modal double peaks in July and September as in most parts of Southern Nigeria. From the determination of the difference in mean, it is again obvious that areas close to Udi escarpment have mean below or slightly above mean, hence affecting rainfall.

Keywords: distance from the sea, distribution method, elevation, latitude, rainfall and variability

INTRODUCTION:

The Udi escarpment of the South Eastern Nigeria is a long cliff or steep slope that separates an area of high elevation from an area of lower elevation as shown in Fig 1 below. How this phenomenon affect rainfall pattern of the area and the water resources management is the subject of this study. While the South Western Nigeria have a fair number of research on topography and water resources management, the South Eastern part have limited works in this regard, hence this work is needful. According to Balogun (1972), areas of high rainfall also have low coefficient of variation and vice versa, this is the same around Udi. Areas around the range of Udi Plateau which runs perpendicular to the coastline of Nigeria have low coefficient of variation of rainfall. The importance of the variability study is seen in agriculture where there could be longer periods of rainfall absence thereby affecting plants and planting, in hydrology, where drought is experienced and other human activities. Analysis of rainfall in general, enhances the management of water resources applications as well as the effective utilization of water resources (Lee, 2005). Hydraulic Engineering designs such as dam height, embankment height, design discharge etc. are determined using results of frequency analysis. Specific areas such as the dimensioning of dams require the knowledge of frequency analysis and variability of annual rainfall to be efficiently carried out. Even more compelling to the study of variability of rainfall data is the effect of climate change and global warming on water resources projects (Ngongondo et. al., 2011; Odekunle, 2004).This research has decided to look into the spatial and temporal variation of the area understudy. It also employed the use of frequency and principal component analysis to examine and interpret the collected data in the chosen areas.

MATERIALS AND METHODS

THE STUDY AREA

The study site is the South Eastern Zone of Nigeria. This region falls within the latitude 6’ N and 8’ N and longitude 4’ 30’E and 7’30’E. Udi escarpment divides the zone into two area viz South Eastern scarp lands under Anambra /Imo River Basin and Eastern borderlands under Cross River Basins and the apex of Udi plateau at 300m above sea level. The whole region which is densely populated covers an area of about 40000 sq. km and represent 4% of the country’s land mass with the physical environment and climate described in the figure below.

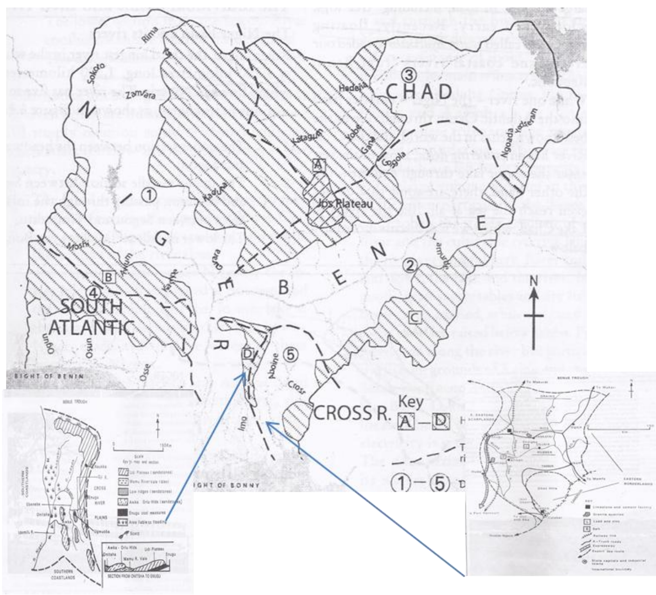

Figure 1: Map of Nigeria showing Udi Escarpment and the

two river basins (Iloeje, 2009).

Physical Environment

The site is of the lowland region of southern Nigeria, which drains to the Atlantic Ocean through the Anambra/Imo River Basin and the Cross River Basin. According to Iloeje (2009), the geology of the area is basically of the stratified sedimentary rock of secondary to tertiary geological era. The unroofing of the anticlines left the Udi escarpment and brought about the undulating Cross River Basin right of the scarp land.

Climate and Hydrology of Study Area.

The South Eastern Nigeria is of the wet tropical type climate with mean annual temperature in the range of between 27℃ and 34℃. The temperature of the area as observed by Iloeje (2009) is highest around March-April when the overhead Sun passes through Nigeria latitude. The rainfall, however, of the area has an annual average of 1744mm, which is decreasing inland from the Niger Delta area or the coast of Nigeria .This is quite clear in Fig 2 below. The Annual rainfall regime of the area is of the double maxima with double peak in July and September and an August break period. The high rainfall between May-September has a lowering effect on temperature of the area.

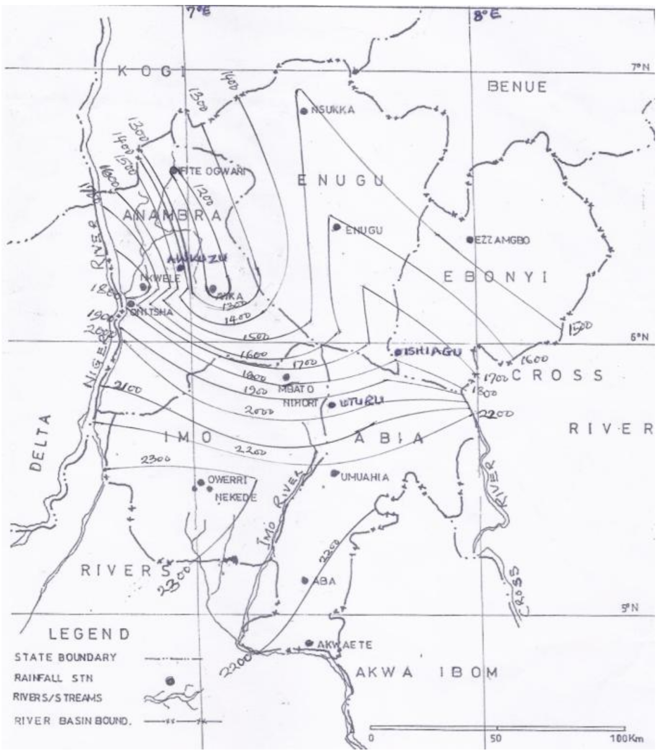

Figure 2: Contour Map of South Eastern Nigeria rainfall

The data for this study area is the secondary data of 12 Stations within the south eastern Nigeria chosen for this research with monthly rainfall which was gotten from Nigeria Meteorological Agency, Lagos, Federal College of Agriculture, Ishiagu, Ebonyi State., Nigeria and Akintola (1986), this data is tabulated in table 1 below. The table shows the location, annual rainfall amount, latitude, longitude elevation and period of data collection. For some areas however, it is necessary to observe that the data was for period less than 10years owing to the absence of sufficient data. However, even with missing data as observed from the table below, the information obtained is tested for reliability and consistency before use.

Table 1: Showing 12 Station with Site parameters

STATION / PARAMETER	**ANNUAL RAINFALL (mm)**	ELEVATION (m)	LATITUDE	LONGITUDE	No. OF YRS OF RECORD
NSUKKA	1517	447.1	6° 52' 12"	7° 24' 0"	1970-1990
ENUGU	1609	141.7	6° 25' 48"	7° 33' 0"	1971-1990
EZZAMGBO	1468	115.8	6° 22' 48"	7° 55' 12"	1981-1990
IFITE-OGWARA	1196	73.8	6° 37' 12"	7° 55' 48"	1975-1989
AWKA	1153	91.4	6° 9' 0"	7° 1' 12"	1975-1989
NKWELLE	1879	71.4	6° 13' 12"	6° 51' 0"	1931-1960
ONITSHA	1759	66.8	6° 10' 12"	6° 45' 0"	1974-1991
MBATO-NIHORT	1786	154.5	5° 33' 0"	7° 22' 48"	1979-1990
ISHIAGU	1799	150.0	5° 55' 48"	7° 31' 12"	1997-2013
UMUDIKE	2237	121.9	5° 28' 48"	7° 31' 12"	1971-1990
OWERRI	2349	91.4	5° 28' 48"	7° 1' 48"	1974-1990
AKWETE	2175	21.3	4° 52' 12"	7° 21' 0"	1972-1990

MEASURE OF RELIABILITY

(a) MEAN

From the annual mean calculation of each station and the region, a departure from average is determined and plotted to indicate how mean rainfall for each stations differ from the mean. This helps us to determine the variability experienced in the rainfall distribution.

(b) COEFFICIENT OF VARIATION

The coefficient of variation or relative dispersion is obtained using the formula

$$Cv = \frac{\sigma}{\bar{x}} \quad (1)$$

A coefficient of variation closer to one indicates greater consistency of data set. It is also an indication of the relationship amongst data set within the same area.

FREQUENCY ANALYSIS

Frequency factors are used to fit theoretical distributions (Mutreja, 1990). As proposed by Chow (1951), the general equation for hydrologic analysis is given as:

$$x_T = \bar{X} + K\sigma \quad (2)$$

Where k is the frequency factor, a function of return period and probability distribution, σ is the standard deviation of hydrologic data and $\bar{X}$ is the mean of hydrologic data. (Kite,1988;Cheng et al.,2000), frequency factor is determined and used to obtain the magnitude of x and the value of x correspond to return period T, denoted by x_T as defined in

$$P(X \geq X_T) = \frac{1}{T} \quad (3)$$

In hydrologic frequency analysis, the probability of occurrence of an event of known return period is evaluated. Several methods of frequency analysis are calculated and compared in this study viz:

(i) Normal Distribution

The Gaussian (1990) distribution is used in the study of measurement errors and characteristics of normal distributions. This is the most important probability distribution.

(ii) Log-Normal Distribution

In situation where hydrologic variables are right skewed due to influence of natural phenomenon, their frequencies do not follow normal distribution but their logarithm does. This distribution as suggested by the US Army corps of Engineers (1993) is valuable for the degree of accuracy in estimation.

(iii) Extreme Value Type I Distribution

This is also known as the Gumbel distribution for flood frequency analysis. In this case, which is specially used for weather study has largest and smallest values known as extreme values associated with floods and drought respectively. The distribution uses mean, standard deviation and skewness in the analysis of the probability of occurrence of an event.

(iv) Gamma (Pearson Type III Distribution)

Pearson Type III distribution is a special case of Gamma distribution and it is a frequency analysis method (Foster, 1924). In this type of distribution, three parameters are used viz mean, standard deviation and skewness.

(v) Log-Pearson Type III Distribution

This is a form of Pearson Type III in which the hydrologic variables are log transformed before analysis using Pearson Type III distribution. The flood magnitude as a variable, for a desired recurrence interval is then estimated from

$$\log Q = \bar{Y} + K\sigma_y \quad (4)$$

Where k is a function of return period and skewness and mean $\bar{Y}$ is the mean of $\log Q$ and standard deviation σ_y.

PRINCIPAL COMPONENT ANALYSIS

Principal component analysis is used as a reduction procedure for variables that tend to empirical relationship. In this regard, large number of observed variables is reduced to smaller number of principal components which accounts for the variance of the observed variable (Lee, 2006). The six component variable is reduced to two with linear combinations of data by this procedure.

RESULTS AND DISCUSSIONS

SPATIAL AND TEMPORAL DISTRIBUTION OF RAINFALL

The figure 2 above, it shows the rainfall concentration and distribution that exist in the South Eastern zone of Nigeria. From the coefficient of variation obtained, it is evident that the rainfall data of the area shows greater consistency with an average of 22% in these zones. Also in figure 3 below, the influence of Udi Plateau is also seen in the dispersion of the rain from the mean. On the location axis, it is seen that from Nkwelle – Akwette, there is a positive value in the rainfall difference which shows the escarpment in contact with the wind bearing rain while the other side of the escarpment is noticed by the negative result obtained from Nsukka –Awka. This has significantly resulted to a variance in rainfall pattern in areas around or within the escarpment.

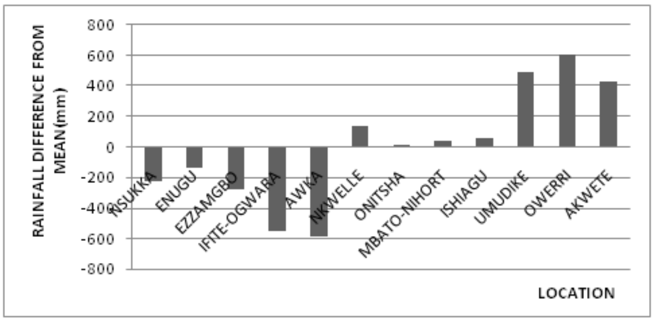

Figure 3: A graph showing the dispersion of rainfall from mean value.

Furthermore, it is clearly seen that Awka has the highest negative dispersion and this is attributed to its closeness to the plateau top with the effect of the distance of each of the stations under observation not neglected.

Generally, South Eastern Nigeria rainfall follow the same pattern as other parts of Southern Nigeria with bi-modal rainfall between May-October, that is, wet season and Nov-April dry season. The rainfall indicates a double peak in July and September.

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 15 (2015) pp 35045-35049

DISTRIBUTION CHARACTERISTICS OF RAINFALL

The rainfall of the South East have high concentration from the coast reducing inland towards the Udi escarpment. From this research, as seen in table 1 above, the mean rainfall of the zone was found to be 1744mm, and Awka having a mean of 1153mm.The heaviest rainfall of the area is around Owerri/Umudike axis at 2349mm.

Figure 4: A graph showing Elevation (m) against Annual Rainfall (mm).

From the relation of elevation vs annual rainfall Fig 4 above, it is seen that rainfall decreases with increase in elevation. However elevation is not as significant as the effect of latitude and distance from the sea Fig 5 and Fig 6 below.

Figure 5: A graph showing Latitude against Annual Rainfall

Fig 6: A graph of distance from sea (m) against Annual rainfall (mm).

FREQUENCY ANALYSIS RESULTS

Frequency analysis of rainfall data for South Eastern Nigeria is computed comparatively using normal, log-normal, extreme value type I, Pearson type III and Log-Pearson type III distributions with rainfall data average 8 years and above. For the 12 stations in the zone, Log-Pearson type III has the best probability distribution at 50% of stations in the zone followed by Pearson type III and with Log-normal and extreme value type I has no significance in the zones.as shown in Figure 7 below.

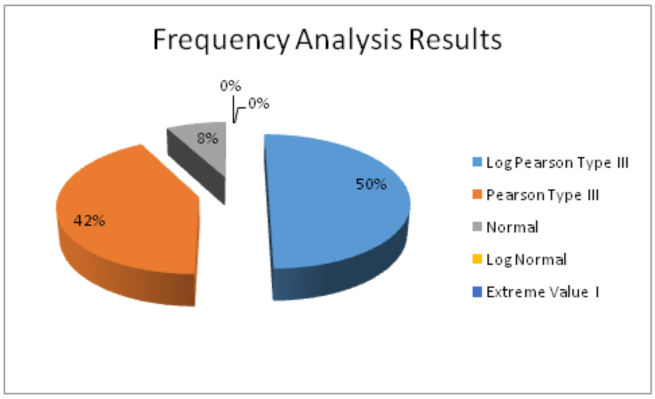

Figure 7: Frequency analysis results

RESULTS FROM PRINCIPAL COMPONENT ANALYSIS

Variables used in this analysis consist of annual rainfall, elevation, latitude, longitude, distance from the sea and distance from the nearest neighbour data. Principal component analysis is carried out to transform the original data with the correlation and eigenvalues determined. The two components are capable of interpreting 71.85% of the entire information as shown in table 2 below.

Table 2 - Extraction Method: Principal Component Analysis.

Total Variance Explained						
Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.036	50.598	50.598	2.972	49.535	49.535
2	1.275	21.248	71.846	1.339	22.311	71.846
3	0.888	14.796	86.642			
4	0.639	10.656	97.298			
5	0.112	1.869	99.167			
6	0.05	0.833	100			

Table 3: The Principal Components determined

Rotated Component Matrix[a]		
	Component	
	1	2
DIST. FROM SEA	0.958	
LATITUDE	0.946	-0.171
ANNUAL RAINFALL	-0.835	0.214
ATTITUDE	0.648	0.378
DIST. FROM NEAREST NEIGB.	-0.205	0.775
LONGITUDE		0.715

Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

From table 3, component 1, shows the strongest correlation exist between rainfall and distance from the sea, rainfall with latitude and rainfall with elevation. In all the cases there is a decrease in rainfall for increase in those parameters, that is, places with high elevation correspond with high latitude and shortest distance from sea and high rainfall value. As for the second component there is an increase in longitude and distance from nearest neighbour with increase in this component. This suggests that places with long distance between stations are also along increase in longitude.

CONCLUSIONS

The result of this study indicates that out of the five frequency distributions, Log-Pearson type III best describes the frequency distribution of 50% of stations. It is necessary to observe that the rainfall data used is on average 8years and above with some missing data. A better result could be achieved with increase in number of data available to a higher accuracy. From the principal component analysis, the variation can be explained with two components and in these, the elevation, latitude, distance from sea and rainfall are the main factors, while others such as temperature, humidity, air pressure, presence of acid rain can be checked for. Since elevation has influence, as one of the main factors, it is evident that the presence of Udi escarpment is affecting the value of rainfall of the South Eastern Nigeria. It is suggested that another study should be conducted to include the South-South zone in order to have a better picture of the influence of the main variables on the rainfall pattern of the Southern part of Nigeria.

ACKNOWLEDGEMENT

We acknowledge with thanks the various contributions of Professors; V .C Ukegbu and V. O Imo. Also noted is the inestimable value of the information obtained from the Nigerian meteorological agency and the various river basin authorities in Nigeria.

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