

A STUDY ON THE VARIABILITY OF RAINFALL IN IBI, TARABA STATE NIGERIA

* Ochoche Gabriel, Audu, B.N., Adda, A. Q. and Kanu, M.O.
Department of Physics, Taraba State University, Jalingo
*+2348086582401, ehiely@gmail.com

Abstract: Rainfall is a highly variable atmospheric parameter, taking on a spatio-temporal dimension. Ibi is located in the Sudan-Savannah vegetation zone of Nigeria and has over the past decades experienced variability in rainfall. For this study, rainfall data for 22 years was analyzed, the Time Series Plot gave a decreasing trend over the 22 years period, while the Standardized Anomaly Index showed drier years from the mid to the end of the period, the Spectrum Analysis gave a periodicity of 3 years cyclical variation, the normal distribution curve has a mean rainfall amount of 1061mm for the 22 years period, running analysis for the July to September rainfall equally showed much variability in the Ibi rainfall regimes.

Key words: rainfall, variability, spectrum, periodicity.

Introduction

Variability in the West African rainfall regime has a large scale feature, possible effects by perturbations from climate change on this variability is a subject of climate observation globally (Onibon *et al.*, 2002). According to Gu and Adler (2003), average rainfall in West Africa is concentrated between two regions i.e. around the Gulf of Guinea and the Latitudes; from July- September there is a northward movement of the Africa Easterly Jet (AEJ) contrasting the Africa Easterly Waves propagating in the western direction (Gu and Adler, 2003). As reported by Zhao *et al.* (2011), the Monsoonal system in West Africa is integral to the existence of the hydrological cycle; the West African Monsoon is a regulator giving rise to the wet and dry seasons resulting from solar atmospheric forcing. Agricultural production is impacted by climatic variability especially on the rural population in West Africa, this impact in effect exerts on the socio-economic live of the people (Sultan *et al.*, 2004). Rainfall is characterized by fluctuations as seen from historical data available; in Sub-Saharan Africa the mode of variation in rainfall assumes both a long

and short time scale, giving insight to the differential nature of rainfall causal factors (Nicholson, 2000). In West Africa, rainfall variability is associated with the hydrological cycle, this variation in time scale is a modulation factor for seasonal changes and the attendant influence of the position of the Inter-Tropical-Convergence-Zone (ITCZ) (Gallée *et al.*, 2004). The variability of rainfall from years to days time scale are important features in climate studies, low rainfall amount does not in finality portray draught. The African continent has a long history of rainfall variability that assumes different spatio-temporal degrees (Gommes and Petrassi, 1996). Seasonal changes in Africa are evident by the difference in the Pressure system, in spatio-temporal modes as well as in the location of the Inter-Tropical-Convergence-Zone (ITCZ). From July-August a low Pressure system is prevalent lying between the Northeast trade wind and the Southwest Monsoon, these pressure belts are obviously separated by the Inter-Tropical-Convergence-Zone (ITCZ) (Nicholson, 2000; Omogbai, 2010).

Causes of rainfall variability

The climate of West Africa is affected by the Global climate system and by the ElNino-Southern Oscillations (ENSO), North Atlantic Oscillations (NAO) and anomalies in the Sea Surface Temperature (SST), (Sarr, 2012; Nicholson and Grist, 2001). Climate change as induced by anthropogenic influences caused fluctuations in rainfall pattern; these perturbations are major causes of draught and flooding in Sub-Saharan Africa thereby informing the need for research on climate variability (Conway et al., 2008). Belli et al. (2009) showed that the West African Monsoon majorly gives rainfall to the region in association with the movement of the Inter-Tropical-Convergence-Zone (ITCZ). According to Janicot et al. (2011) the Inter-Tropical-Convergence-Zone experiences meridional displacement as characterized by 'on' and 'off' at the outset of the rainy season between April and June after which the summer Monsoon ensues with a northward movement of the Inter-Tropical-Convergence-Zone. The West African Monsoon is reportedly sensitive to anomalies in the Sea Surface Temperature (SST) and the ElNino-Southern Oscillation in the equatorial pacific (Bielli et al., 2009). The study area is within the West Africa sub region and a part of the Sudan Savannah vegetation zone; it has a season of rainfall that spans seven months from April to October. Agricultural activities are dependent on rainfall; this implies that much rainfall variability in any season occurring for this area strongly imparts agricultural activities (Ati et al., 2009). Global rainfall has increased as a result of changes in temperature. This upward trend is stepped up by the light intensity reaching the earth. Key hydrological parameters like evaporation increase and upsurge in the

atmospheric water vapour have correlation to an upward change in the air temperature (Babatolu et al., 2014). Rainfall is the main source of water for agriculture in northern Nigeria where subsistent farming is prevalent (Ati et al., 2009). Obot et al. (2010) implied that having a good understanding of rainfall and the pattern of change is of great benefit to farmers. In northern Nigeria, rainfall varies in both a cyclical mode with an asymmetric feature characterizing the trend, these periodicities are of the order of 3 to 5 years, 10 to 20 years and 30 to 40 years in time from different stations studied (Ekpoh and Nsa, 2011).

Materials and Methods

Ibi is a Local Government Area in Taraba State of Nigeria located between latitude 7⁰55'N to 8⁰43'N and longitude 9⁰25'E to 10⁰25'E of the prime meridian.

The rainfall data used for this study was obtained from the Nigeria Meteorological Agency (NIMET) Jalingo office; it contains 22 years rainfall data.

The statistical methods for assessing rainfall variability used were the standard deviation, coefficient of variation, moving average, the standardized rainfall anomaly index, Gaussian distribution and the Periodogram.

The Gaussian Probability Function used is as follows.

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Where μ is the mean or expectation of the probability function, while σ is the standard deviation (Wilks, 2006).

A Periodogram is a graphical data analysis technique for examining frequency-domain models of an equi-spaced time series; it is a Fourier transform of the autocovariance function. The periodogram (spectrum) for a time series x_t is

$$S(f) = \frac{\Delta}{n} \left[\left(\sum_{t=-1}^{n-1} x_t \cos(2\pi f t \Delta) \right)^2 + \left(\sum_{t=-1}^{n-1} x_t \sin(2\pi f t \Delta) \right)^2 \right]$$

Where f is the frequency, n is the number of the observation in the time series, Δ is $(n + 1)/2$ for n odd and $(n + 2)/2$ for n even.

The dominant frequency in this model is given by the peak for the periodogram.

Results and Discussion

From the analysis carried out on the Ibi rainfall data the following are the results obtained; Table 1 is a summary statistics for Ibi rainfall variability covering the period under study. Figure 1 is the annual rainfall chart from 1991 to 2012; it is characterized by a decreasing trend with the maximum rainfall occurring during the 2009 season while the 2003 season experienced the lowest rainfall. Figure 2 is the standardized anomaly index for Ibi rainfall from 1991 to 2012; this confirms the decreasing trend shown in Figure 1, as a departure from the long term mean it clearly projects a bimodal characteristic of alternating wet and dry years demonstrated by the annual rainfall standardized anomalies studied by Nicholson and Grist (2011). It had more dry years from the mid of the study period to the end of it. Figure 3 is the spectrum chart characterizing the periodic change in Ibi rainfall, the periodicity is of 3 years cycle, the normal distribution curve for the entire period is shown in Figure 4 which gives a mean rainfall amount of 1061mm. Figure 5 is the

July rainfall for the 22 years data, it has an increasing trend, with year 2012 recording the highest rainfall amount while the year 2011 recorded the lowest amount of rainfall for July. Figure 6 is the August rainfall showing a decreasing trend with the year 2010 recording the highest amount of rainfall with the lowest occurring in the year 2003. The September rainfall is as given by Figure 7, it is characterized by an increasing trend, and the year 2001 recorded the maximum rainfall while the minimum rainfall occurred in the year 2003. The spectrum chart for July rainfall is given by Figure 8. It has a periodicity of the order of 3.7 years cycle, for July rainfall Figure 9 shows the normal distribution curve, the mean rainfall distribution is 183.41mm, the spectrum of Ibi August rainfall is shown in Figure 10. It has a periodicity of 2.8 years cyclical variation. Figure 11, is the normal distribution curve for Ibi August rainfall with a mean amount of 196.52mm. Figure 12, is the spectral chart of Ibi September rainfall with a periodicity of 4.4 years cyclical variation while Figure 13 is the normal distribution curve for September Ibi rainfall with a mean spread of 210.7mm. In contrast the Figures 1 and 2 had dryness in most part of the years considered, as the initial period had wetter years falling above the long term mean as obtained in Yelwa (Ati, et al., 2009)

Table 1: Summary statistics showing key rainfall parameters measured

Parameter	Result	Parameter	Result
Mean	1061.4	Median	1006.5
Minimum	718.50	Maximum	1530.1
Standard deviation	207.55	C.V.	0.19554
Skewness	0.53707	Ex. kurtosis	-0.56627
5% percentile	735.83	95% percentile	1504.3
Interquartile range	319.40	Missing obs.	0

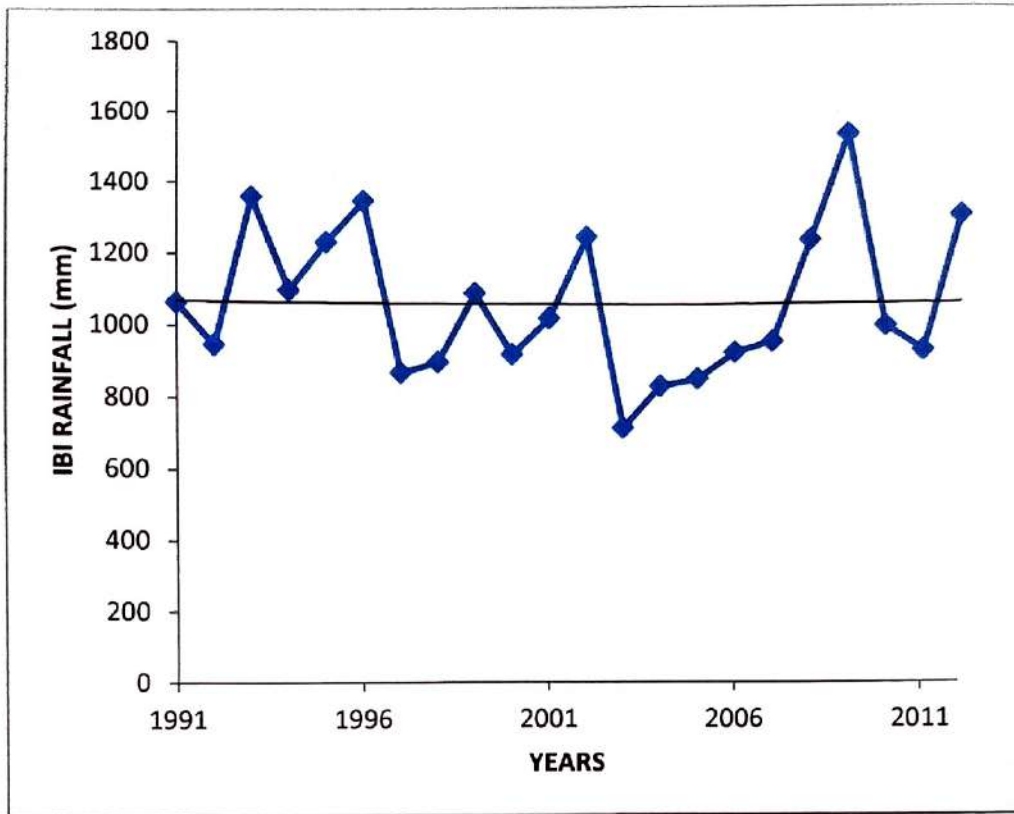


Figure 1: Annual rainfall of Ibi

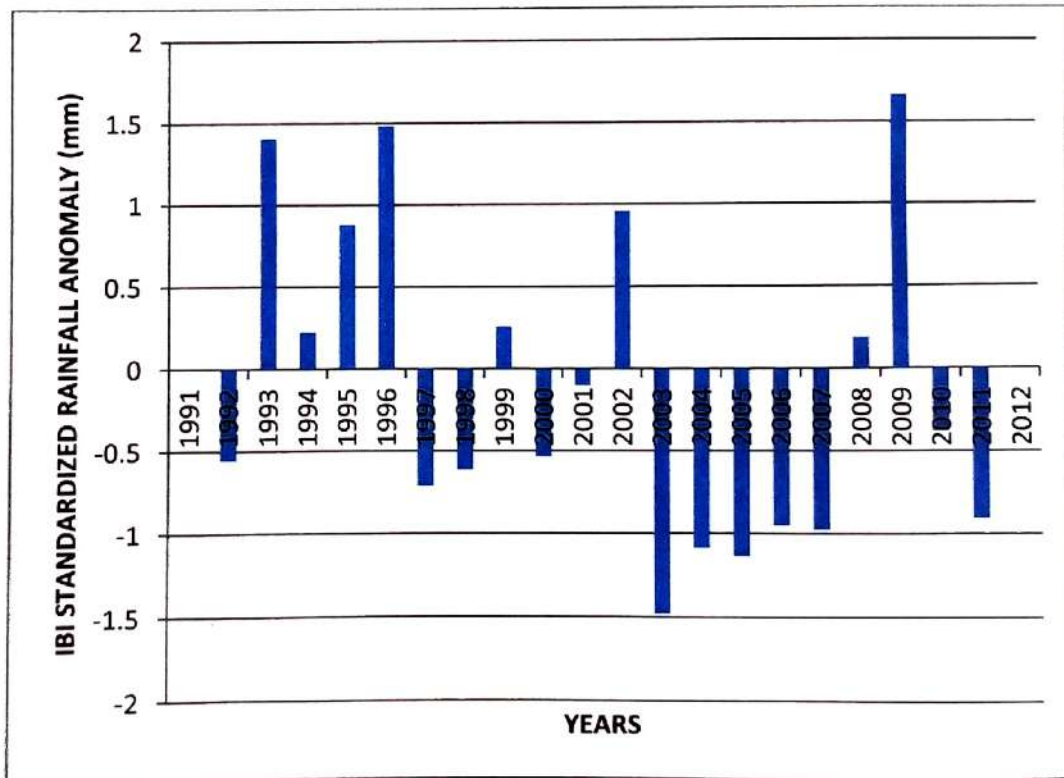


Figure 2: Standardized rainfall anomaly of Ibi

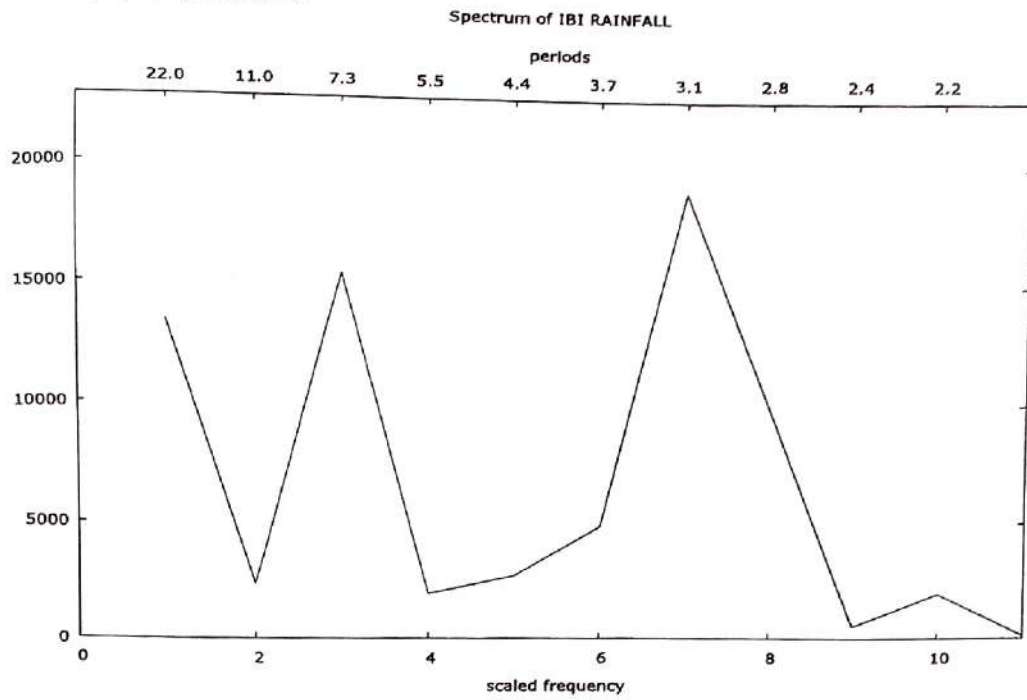


Figure 3: Spectrum of Ibi rainfall

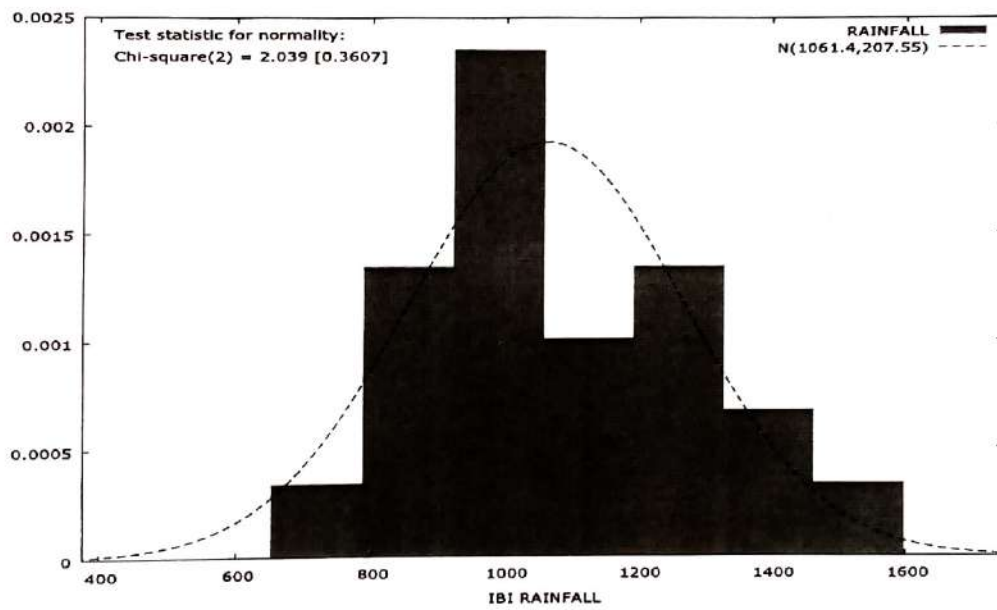


Figure 4: Normal distribution curve of Ibi

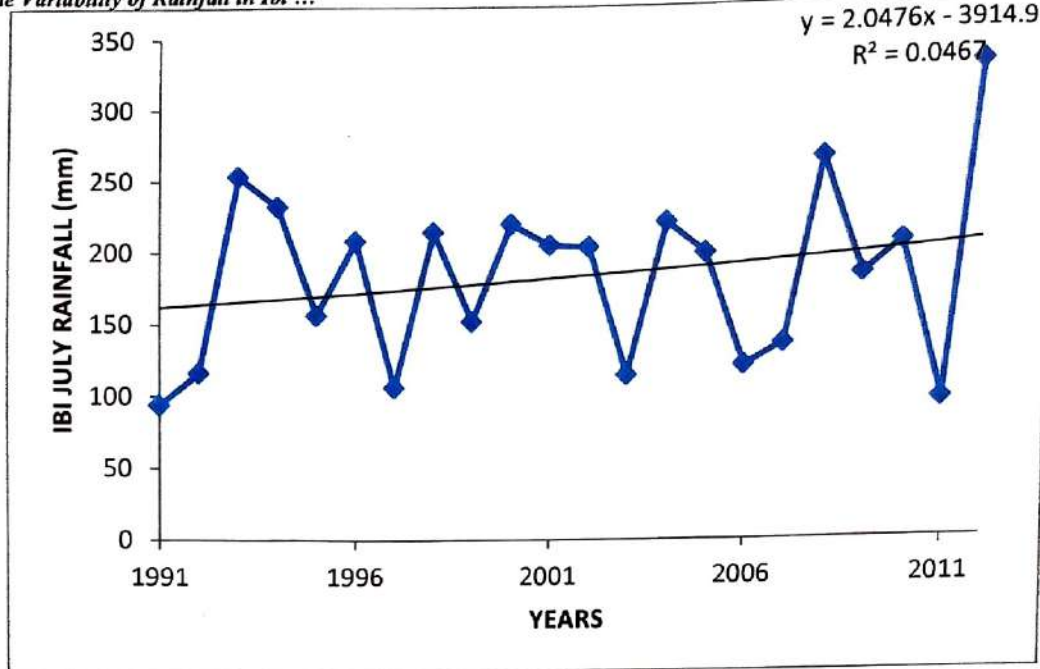


Figure 5: Ibi July rainfall

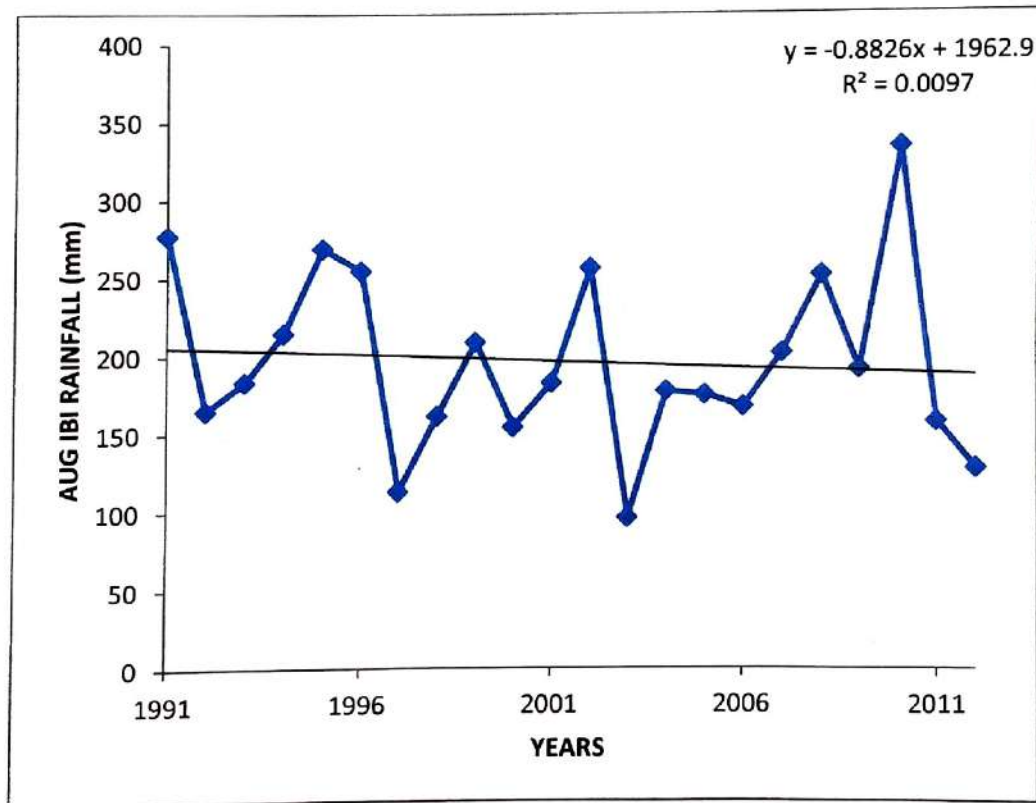


Figure 6: Ibi August rainfall

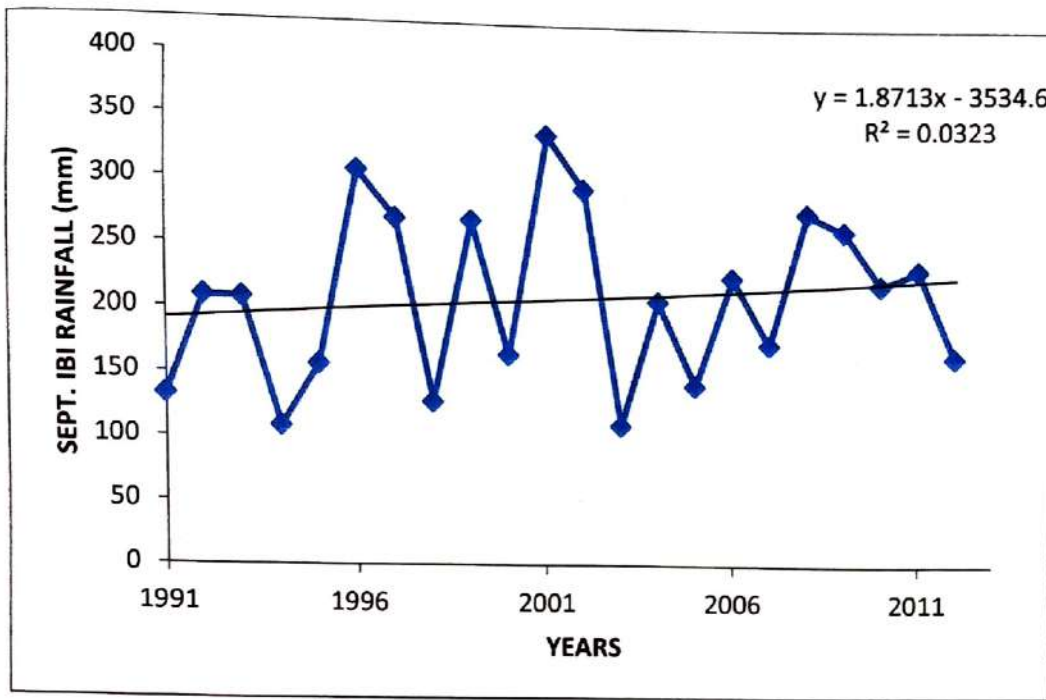


Figure 7: September Ibi rainfall

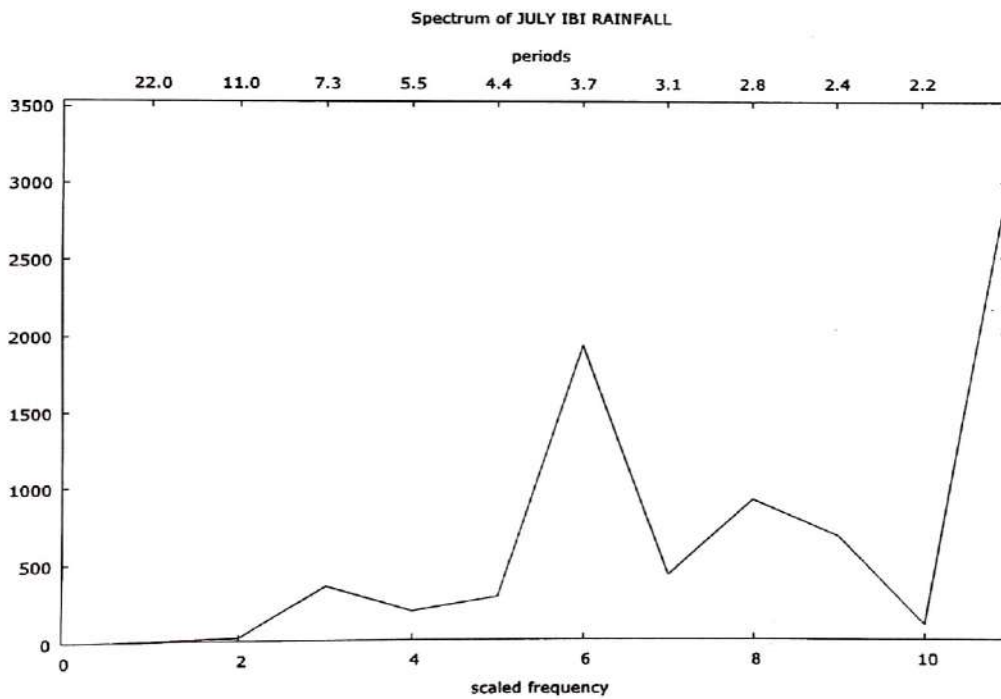


Figure 8: Ibi July Rainfall spectrum

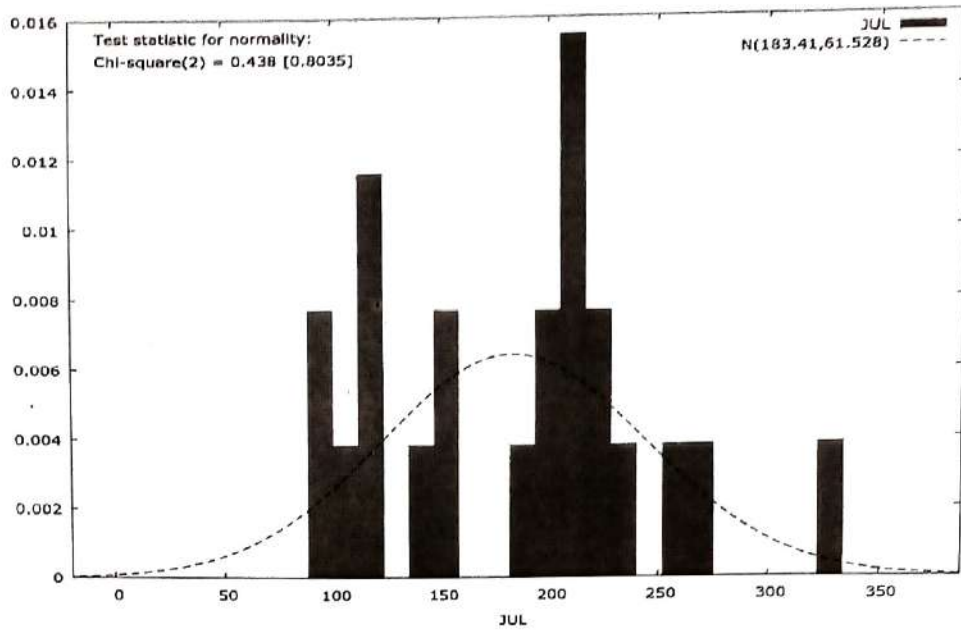


Figure 9: Ibi July Normal distribution curve

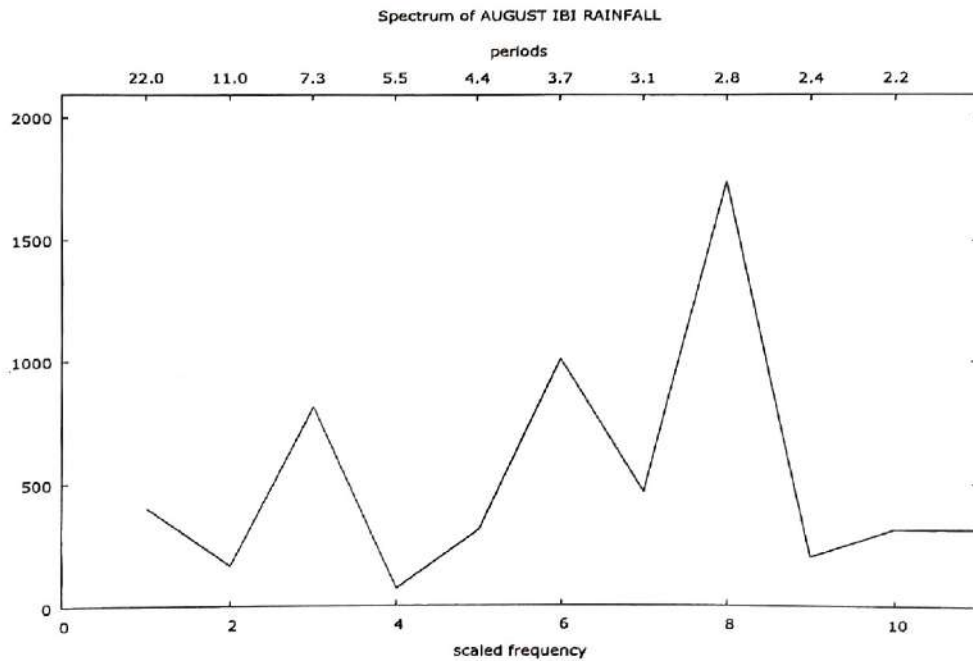


Figure 10: Ibi August rainfall spectrum

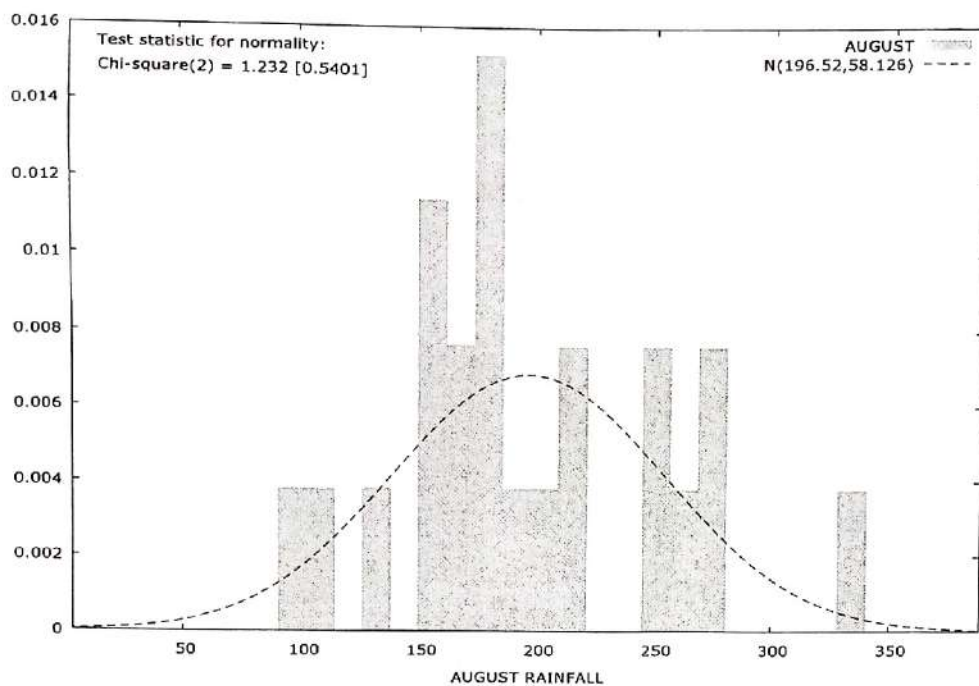


Figure 11: Normal distribution curve for August

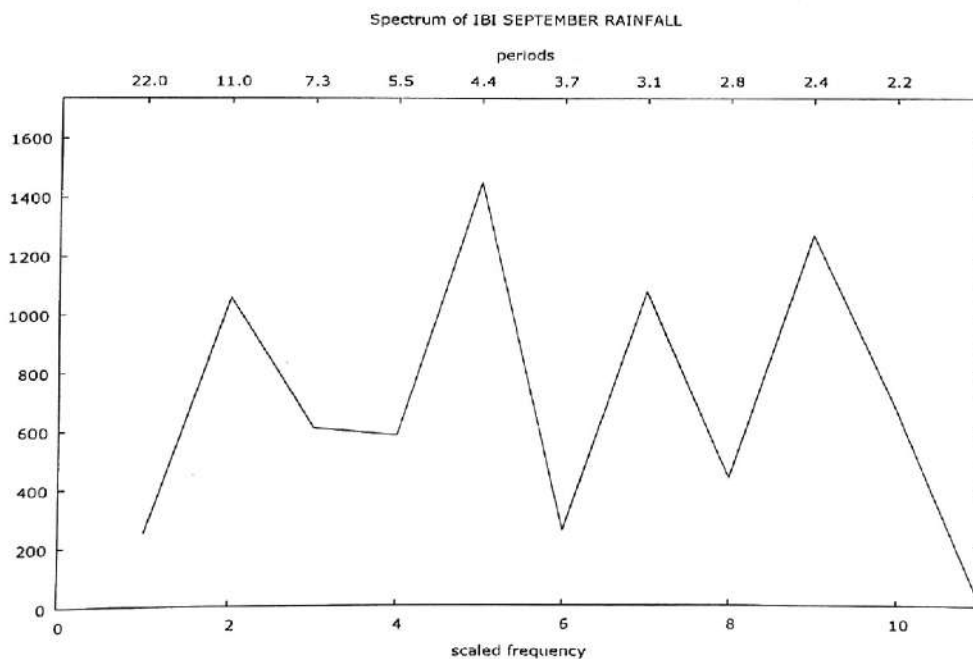


Figure 12: Ibi September rainfall spectrum

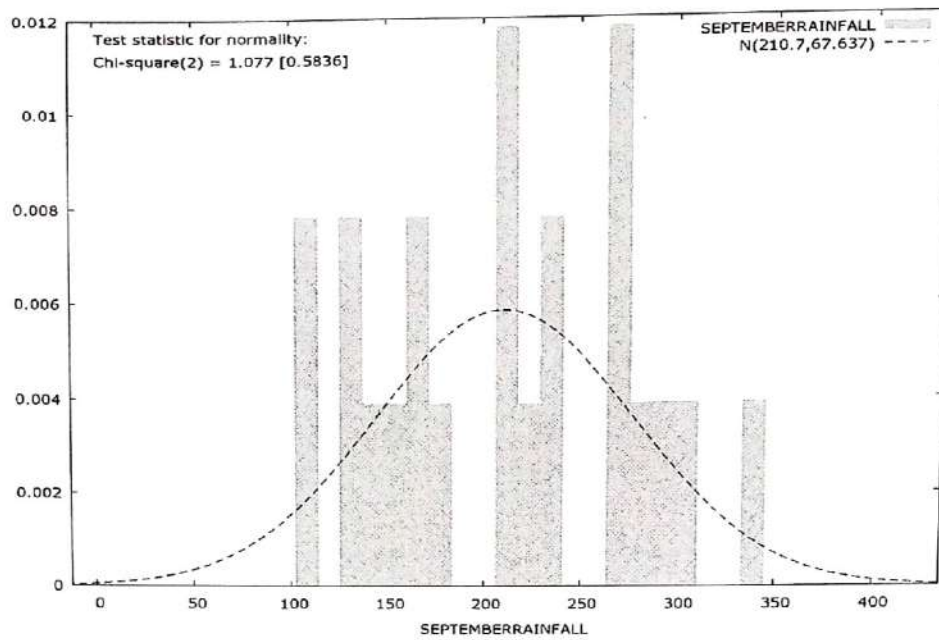


Figure 13: Normal distribution curve for September Ibi rainfall

Conclusion

In this study, it is obvious from the annual rainfall chart that the 22 years period is characterized by a decreasing trend and the standardized anomaly index for the same period confirms this trend. For this same period, it is established that the occurrence of rainfall in this area takes a short range, i.e. the periodicity of rainfall in Ibi is of 3 years cycle with a mean rainfall amount of 1061mm.

Recommendation

It is recommended that, in order to better understand the underlying critical factors affecting the variability of rainfall in Ibi, a regional model should be developed incorporating other elements like temperature, pressure, atmospheric forcing and relative humidity to enhance our knowledge of how this variables change and evolve in time to aid in planning for future short time purposes.

Acknowledgement

The Authors want to thank the Nigerian Meteorological Agency (NIMET) Jalingo office for making available the data for this study.

References

Ati, O. F., Stigter, C. J., Iguisi, E. O. and Afolayan, J. O. (2009). Profile of Rainfall Change and Variability in the Northern Nigeria, 1953-2002. *Research Journal of Environmental and Earth Sciences* , 1 (2), 58-63.

Babatolu, J.S., Akinnubi, R.T., Folagimi, A.T. and Bukola, O.O. (2014). Variability and Trends of Daily Heavy Rainfall Events over Niger River Basin Development Authority Area in Nigeria. *American Journal of Climate Change* , 3, 1-7.

Bielli, S., Douville, H. and Pohl, B. (2009). Understanding the West African Monsoon variability and its remote effects: an illustration of the grid point nudging methodology. *Climate Dynamics* , 1-16.

Conway, D., Persechino, A., Ardoin-Bardin, S., Hamandawana, H., Dieulin, C., and Mahe, G. (2008). Rainfall and Water Resources Variability in Sub-Saharan Africa during the 20th Century. *Tyndall Centre for Climate Change Research* , 1-30.

- Ekpoh, I. J. and Nsa, E. (2011). Extreme Climatic Variability in North-Western Nigeria: An analysis of Rainfall Trends and Patterns. *Journal of Geography and Geology*, 3 (1), 51-62.
- Gallée, H., Moufouma-Okia, W., Bechtold, P., Brasseur, O., Dupays, I., Marbaix, P. et al. (2004). A high-resolution simulation of a West African rainy season using a regional climate model. *Journal of Geophysics Research*, 109, 1-13.
- Gommes, R. and Petrassi, F. (1996). Rainfall Variability and Draught in Sub-Saharan Africa. *Sustainable Development Department, Food and Agriculture Organisation of the United Nations (FAO)*, 1-4.
- Gu, G. and Adler, R. F. (2003). Seasonal Evolution and Variability Associated with the West African Monsoon System. *Journal of Climate*, 1-39.
- Janicot, S., Sultan, B., Mounier, F., Chauvin, F., Lafore, J. P., Roehrig, R., Kiladis G., Taylor C.M. and Lavender S.L. (2011). Seasonal and intraseasonal variability of the West African monsoon. *Atmospheric Science Letters, Special Issue*, 12 (1), 67-74.
- Nicholson S.E. and Grist, J.P. (2001). A conceptual Model for understanding Rainfall Variability in the West African Sahel on Interannual and Interdecadal Time scales. *International Journal of Climatology*, 21, 1733-1757.
- Nicholson, S. E. (2000). The nature of rainfall variability over Africa on time scales of decades to millenia. *Global and Planetary Change*, 26, 137-158.
- Obot, N. I. and Onyeukwu, O. N. (2010). Trend of Rainfall in Abeokuta, Ogun State, Nigeria: A 2 Year Experience (2006-2007). *Journal of Environmental Issues and Agriculture in Developing Countries* 2 (1), 70-81.
- Omogbai, B. (2010). An Empirical Prediction of Seasonal Rainfall in Nigeria. *Journal of Human Ecology*, 32 (1), 23-27.
- Onibon, H., Lebel, T. and Afouda, A. (2002). Space-time rainfall variability in West Africa \derived from observations and GCMs. *Proceedings of the Fourth International FRIEND Conference*. 274, pp. 483-490. Cape Town: IAHS.
- Sarr, B. (2012). Present and future climate change in the semi-arid region of West Africa: a crucial input for practical adaptation in agriculture. *Atmospheric Science Letters*, 1-5.
- Sultan, B., Baron, C., Dingkuhn, M., Sarr, B. and Janicot, S. (2004). Agricultural impacts of largescale variability of the West African monsoon. *Agricultural and Forest Meteorology*, 1-18.
- Wilks, D. S. (2006). *Statistical Methods in the Atmospheric Sciences*. (2 ed., Vol. 91). Burlington, USA: Academic Press.
- Zhao, C., Liu, X., Leung, L. R., and Hagos, S. (2011). Radiative impact of mineral dust on monsoon precipitation variability over West Africa. *Atmospheric Chemistry and Physics*, 11, 1879-1893.