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Determination of the Dominant Rainfall Cycles in Adamawa Stateof North Eastern Nigeria

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Abstract:- The aim of this paper was to determine the dominant rainfall cycles in Adamawa State of north – eastern Nigeria. This was necessitated by the devastating flood events that occasionally ravage the area destroying lives, farmlands and property. In spite of this frequent hazard, research of erratic rainfall events in the area have remained scanty. Thirty five (1977 – 2011) years rainfall data were used to calculate the order of importance, cycles and periodicities of rainfall of the area. The technique employed to achieve this is the Harmonic Analysis which was used to mathematically express the complex fluctuations usually observed in the time series trend. Result shows that four cycles namely 1,5,10 and 13 with amplitudes of 162.21mm, 129.40mm, 124.66mm and 120.22mm and periodicities of 35, 6.20, 5.40 and 3.30 respectively were dominant. All calculations were performed with the aid of SPSS version 20 statistical program. Following from the findings, it is suggested that relevant authorities should use the result obtained to alert the populace in the area on the probability of flood in any identified year, while a comprehensive flood management plan for the area should be developed. With these measures, we hope that the devastating effect of flooding in that part of the country will be greatly minimised.

Keywords:- Flood, Harmonic, Hazards, Probability, Rainfall.

I. INTRODUCTION

The importance of rainfall to the entire economic wellbeing of any region has been extensively discussed in the literature (Adefolalu, 1984, Anyadike 1987, Knippertz, 2003 and Hardy, 2009). However, because of its direct and sometimes harmful impacts on the socio-economic life of people, rainfall is regarded as the most important climatic event in West Africa (Anyadike, 1994). Nnamchi and Anyadike (2008) saw rainfall as the most significant climatic determinant of the landscape in terms of natural vegetation and land use activities. Apart fromits importance as a source of water supply, it plays primate roles in the economy of any agricultural region especially. Washington et al (2006) in adding to this, noted that it helps in industrial production and ensures the reduction in the poverty level of people.

In Nigeria, extensive studies have been done on the relationship between rainfall and major sectors of the economy including agriculture, water supply and industrial production (Ayoade, 1973, Adefolalu and Oguntoyinbo, 1985, Folorunsho et al, 1998, Madu and Ayogu, 2010, Sawa and Adebayo, 2011). Furthermore, the impact of rainfall on flooding in Nigeria received an equal comment from scholars (Utang et al, 2008, Iguisi and Awwal, 2008, Nwagbara, Ijioma and Chima, 2010, Aguolu 2012) and most of them agree that rainfall is the most important factor contributing to flooding in the tropical world. Most rainfall studies including the work of some of the above scholars have concentrated on rainfall variability and distribution in space which do not determine future rainfall behaviour of a place rather they reveal their spatial character and relationship with regional agricultural and socio-economic development. However, future rainfall characteristic of a place is also important for the determination of future socio-economic activities of an area. This being the case, to ascertain future rainfall conditions that will undoubtedly result in extreme weather events of an area, time series analysis of the rainfall of that area is, therefore, inevitable. Anyadike (2010) noted that the identification of cycles and periodicities which explain the future rainfall behaviour from available rainfall data is important as aid in the prediction and adoption of suitable responses. Ayele (2012) noted that the study of rainfall harmonics (cycles) is necessary in determining the occurrence of sporadic events such as floods, which are very largely rainfall dependent. In Adamawa State, the recent repeated destruction of lives, property and farmlands by floods has provoked fear and anxiety especially concerning its future occurrence and the general effect on the State's economy. Despite this concern, few studies have been directed to the harmonics of rainfall in the region and its association with flooding. Except, however, for the study of the spatial and temporal variability of annual rainfall as well as the relationship between annual rainfall and discharge regime of rivers (Amahwa, 2010), work on thedetermination of rainfall harmonics in the State has been scanty. The purpose of this paper,therefore, is to

determine the dominant rainfall cycles in Adamawa State and employ the result obtained to forecast future rainfall behaviour and flooding in the State.

II. MATERIALS AND METHOD

Area of Study

Adamawa State (Fig. 1) is one of the 36 States of Nigeria. It covers an area of 3,432,360 hectares and lies between latitudes 7°20`N and 10°56`N and longitudes 11°30`E and 13°45`E in the upper Benue catchment (Nwilo, Olayinka & Adzandeh, 2012). The mean annual rainfall hovers between 750mm and 850mm in the Savannah area in the northern parts of the State and 1400mm – 1600mm in the Guinea zone of the south. The rainy season usually begins in May and ends in mid-October. July and August are the wettest months, while the entire rainfall regime is characterised by a single maximum.Temperature is generally high in the northern parts of the region, while sometimes it is as low as 18°C in the south, because of the orographic effects. In terms of geology, the entire area is underlain by basement complex rocks although patches of sedimentary rocks are found in some areas of river Benue trough. Two major rivers that drain the State are the Benue and Gongola which is its most important tributary in the State. Vegetation is the Sudan savannah in the north and woodland (Guinea) savannah in the south. The population of the State in 1991 was 2,102,053, which rose to 3,168,101 in 2006 (NPC, 2006), while its 2011 projected population stands at 3,720,061.

Data Collection and Analysis

Thirty-six (1977 – 2011) years rainfall data were sourced from both the Nigerian Meteorological Agency (NIMET) Oshodi, Lagos for the 1977 to 2006 and the Centre for Basic Space Science UNN (2007 – 2011) and utilized for the analysis (Table 1).

Table 1: Annual Rainfall of Adamawa State 1977 – 2011

Year	Rainfall amount (mm)	Year	Rainfall amount (mm)
1977	1080	1999	933
1978	1035	2000	1013
1979	1091	2001	944
1980	888	2002	1112
1981	923	2003	944
1982	954	2004	965
1983	420	2005	1161
1984	638	2006	1138
1985	921	2007	1108
1986	980	2008	959
1987	1023	2009	1074
1988	974	2010	1210
1989	1100	2011	1205
1990	1084		
1991	1046		
1992	1081		
1993	944		
1994	907		
1995	1040		
1996	1029		
1997	1120		
1998	1046		

In analysing the data, Harmonic Analytical Technique was employed to mathematically express the fluctuations observed in the trends as the algebraic sum of a series of simple sine and cosine curves with amplitudes and frequencies (Anyadike, 2010). The mathematical expression is written

$$f(x)\bar{x}+\sum_{r=1}^{r=N/Z}\left[arCos\left(\frac{2\pi rx}{p}\right)+brSin\left(\frac{2\pi rx}{p}\right)\right] \qquad (1)$$

Where a and b are Fourier coefficients for Cosine and Sine terms respectively, r is any harmonic (cycle); x is the individual time units, p is the fundamental periods meaning that N = P.

The Fourier coefficients a & b for each harmonic (r) are expressed as

$$ar = 2/N\sum_{x=1}^{N}\left[yCos\left(\frac{2\pi rx}{p}\right)\right] \qquad (2)$$

$$br = 2/N\sum_{x=1}^{N}\left[ySin\left(\frac{2\pi rx}{p}\right)\right] \qquad (3)$$

Equations 2 and 3 could be rewritten as

$$ar = 2/N \sum_{x=1}^{N} \left[yCos\left(\frac{360rx}{p} \right) \right] \quad (4)$$

$$br = 2/N \sum_{x=1}^{N} \left[ySin\left(\frac{360rx}{p} \right) \right] \quad (5)$$

Where ar and br are coefficients for each harmonic
N is the length of the time
Y is each value in time series
X are the individual time units (i.e. 1 to N)
r is any harmonic (from r = 1 to r = N/2) and
P is the fundamental period N.
The percentage variance (%V) explained in any cycle is given by

$$\%V = \left(\frac{ar^2 br^2}{2Sy^2} \right) \times 100 \quad (6)$$

Where Sy is the standard deviation of y (i.e. the individual value of time series). Harmonics which best fits the Time Series curve will have the largest amplitude. The amplitude A is given as A = $\sqrt{ar^2 + br^2}$ (7)

The maximum number of harmonics that can be extracted from a Time Series is therefore N/2 because after N/2 harmonics the values wrap round and began afresh. Periodicities are determined by dividing the length of Time Series by harmonic number r i.e. each period is N/r (8).

The entire analysis was performed with the aid of SPSS version 20 Statistical program running under PC/windows2007, with which we were able to isolate dominant cycles on the basis of their percentage contributions of the variance explained.

III. RESULTS AND DISCUSSION

Results

Table 2 is the result of the harmonic analysis of annual rainfall in Adamawa State.

Table 2: Harmonic Analysis of Annual Rainfall of Adamawa State of North – Eastern Nigeria.

Harmonic (cycles per 36 years)	Cycles (years)	% of variance explained	Amplitude (mm)
1	36.00	26.94*	162.21
2	16.00	4.28	51.83
3	10.00	3.46	34.30
4	8.5	1.29	32.47
5	6.20	14.88	129.40
6	6.10	7.66	82.75
7	4.55	0.86	64.30
8	5.71	9.20	94.52
9	5.60	5.06	71.33
10	5.40	12.86*	124.66
11	4.90	24.69	62.18
12	3.73	0.64	13.87
13	3.30	11.49*	120.22
14	2.31	9.61	100.88
15	2.15	2.73	59.66
16	2.00	9.07	91.69

Source: Author's calculation
* Important Harmonics.

Faced with so many harmonics, it is usual to select the dominant cycles in the data set. On the basis of percentage (%) contributions of the variance explained, four dominant harmonics namely 1,5,10 and 13 were selected. The representative cycles of 36, 6.20, 5.40 and 3.30 years respectively. Their details are presented in Table 3.

Table 2: Dominant Rainfall Cycle in Adamawa Area, North Eastern Nigeria

Order of importance	Harmonic (cycles) per 36 years	Periodicities (years)	% of variance explained	Amplitude (mm)
1st	1	36.0	26.94	162.21
2nd	5	6.20	14.88	129.40
3rd	10	5.40	12.86	124.66
4th	13	3.30	11.49	120.22

Source: Author's calculation

From Table 2, the dominant cycle in the Adamawa rainfall series and the one that explains 26.94% of the variance would appear to be one with a periodicity of 36 years.

Discussion

From available records the last 36 years i.e. 1977 had an annual mean rainfall of 161.91mm which approximates the mean rainfall amounts expected to be recorded this year. The mean rainfall so far recorded for the area for 9 months of the year (Jan. – Sept. 2012) form real time monitored rainfall is 154mm out of which 112.4mm or 73% was recorded in the months of July and August 2012.

From the result achieved, it could be seen that it would appear that this year coincides with the year with the cycle of 1 in 36 years and that is the reason why we have much rainfall in Adamawa area. However, this high rainfall amounts resulted in large volume of water flowing into the artificial lakes created by dams constructed at the upper course of river Benue. In Adamawa area, which are the Logda and Lake Nyos dams in the Cameroons and the Dadin Kowa dam on the Gongola river. This year, the volcanic lake Nyos which covers an area of about 1.5sqkms and is over 200 metres deep received a rainfall which averages 2500mm with an appropriate mean value of 236mm. During the last rainy season, the excess lake water from the lake escaped over a low spill way into the northern rim of the Maar Crater and down the valley towards Nyos village into Adamawa area of Nigeria. The same high rainfall amounts generated floods that made the Logda damattained the highest water levels in over 36 years, leading to the application of enormous pressure on the dam which forced the authorities to open the floodgate resulting in the flooding of Adamawa area. The problem caused by this development in six States namely Adamawa, Benue, Kogi, Anambra and Bayelsa States are enormous. It takes appropriately one week of the releasing water to move a distance of 100km (Dogla, 2012), because of this, those who did not know that it could get to them have come to live with the bitter experience.

IV. CONCLUSION/ RECOMMENDATIONS

Conclusion

In this paper, we have tried through statistical analysis to determine the dominant rainfall cycles in Adamawa State of Nigeria. The analysis revealed that there are four major cycles with the periodicities of 36years, 6years, 3½years and 3years. This means that the cycle with the periodicity of 36years will produce large annual rainfall that would swell the water held in the reservoirs of the dams, which subsequently resulted in flooding. The findings from the paper will enable the authorities warn people early enough regarding the danger ahead.

Recommendations

Based on the foregoing, the following recommendations are made;

1) The result obtained in this paper should be employed to ensure that the target population are warned early enough. For example, we now know that every 36years we will experience a rainfall of above normal value. Not only this, rainfall of considerable amount (129.44mm) and that of 124.66mm and 120.22mm should be expected every 6.20, 5.40years and 3.30years which will occur 5, 10, and 13 times in 36years. As a result of this, the following are suggested;
   i. All flood plains should be evacuated early enough as settlements in such area will undoubtedly be the first casualties during any flood episode.
   ii. Furthermore, disturbing the ecology of the flood plain, like forest clearing and persistent cultivation of the soil will destroy the local hydrological cycle which may lead to extreme weather events such as floods.
   iii. Since the years when floods could be expected have been known (see the result of our analysis), there is every need to begin stronger collaboration with Cameroon that is located upstream of many rivers that flow into Nigeria to announce well ahead of time of their intention to open the dams.
   iv. The need to collect accurate and real time hydrometeorological data through the establishment of adequate numbers of meteorological network all over the country cannot be over laboured.
   v. The Nigerian Meteorological Agency (NIMET) should be adequately funded to be able to procure modern and state-of-the-art equipment to both collect data and analyse them. Again the funding of the Agency should be done on first line charge. Finally, the agency should be made a full Ministry which may be called the Ministry of Climate Change and Weather Services or any other more adequate name. This is important as it will need ministerial powers for the execution of its responsibilities.
   vi. Integrated Flood Management is necessary where there should be an integration of Land and Water Resources Development in a flood plain within the context of Integrated Water Resources Management (IWRM) with aview to maximizing the efficient use of the flood plains and minimize losses of property and life. This will ensure that a well-functioning integrated measures for flood management which enhances the

benefits of flood and minimize its destructive effects are put in place. At present, we do not have any such measure in place.

vii. Each State of the federation should establish very strong Meteorological Agency to be linked to NIMET. We hope that this will equally help the citizenslike those of Adamawa understand the local meteorological conditions of their area.

viii. The river Basin Development Authorities in Nigeria are largely demarcated on political boundaries. This is why the hydrological problem with our Cameroonian neighbours will persist. It is our considered opinion that because the boundaries of the river basins extend outside Nigeria, all States located at the boundaries of the country therefore should form one local River Basin Development Authority that will cover the national boundaries of the basin in Nigeria and the Country concerned. This does not intend to replace the already existing supra – national river Basin Commissions such the River Niger and Lake Chad.

REFERENCES

[1]. Adefolalu, D.O. (1984). "The Total Static Energy of the tropical atmosphere and the little dry season in West Africa". Nigerian Geographical Journal, 27 pp 28 – 43.

[2]. Adefolalu, D.O., and Oguntoyinbo, J.C. (1985). On Rainfall Distribution and Agricultural Planning. Journal of Tropical Geography, vol. II, pp 64 – 72.

[3]. Aguolu, B. (2012). Rainfall and Flash Flooding in Ogbaru L.G.A. Anambra State: Journal of Ecological Review, Vol. 10, No. 3, pp 44 – 58.

[4]. Amahwa, J. (2010): Rainfall and River Discharges in Middle Owena River Basin". Basin Analysis, Vol. 1, No. 11, pp 84 – 91.

[5]. Anyadike, R.N.C. (1987). "A multivariate classification and regionalization of West African Climates". Journal of Climatology, 7 pp 157 – 164.

[6]. Anyadike, R.N.C. (1994). "Rainfall over Lagos, Nigeria 1892 – 1987 part I: monthly and annual variations" Weather 49, pp 163 – 168.

[7]. Anyadike, R.N.C. (2010). Statistical Methods for the Social and Environmental Sciences. Spectrum Books Ltd, Ibadan.

[8]. Ayele, M. (2012). "An Examination of Sporadic Climatic Events in Southern Nigeria'. Tropical Environment, Vol. 8, No. 3, pp 1104 -1115.

[9]. Ayoade, J.O. (1973). The Role of Climate and Agriculture in Nigeria. Papers Presented at the WMO/FAO Conference on the application of Meteorology to Agriculture in Africa, IITA Ibadan.

[10]. Folorunsho, I.O., Adeofun, O. and Rufai, S. (1998). "The Influence of Climatic factors on maize yield between 1968 - 1990 in Akure, Ondo State". NJTE, Vol. 15, No. 2, pp 65 -75.

[11]. Hardy, M. (2009): "Beneficial Effects of Rainfall in the Tropical Environment". Journal of Tropical Weather, Vol. 3, pp 89 – 110.

[12]. Iguisi, E.O. and Awwal, A. (2008). "The Impact of Climate Variability on Irrigation Dams in Northern Nigeria: A case study of Bagauda Dam". In Bisong, F.E. (ed.) Geography and the Millennium Development Goals; Translating Vision in Reality in Nigeria. Index Books, Calabar.

[13]. Knippertz, P. (2003). "Tropical – Extropical Interactions causing precipitation in North West Africa: Statistical Analysis and Spatial variations". Monthly Weather Review, 131, pp 3069 – 3076.

[14]. Madu, I.A. and Ayogu, C.N. (2010). "The Effects of Rainfall Variability on Crop Productivity in Northern Nigeria". In Anyadike, R.N.C., Madu, I.A., and Ajaero, C.K. (2009) Climate Change and the Nigerian Environment, Jamoe Publishers, Nigeria.

[15]. Nnamchi, H. C. and Anyadike, R.N.C. (2008). A Preliminary Study of the Annual Rainfall over West Africa, based on Hulme 98 Data. NigerianJournal of Geography and the Environment, Vol. 1, 58 – 67.

[16]. Nwagbara, M.O., Ijioma, M.A. and Chima, G.N. (2010). "Climate Change and Flooding in Northern Nigeria: An Examination of Rainfall trends over the Region. Anyadike, R.N.C., Madu, I.A. and Ajaero, C.K. (eds.) Climate Change and the Nigerian Environment. Jamoe Publishers, Nigeria.

[17]. Sawa, B.A., and Adebayo, A.A. (2011). "Climate Change and Yield of Grain Crops at Samaru, Zaria". Nigerian Journal of Geography and Environment, Vol. 2, No. 1, pp 255 – 265.

[18]. Utang, P., Akintoye, B., Ayorinde, O. And Wilcox, R.I. (2008). Implications of Climate Variability in the Intra – Annual and Maximum Stream flow for flood recession Agriculture in Aya Basin, South – Eastern Nigeria, in Bisong, F.E. (ed.) Geography and the Millennium Development Goals; Translating Vision in Reality in Nigeria. Index Books, Calabar.

[19]. Washington, R., Harrison, M., Conway, D., Black, E., Challinor, A., Grimes, D., Jones, R., Morse, A., Kay, G., and Todd, M. (2006): "African Climate Change: taking the shorter Route". Bulletin of the American Meteorology Society. Pp 1355 – 1366.