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Mathematical Study of Monthly and Annual Rainfall Trends in Nasarawa State, Nigeria

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Abstract: *Rainfall is very important for the economic growth and development of any nation; hence there is dire need to study the monthly and annual trends. This paper critically examines the mathematical study of monthly and annual rainfall patterns in Nasarawa State for 20 years (1993-2012) using data obtained from the archives of Meteorological Observatory at the College of Agriculture, Lafia, Nasarawa State. Statistical techniques like time series analysis, mean and standard deviation were employed to depict the temporal distribution of rainfall over the area. The study shows that 1996 is the wettest year, while 2010 shows a year with the lowest negative rainfall deviation. In analyzing the months for the period, it was noticed that August recorded the highest rainfall value of 2498mm which is the month where clouds pervades the sky.*
Keywords: *Rainfall, time series analysis, Nasarawa State, standardized anomaly index, temporal variations*

I. Introduction

Rainfall is very pertinent for the economic growth and development of Nigeria at large and Nasarawa State in particular as the greater percentage of the people (especially adults of age ranging from 45 years and above) actively participate in rain fed agricultural practices (crop production, animal husbandry and plantation). As a state whose economy largely depends on efficient and productive rain-fed agriculture, rainfall patterns and trends are often quoted as one of the major causes of several socio-economic problems like food insecurity in the state.

The Sahelian region is usually characterized by climatic variations and irregular rainfall patterns which ranges between 200–600mm with coefficient of variation ranging between 15–30% (Mitchell et al., 1966; Kandji et al., 2006). Rainfall decline of 29–49% has been reported during 1968–1997 period compared to the 1931-1960 baseline period within the Sahel region (McCarthy et al., 2001). The West African region has experienced marked decline in rainfall patterns depending on the location (Niasse, 2005). This pattern and trend was truncated by the return of adequate rainfall conditions in 1994 which was considered the wettest year of the past thirty (30) years and was a period thought to end the period of drought. Unfortunately, drier conditions returned after this period (1994) (McCarthy et al., 2001).

Climate variability has been attributed to changes in rainfall patterns (Adger et al., 2003; Obot et al., 2010). Studies have shown that climate variability is as a result of changing rainfall pattern (Goswami et al., 2006; Adger et al., 2003). Gregory, 1983 reported that changing spatial pattern of annual and rainy season monthly rainfall indicated a long run of dry years for sub-Saharan West Africa during the 1940s. Climate is classified based on the average annual rainfall which assists in differentiating climatic regimes. Rainfall variability in Africa has been studied by several researchers since the inception of recent drought period in the 70's. Many studies compared Sahelian rainfall with rainfall over West and Central African sub-regions (Ogo & Adeyemi 2009; Gbuyiro et al., 2002). Others focus on Spatial and sub-seasonal patterns of the long-term trends (Kumer et al., 1992). Omogbai (2010) studies rain days in South Western Nigeria between 1970-2006. Guhathakurta and Rajeevan (2006) study the trends in the rainfall pattern over India between 1901-2003. Subyan (2004) studied the Geostatistical study of annual and season mean rainfall patterns in southwest Saudi Arabia. The difference of mean annual rainfall over West and Central Africa because of the severity of drought was confirmed by Ragab and Prudhomme (2002). Their findings and results showed that long-term trend of rainfall series over these regions depict major climatic discontinuity.

Obot et al., (2011) studied the trends of rainfall in Abeokuta, Nigeria between 1981-2002. Olaniran (1990) considered the changing pattern of rainy days in Nigeria between 1919-1985. In their paper entitled 'Analysis of rainfall distribution over Enugu during the little dry season (1990-2005)', Enete & Ebenebe (2009) showed that the trend suggested a general decline in rainfall values in recent times. Rainfall values for the years under study suggested values between 265.37mm and 320.21mm. Rainfall characteristics in Nigeria have been studied for dominant trend notably by Olaniran & Summer (1989, 1990). They found that there was a progressive early decline of rainfall over the country. Following the pattern, they reported a noticeable and significant decline of rainfall frequency in September and October which coincide with the end of rainy season in almost every parts of the country especially in the Northern and Central parts.

The impact of climate change is becoming more pronounced worldwide with consequences of climatic hazard such as severe storms, floods, heat waves and droughts. As a result of the large inter-annual rainfall variability which often results in climatic and environmental hazards, there is dire need to study rainfall characteristics in the study area as a result of recent socio-economic developments such as urbanization, industrialization and over-population (Joshua & Ekwe, 2013).

Study Area

Nasarawa State has a central location in the middle belt region of Nigeria.The area lies within latitude $8^0$32 N and longitude 8^o 18'E and occupy a land area of about 27, 117 Km^2 with total population of 20, 40097 with density of 75/km^2.These includes: Mada, Eggon, Buh, Gbagyi, Koro, Yeskwa, Gwandara, Gade and other Nigerian ethnic groups who migrated to the area to take advantage of its economic potentials (Yari et al, 2001). The State is bounded with Kaduna state in the north, Abuja, the Federal Capital Territory to the west,Kogi and Banue states in the south and Taraba and Plateau states in the east, with agriculture as the mainstay of its economy with the production varieties of food and cash crops throughout the year(Marcus and Bimbol, 2007).

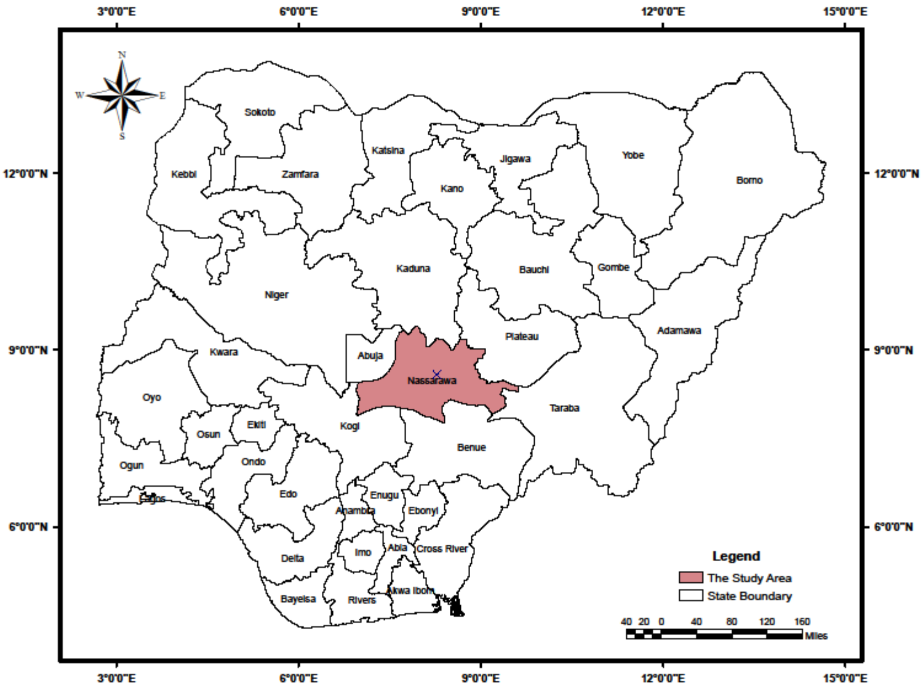


Figure 1. Map of Nigeria showing the study area.

Located in the North Central Geo-political zone of Nigeria, Nasarawa State is blessed with abundant mineral resources and for this reason it is appropriately tagged the 'Home of Solid minerals'' In Nigeria. The state is endowed with abundant solid mineral resources with also the possibility of petroleum occurrence in parts of her sedimentary basin (Obaje et al, 2007). Prominent among the mineral deposits of the State are coal, barytes, salt, limestone, clays, glass sands, tantalite, columbite, cassiterite, marble, iron ore and gold. The three rock types that constitute the components of Nigeria geology, namely the rocks of the Basement Complex, the Younger Granites and Sedimentary rocks are all exposed in Nasarawa State.

The importance of the study of regional climatology cannot be over emphasized as demonstrated in the work of Adebayo, (1999), Adefulalu, (1989) and Olaniran, (1988). Regional analysis of climate has helped tremendously in the planning of agricultural activities in the study area because of its vast agricultural potentials. The spatial pattern of rainfall in the area is slightly influenced by the north central highlands. The entire region represents a wet 'island', disturbing the otherwise east-west alignment of the isohyets in this part of Nigeria. Such rainfall distinctiveness is as a result of the position of the land mass of the Jos Plateau and associated hill ranges in relation to the south-westerly and westerly rain-bearing prevailing winds (Binbol, 2007).

Tropical humid climate characterized by two distinct seasons is experienced in the study area and occurs as intense thunderstorms. The wet (rainy) season last from the ending of March and ends in October while the dry season is experienced between November and February, Monthly total can vary widely, and so the annual total (Yari et al, 2001).Temperature is generally high in the area during the day between the month of March and April partly because of its location in the tropical sub-humid climatic belt. The high radiation income in this part of the globe, which is also evenly distributed throughout the year, also accounts for the high temperature recorded in the area. However, there is a marked seasonal variation in temperature in the area. There is a gradual increase in temperature from January to March. The onset of rains in April ushers in a noticeable decline in temperature. This is made possible by the blanket effect of cloud cover over the region. This continues in the cessation periods by October ending when further decline is made possible in November/December by the coming of the harmattan winds. A single maximum is achieved in March when maximum temperatures can reach 39^o C. minimum temperatures on the other hand in the study area can drop to as low as 17^oC in December and January (Binbol, 2007).

The vegetation type within which the study area lies is the Guinea Savannah which itself is a derivative of tropical deciduous forest that existed centuries ago. Largely the vegetation is characteristics of Northern Guinea Savannah or park Savannah with dense tropical woodland with trees, shrubs grasses, and leguminous fauna that provide dry season grazing grasses with interspersion of thicket, grassland, tree savannah, fringing woodlands or gallery forest common along major streams, valleys and pronounced depression (Illoeje, 1985).The major soil units of the area as observed by Samaila and Ezeaku, (2007) belong to the category of the tropical ferruginous soils. The soils are derived mainly from the basement complex formation and older sedimentary rocks. Lateritic crust occurs in extensive areas on soils on the basement complex while hydromorphic soils are common along the Uke River and floodplains of major rivers. Soils in the area are generally deep and well drained with high fertility rating and variable run-off potential.

II. Materials and Methods

Monthly rainfall dataset for Nasarawa State for 20 years (1993-2012) was obtained from the archives of Meteorological Observatory at the College of Agriculture, Lafia, Nasarawa State. Time series analysis of the monthly and annual rainfall values were used to illustrate the trend in the behavior of rainfall and in estimating seasonal variation. Linear regression analysis was also employed using Microsoft Excel statistical tool as it has proved effective in investigating trends in many climatic time series (Hutchinson, 1985; Ayoade, 1973).
The moving average and least square models were employed in trend analysis while additional model was employed in the estimation of seasonal variation.

III. Method of Data collection

Rainfall observation and collection was performed at the interval of six (6) hours by the Met Observers at the enclosure located at Federal College of Agriculture, Lafia, Nasarawa State. The rainfall measurement is done by removing the funnel and emptying the collected rain (water) in the bottle into a calibrated cylinder with a 3.8 cm (about 1.5 inches) diameter. The reading is done at eye level to an accuracy of 0.25 mm (0.01 inches).
Descriptive Statistical Analysis

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

Where $x =$ rainfall variable

$N =$ number of years

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

Where $\bar{x}$,the mean value as is defined above.

In computing the deviation score and the standardized anomaly, we use the following formulae viz;

(iii) Deviation score $= x - \bar{x}$

(iv) Standardized anomaly = $\frac{(X-\overline{x})}{STD}$

Where x is the annual rainfall totals, $\bar{x}$ is the mean of the entire series and STD is the standard deviation from the mean of the series.

Table 1: Seasonal Variation and Seasonal Index of Monthly Rainfall Data from 1993 -2012 over Nasarawa State.

MONTH/ YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1993	-40.33	-40.33	-40.33	-40.33	-10.03	61.77	72.87	141.87	11.1	-35.53	-40.33	-40.33
1994	-42.58	-42.58	-42.58	-42.58	7.12	56.32	85.32	103.22	26.9	-23.38	-42.58	-42.58
1995	-43.44	-43.44	-43.44	-42.54	-0.84	45.16	66.36	148.96	31.0	-30.94	-43.44	-43.44
1996	-43.58	-43.58	-43.58	-33.98	-3.88	54.62	103.9	157.82	106.2	-32.18	-43.58	-43.58
1997	-42.42	-42.42	-42.22	-28.22	-10.93	47.27	94.47	106.78	36.08	-33.52	-42.425	-42.425
1998	-43.98	-43.98	-43.67	-43.98	-2.78	35.53	130.2	94.93	19.53	-13.87	-43.98	-43.98
1999	-48.88	-48.88	-48.88	-48.88	-7.38	17.83	133.6	183.23	-4.98	-29.08	-48.87	-48.88
2000	-29.48	-29.48	-29.48	-29.48	-29.48	26.92	56.62	75.17	50.72	-2.98	-29.48	-29.48
2001	-38.83	-38.83	-38.83	-38.83	-10.23	58.67	73.07	136.17	10.57	-35.23	-38.83	-38.83
2002	-36.80	-36.80	-36.80	-36.80	16.10	41.70	75.80	71.10	31.70	-15.60	-36.80	-36.80
2003	-27.38	-27.38	-27.08	-27.38	-25.57	-25.8	69.42	160.1	13.23	-27.38	-27.38	-27.37
2004	-45.25	-45.25	-45.25	-32.55	-28.55	42.45	21.25	164.05	104.9	-45.25	-45.25	-45.25
2005	-43.26	-43.26	-43.26	-25.85	-16.65	32.14	113.9	110.34	45.64	-43.25	-43.25	-43.25
2006	-36.54	-36.54	-36.54	-36.54	-35.54	-24.0	128.5	141.96	15.85	-7.54	-36.54	-36.54
2007	-40.35	-40.35	-40.35	-40.35	-1.25	-0.65	75.65	218.55	-9.85	-40.35	-40.35	-40.35
2008	-28.24	-28.24	-28.24	-28.24	-16.24	-2.24	113.1	99.66	-1.64	-23.74	-28.24	-27.64
2009	-30.54	-30.54	-30.54	-30.54	-15.34	-26.2	128.8	58.66	51.46	-14.15	-30.54	-30.54
2010	-38.93	-38.93	-38.93	-38.93	-35.03	46.27	75.66	113.66	65.16	-32.13	-38.93	-38.93
2011	-41.05	-41.05	-41.05	-41.05	-11.35	60.35	87.85	128.65	13.65	-32.85	-41.05	-41.05
2012	-45.33	-45.33	-45.33	-45.33	18.07	44.17	123.4	83.37	28.27	-25.23	-45.33	-45.33
TOTAL	-787.2	-787.2	-786.4	-732.4	-219.8	592.1	1829	2498	645.5	-544.2	-787.2	-786.5
S. I	-78.72	-78.72	-78.64	-73.24	-21.98	59.21	182.9	249.8	64.55	-54.42	-78.72	-78.65

Table 2: Annual Mean Rainfall and Standardized Anomaly from 1993 -2012 over Nasarawa State.

YEAR	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Rainfall	484	511	521.3	657.6	509.1	527.7	586.5	353.8	466	441.6	328.5	543	519.1	438.5	484.2	338.9	366.5	467.2	492.6	544
Anomalies $(X-\overline{x})/STD$	0.06	0.39	0.52	2.18	0.37	0.60	1.31	-1.53	-0.16	-0.46	-1.84	0.78	0.49	-0.49	0.06	-1.71	-1.38	-0.15	0.17	0.79

Figure 1: Standardized rainfall anomaly over Nasarawa State from 1993 and 2012.

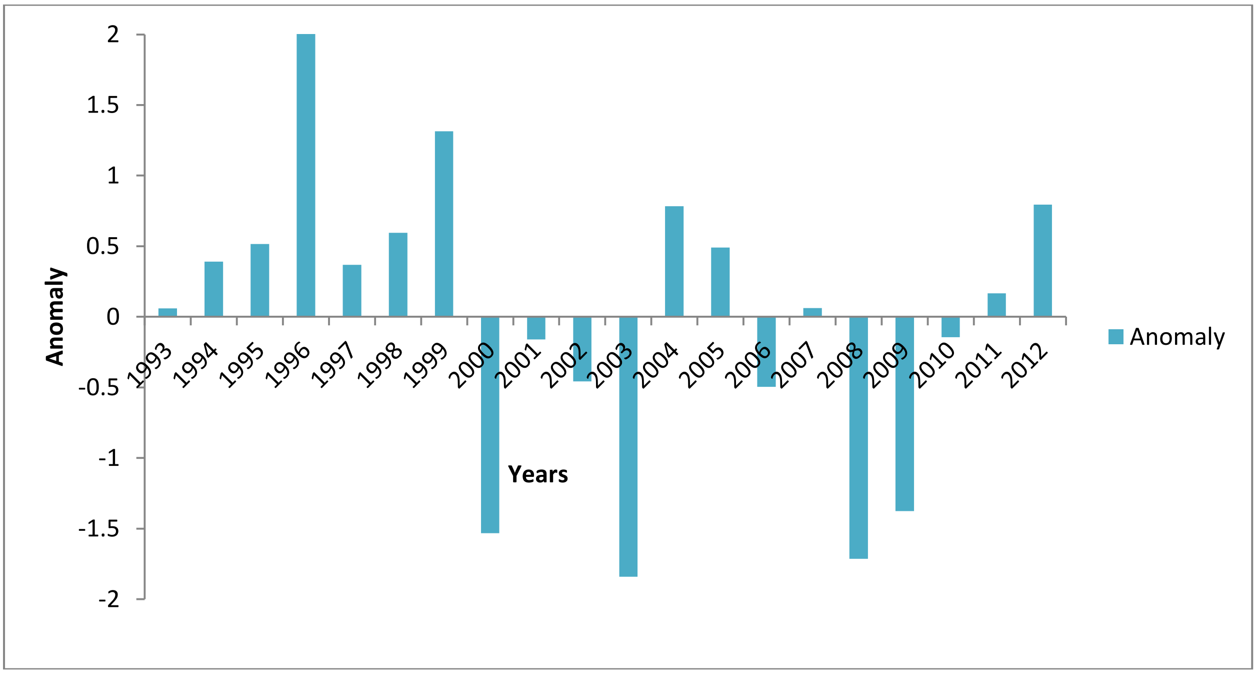


Figure 2: Annual mean rainfall for Nasarawa State from 1993-2012.

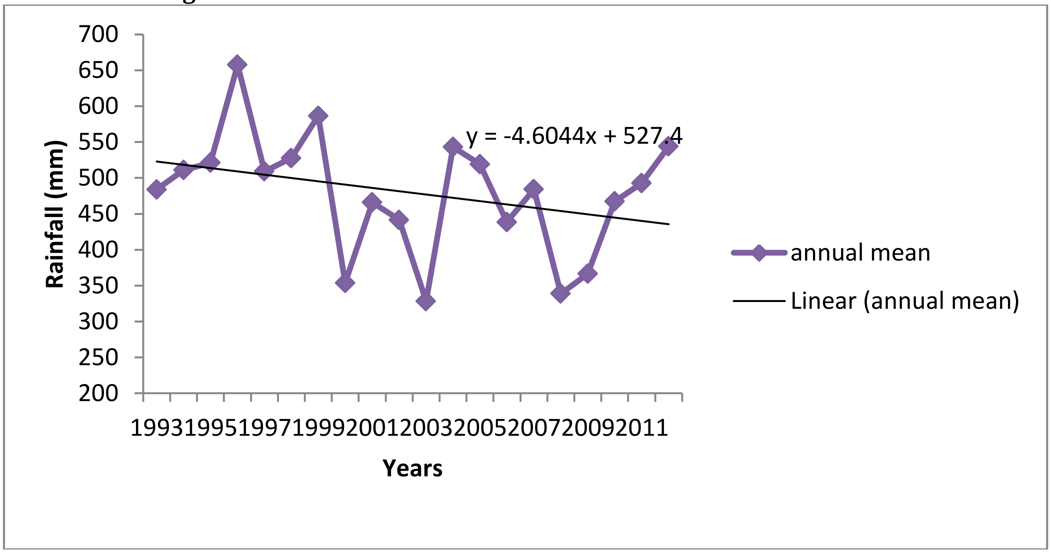
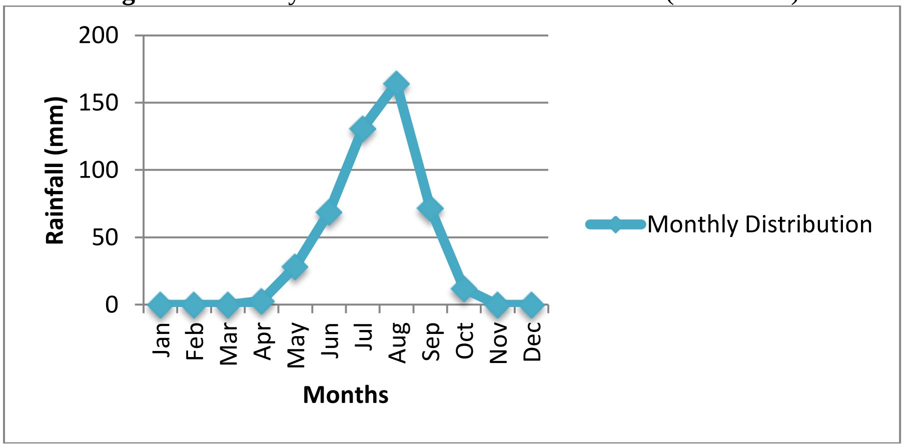


Figure 3: Monthly mean rainfall for Nasarawa State (1993-2013).



IV. Results and Discussions

The annual and monthly rainfall data series from January to December during the period (1993-2012) are examined using time series analysis. The result in Table 1 shows that over Nasarawa State, the monthly rainfall decreased progressively between January-May and October-December. It is worthy of note that the double maxima occur during the months of July and August while April-May that used to be the beginning of the rainy season are tending towards dry month and October that used to be the beginning of dry season is also tending towards rainy month over Nasarawa.

The beginning of rainy reason around May and its subsequent cessation in October has known implications on the ecosystem and agricultural practices as early and late crops are planted by farmers during these critical months of annual agricultural cycles. Consequently, crop failures and food shortages characterize these period as most grains planted late are more prone to pests attack. In addition, this could also leads to desert encroachment as uncontrolled bush burning by nomads, peasant farmers in rural areas and hunters are more pronounced with prolonged drought.

Table 2 depicts the computed annual mean rainfall and standardized anomalies within the year under consideration (1993-2012) over Nasarawa State. Figure 1 shows the standardized rainfall deviations viz; 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2004, 2005, 2007, 2011 and 2012 are years with above average rainfall with 1996 showing the highest positive rainfall anomaly while the other years show rainfall below normal with 2010 showing the lowest negative rainfall deviation.

Figure 2 illustrates the inter-annual rainfall variability over Nasarawa State during the period 1993-2012. The trend suggests a fluctuating and general decline in rainfall values in recent times over the study area. Figure 3 shows a noticeable rise in rainfall values as from May-August with rainfall peak recorded during

August while October marked the beginning of the dry season as rainfall values are seen declining progressively till January-April slightly below May rainfall. This further establishes the shift in the pattern of rainfall in the Nasarawa State.

V. Conclusions

This present study has revealed to us to the temporal variations in annual, monthly and seasonal rainfall amounts over Nasarawa State. The driest and the wettest year and month in Nasarawa State for the period (1993-2012) has been identified too and the sequence documented for future purposes on the probability of droughts and floods over the area. Comparing the total annual mean rainfall during the period under study, it could be revealed there is a slight high value of mean annual rainfall recorded in 1996 while least value was gotten in 2008. It is clear from the results that there is shift in the onset and cessation of the rainy season over the area.

The anomalous departures from the mean were observed to be very small with the highest positive departure from the mean of approximately 12% in 1996. The standardized anomalies results obtained show a fluctuating rainfall pattern across the years over Nasarawa State which makes it hard to freely forecast rainfall trend for a future season. The delay in rainfall till April-May will force the nomads and peasant farmers to engage in indiscriminate burning of bushes thereby causing deforestation and environmental degradation over the area under study. The high rainfall amounts in August might have serious agricultural implications as some crops planted during this month will be adversely affected by heavy rainfall.

The information on this paper will be very handy for agriculturists and policy makers on critical issues is it affects seasonal agricultural practices such as plantation management, flood control, application of agricultural inputs (e.g. fertilizers, herbicides, etc), water resources maintenance and management practices and so on.

References

[1] J.O. Ayoade, Annual rainfall trends and periodicities in Nigeria, Nigerian Geog. J., 16(2) (1973), 167-176.

[2] W.N. Adger, S. Huq, K. Brown, D. Conway and M. Hulme, Adaptation to climate change in the developing world, Progress Dev. Stud., 3(2003), 179-195.

[3] I.C. Enete and I.N. Ebenebe, Analysis of rainfall distribution over Enugu during the little dry season (1990-2005), J. Geog and Regional Planning, 2(7) (2009), 182-189.

[4] P. Hutchinson, Rainfall analysis of the Sahelian drought in the Gambia, J. Climatology, 5(1985), 665-672.

[5] S. Gregory, A note in the mean season rainfall in the Sahel, 1931-60 and 1961-80, Geography, 68(1983), 31-36.

[6] B.N. Goswami, V. Venugopal, D. Sengupa, M.S. Madhusoodanan and P.K. Xavier, Increasing trend of extremerain events over India in a warming environment, Science, 314(2006), 1442-1445.

[7] P. Guhathakurta and M. Rajeevan, Trends in the rainfall pattern over India, National Climate Centre, India, Research Report No: 2/2006, (2006).

[8] N.I. Obot, T.T. Emberga and K.S. Ishola, 22 years characterized trends of rainfall in Abeokuta, Nigeria, Research Journal of Applied Sciences, 6(4) (2011), 264-271.

[9] N.I. Obot, M.A.C. Chendo, S.O. Udo and I.O. Ewona, Evaluation of rainfall trends in Nigeria for 30 years (1987-2007), Int. J. Physical Sci., 5(2010), 2217-2222. P.J. Lamb, Sahelian drought, New Zealand J. Geog., 68(1980), 12-16.

[10] P.J. Lamb, Persistence of sub Saharan drought, Nature, 299(5878) (1982), 46-48. J.M. Mitchell, B. Dzerdzeevskii, H. Flohn, W.L. Hofmey, H.H. Lamb, K.N. Rao and C.C. Wallen, Climate change, World Meteorological Organization, Geneva, Switzerland, WMO Tech. Note, 79(1966), 80.

[11] Olaniran, O. J., and G.N. Summer. 1989. Climate change in Nigeria:change in the rainfall receipt per rain day. Weather: 43(6): 242-248pp.

[12] Olaniran, O. J., and G.N. Summer. 1990. Long-term variations of annual and growing season rainfalls in Nigeria. Theor. Appl. Climatol.(41): 41-53. Olaniran, O.J. (1990). Changing patterns of rain-days in Nigeria. GeoJournal. 22(1): 99: 107-137.

[13] Olaniran, O. J. (1992). An analysis of rainfall trends in Nigeria on the inter annual and multi-year time scales, Staff/PG seminar, Dept. of Geography, Uni. Of Ilorin, 14pp. Olaniran JO (1988). The July – August Rainfall Anomaly in Nig. Climatol.Bull. 22(2): 26-38.

[14] Fox, P. and Rockstrm, 2003. Suplemental irrigation of dry-spell mitigation of rainfed agriculture in the Sahel. Agric. Water Manage., 61: 29-50.

[15] Joshua J.K and Ekwe M.C, 2013. Indigenous Mitigation and Adaptation Strategy to Drought and Environmental Changes in Nigerian Section of Lake CHAD Basin. International Journal of Applied Research and Studies (iJARS) ISSN: 2278-9480 Volume 2, Issue 5 (May- 2013).

[16] Kandji, S.T., L. Verchot and J. Mackenson, 2006. Climate Change and Variability in the Sahel Region: Impacts and Adaptation Strategies in the Agricultural Sector. World Agroforestry Centre/United Nations Environment Programme.

[17] McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group 11 to the Third Assessment Report to the InterGovernmental Panel on Climate Change, pp: 487-532. Cambridge. Cambridge University Press.

[18] Niasse, M., 2005. Climate Induced Water Conflict Risks in West Africa: Recognizing and coping with increased climate impacts on shared watercourses. An International Workshop organized by Centre for the Study of Civil War, International Peace Research Institute, Oslo (PRIO) and Centre for International Environmental and Climate Research at University of Oslo (CICERO) for the global environmental change and human security program (GECHS). Retrived from: http:www.gechs.org/downloads/holmen/Niasse.pdf.

[19] B.E. Omogbai, Rain days and their predictability in south-western region of Nigeria, J Hum Ecol., 31(3) (2010), 185-195.

[20] P. Guhathakurta and M. Rajeevan, Trends in the rainfall pattern over India, National Climate Centre, India, Research Report No: 2/2006, (2006).

[21] J.M. Mitchell, B. Dzerdzeevskii, H. Flohn, W.L. Hofmey, H.H. Lamb, K.N. Rao and C.C. Wallen, Climate change, World Meteorological Organization, Geneva, Switzerland, WMO Tech. Note, 79(1966), 80.

[22] S.O. Gbuyiro, M.T. Lamin and O. Ojo, Observed characteristics of rainfall over Nigeria during ENSO years, Journal of Nigeria Meteorological Society, 3(1) (2002), 1-17.

[23] E.O. Ogolo and B. Adeyemi, Variations and trends of some meteorological parameters at Ibadan, Nigeria, The Pacific Journal of Science and Technology, 10(2) (2009), 981-987.

[24] Yari, K., Hadziga, B., and Ma-aruf, S. (2002).Karu City Alliance Initiatives, Karu Governance and Management Institutions, land use Management and Urban Services Management. In: Technical Report for the UN-HABITAT Component of Karu Development Strategy.

[25] Marcus, N.D and Binbol, N.L, (2007). "In Geographic Perspectives of Nasarawa State".A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria.Onaivi publisher, Keffi.

[26] Obaje, N.G, Lar, U.A, Nzegbuna, A.I, Moumouni, A, Chaanda, M.S. and. Goki, N. G, (2007).Geology and Mineral Resources of Nasarawa State. (Preliminary Investigation):"In Geographic Perspectives of Nasarawa State". A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria.Onaivi Publisher, Keffi.

[27] K.R. Kumar, G.B. Pant, B. Parthasarathy and N.A. Sontakke, Spatial and sub-seasonal patterns of the long-term trends of Indian summer monsoon rainfall, Int. J. of Climatol., 12(1992), 257-268.

[28] A.M. Subyani, Geostatistical study of annual and season mean rainfall patterns in southwest Saudi Arabia, Hydrological Sciences–Journal–des Sciences Hydrologiques, 49(5) (2004), 803-817.

[29] R. Ragab and C. Prudhomme, Climate change and water resources management in arid and semi -arid regions: Prospective and challenges for the 21st century, Biosyst Eng., 81(2002), 3-34.

[30] Adefolalu, D.O. (1989). Precipitation, Evapotranspiration and the Ecological zones in Nigeria.Theor. Appl. Climatology.

[31] Adebayo, A. A. (1999). Climate II. In Adebayo and Tukur (eds) Adamawa State in map. YolaParaclete publisher.

[32] Olaniran, O. J. (1988). Climate and the planning of Agricultural Land Use in Nigeria.NRBDA area as Case Study. Jour. Agro Met. 43 (4) Pp286-294.

[33] Binbol, N.L, (2007) Climate of Nasarawa State: "Geographic Perspectives of Nasarawa State". A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria.Onaivi Publisher, Keffi.

[34] Iloeje, N. P (1985).Geography of West Africa. London, Longman Group in Nigeria: A Case Study of Akure. Theoeretical and Emperical Research in Urban Management Adekunleajasin University, Nigeria.

[35] Samaila, K.I and P.I, Ezeaku, (2007).Soils and Erosion in Nasarawa State." Geographic Perspectives of Nasarawa State". A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria.Onaivi Publisher, Keffi.