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Comparative Study of Climate Variability over Two Climatic Zones of Nigeria

Olawepo, A. O. and Enu-iyin, O.

Department of Physics, University of Ilorin, P.M.B 1515 Ilorin, Kwara State, Nigeria

Abstract

Temperature and rainfall data covering a climatic period of thirty years for Jos and Makurdi representing the tropical savannah and Ogoja representing the tropical rain forest climatic zones in Nigeria have been used to study climate variability. Statistical analyses were employed in this study. The results show that the trends of variability in both temperature and rainfall are increasing at the three stations. The rate of temperature increase is highest in Jos with 0 .023 ^{0}C/year. The extent of variability in maximum temperature at Jos is 1.4, Makurdi 1.0 and Ogoja 1.5. Ogoja exhibits the greatest variability both in temperature (1.63) and rainfall (94.88).

Keywords: weather, climate, temperature, rainfall, variability

1. Introduction

The earth's atmosphere is in constant motion and its state at a given time and place is described as weather. This state is characterized by the scale of atmospheric parameters such as temperature, pressure, wind, humidity and precipitation. Thus, weather can be rainy, dry, hazy, windy or humid. Climate however is the average weather and it describes the condition of various weather variables for an area over a long period of time ranging from months to several years. Climate in a given region is therefore characterized by the average values of the atmospheric parameters such as temperature, precipitation and wind.

Climate fluctuation or variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, e.t.c.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or variations in

Corresponding Author: Olawepo, O.A.
Email: olawepson@unilorin.edu.ng

natural or anthropogenic external forces (external variability). According to the Intergovernmental Panel on Climate Change (IPCC, 2007), most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in human greenhouse gas concentrations. There is also a scientific consensus that climate change is occurring, and that human activities are the primary driver (e.g. Lotze-Campen et al, 2009; Odjugo, 2010; Odjugo, 2013; Tugba et al., 2012,). The on-going climate change and its associated global warming are expected to cause distinctive climate patterns in different climatic zones, which will influence the ecosystem negatively (IPCC, 2007). According to Ojo (1991), weather and climate should not be taken for granted in the pursuit of technological development, exploration and processing of environmental resources. It has also been opined that the impact of climate change will fall disproportionately upon developing countries and the poor persons within all countries, thereby exacerbating inequalities in health status and access to adequate food, clean water and other resources (Susannah et al., 2009). According to the United Kingdom Department for International Development (UK-DFID) Research 2009-2010, climate change impacts will be worse for vulnerable groups such as the poor, elderly, women, and children and for those that depend on agriculture for their livelihoods, since they are less able to fend for themselves and are less able to adapt to changing circumstances.

Rainfall variability and higher temperatures can reduce the yield of crops (Rozenweig & Hillel, 1995). The degree of uncertainty about the onset of the farming season will increase due to changes in rainfall characteristics; early rains may not be sustained, and crops planted at their instance may become affected by heat waves. The agricultural sector is directly affected not only by changes in precipitation but also by changes in temperature and CO_2 concentrations in the atmosphere (Lotze- Campen et al., 2009).

Studies (e.g. BNRCC, 2011; Odjugo, 2010) have shown that Nigeria is already being plagued with diverse ecological problems, which have been directly linked to the on-going climate change. According to the Building Nigeria's response to Climate Change Projects (BNRCC) 2011 report, the communities in Nigeria identified to be most at-risk are those in the far north and those along the coastline. In the Niger Delta, the main direct effects will be through changes in temperature, precipitation, length of growing season, and timing of extreme or critical threshold events relative to crop development. Changes in climate in Nigeria are evident by inter-annual variability of rainfall and temperature trends across the entire

geographical spread but more significantly within the middle belt and the far north. Existing statistics show that average temperature of the country is increasing by about 0.3^{o} C to 0.6^{o} C while rainfall is decreasing. The savannah region of the north has a lot more rainfall reduction while the forested south shows slight increment. The impacts of climate changes include erosion of exposed unstable surfaces in both rural and urban areas, floods from concentrated rains and releases of uncontrollable waters in dams upstream, reducing access to portable water especially in the drier north, dwindling food production, exacerbated sea level changes, saltwater intrusion and loss of biodiversities (Soneye, 2013).

Since weather is dynamic and consequently, climate change is a continuous phenomenon, there is the need for continuous study of the trend in order to be able to provide guidance for policy makers towards the mitigation of the effect of the variability in climate. And to do this it has been suggested (e.g. Nwafor, 2006) that such studies must cover a long period of time. This paper seeks therefore to examine the variation in climate over a climatic period of thirty years with the aim of ascertaining the trend of climate variability within two climatic zones in Nigeria namely: middle/ central (Tropical Savannah) Climate represented by Jos and Makurdi, and the southern/Delta (Tropical Rainforest) Climate represented by Ogoja with the aim of ascertaining the extent of variability of two important meteorological variables (temperature and rainfall) and the likely consequence on the human life.

2. Materials and Methods

Meteorological data covering a period of thirty years (1980-2009) obtained from three meteorological stations of Jos (9.9^{0} N, 8.9^{0} E), Makurdi (7.7^{0} N, 8.5^{0}E) and Ogoja (6.7^{0} N, 8.8^{0} E) (see Plate 1) collected from the Nigerian Meteorological Department in Lagos, Nigeria were used for the purpose of this study. The choice of stations was based on their strategic locations within the country; they are representative of the two climatic regions of Nigeria namely the southern/delta (Ogoja) and the central zones/regions (Jos and Makurdi). The choice of thirty years' worth of data makes it possible to study the long term trend in the climate. Two key climatic parameters; rainfall and temperatures (minimum and maximum) are used. The monthly and annual mean values of these parameters were obtained and used to examine their variations. The solar sunspot number (SSN) for the years under study were obtained from NASA solar data archive. This was used to examine the variation pattern of the

temperatures. Standard deviation of the parameters were also computed and used to study their variability patterns.

4. Results and Discussion

Figure 1 shows the variations in the mean monthly and annual minimum and maximum temperatures. Fig. 1a shows that the variations in monthly mean maximum temperatures tend to follow a sinusoidal trend. Temperature increases gradually from a minimum (trough) in January and reaches a maximum (crest) around March and then gradually decreased to a trough in July and August and thereafter rises again to another crest around November and December. Although the pattern is the same at the three stations, it is observed that the troughs and peaks for Jos are lower than that of the other two stations. The March crest in Jos is 30.6^0C while that of Ogoja and Makurdi is around 37^0C. The July-August trough in Jos is around 25^0C while that of Ogoja and Makurdi is 35^0C. In Fig. 1b, the monthly mean minimum temperature is observed to rise gradually from January reaching a maximum and then plateau before a gradual descent to its minimum. This trend is seen in all the three stations. Jos is however observed to have the lowest values at all time while Ogoja is in-between the two. This shows that though the trend of variation in temperature over the three stations is the same, there exists a difference in the climatic condition at these stations. Thus Ogoja and Makurdi exhibit high maximum temperatures compared to Jos.

Fig.1c shows the variation in the annual mean maximum temperatures. The result shows that the maximum temperatures increased almost linearly at all the stations. While the rate of increase in temperature with time (i.e. the slope) is greatest in Jos with a slope of 0.023 ^{0}C/year, it is least for Makurdi which has a slope of 0.003 ^{0}C/year. The rate of increase at Ogoja is 0.016 ^{0}C/year showing that the rate of temperature increase at Ogoja is moderate compared with the other two stations. However, maximum temperatures at Jos is all time low while Makurdi has all time high values of maximum temperatures. Fig.1d shows a plot of the annual mean minimum temperatures. The plot shows that both Makurdi and Ogoja show decreasing trend in minimum temperatures while the opposite is the case for Jos. The slope at the two stations (i.e. Ogoja and Makurdi) is - 0.0278 ^{0}C/year. The minimum temperature shows an increasing trend for Jos with a slope of 0.024 ^{0}C/year. These results show that Jos is gradually being warmed up at a faster rate compared to the other two stations while temperature at Makurdi has been relatively stable over the thirty year under study. Fig. 2a

shows that the variations of annual mean maximum temperatures at Ogoja and Makurdi did not show much dependence on the solar sunspot number (SSN). However this is not the case for Jos where annual mean maximum temperature shows a positive correlation with the solar sunspot number. This assertion becomes more apparent in Fig. 2b -2d in which temperatures are correlated with sunspot numbers for the thirty year under study. Except for Jos in which temperature has a decreasing trend with respect to decreasing SSN, there is no evidence of dependence of temperatures on SSN for the other two stations.

The variability patterns of temperatures are shown in Fig.3. The maximum temperature at Ogoja shows the greatest extent of variability of 1.38 while Jos and Makurdi are 1.23 and 1.02 respectively. Variability plot for the minimum temperatures (Fig. 3b) shows that Jos has the greatest value of 1.74 while Ogoja and Makurdi have variability of 1.63 and 1.26 respectively. This means that temperature variability at Ogoja is generally high compared to the other two stations. The result for Ogoja also shows a deviation from the the Koppen Climate Classification System which asserts that the type of climate that encompasses southern Nigeria is that of the "Af" classification with a constant temperature range with little differentiation; the temperature is far from constant. The result obtained for Makurdi might not be unconnected with the closeness of Makurdi to the Niger Benue River which may be responsible for the low rate of increase in temperature compared to Jos.

Fig.4 shows the pattern of variations in the rainfall at the three stations under study. Fig.4a shows the monthly variation in rainfall over the thirty years in consideration. Rainfall increases from almost zero in January at all the stations; rises over the months and attains a peak between August and September and then decreases to almost zero in November. Ogoja and Makurdi however exhibit two peaks while Jos has only one peak (in August). Rainfall in Ogoja peaks in June (265 mm) and September (337 mm) while Makurdi had its peaks in June (211 mm) and August (230 mm). Fig. 4b is the plot of annual mean rainfall. The plot reveals that Ogoja has the greatest rainfall throughout the years. It also shows increasing trend in rainfall at all stations with Ogoja having the greatest slope of 6.76 mm/year compared with Makurdi having a slope of 2.05 mm/year and Jos 3.07 mm/year. The variability plot (Fig.4c) shows that rainfall at Ogoja experienced the highest degree of variability of 94.88 followed by Jos, 64.09 and Makurdi, 60.68. These results further reveal that though, Makurdi shows some similarities in the rate of temperature increase with Ogoja, it does not respond to changes in climate the same way with Ogoja. Also this result exhibit the fact that temperature analysis is not sufficient in the study of climate variability. The result of correlation of the

annual mean maximum temperature with annual mean rainfall (Fig. 5) shows that rainfall and temperature are independent at Jos (with a regression coefficient R = 0) while Ogoja and Makurdi show insignificant (correlation coefficient, R = - 0.01 and - 2.25 x 10^{-4} respectively) and negative correlation between the two parameters. This result further justifies the fact that one meteorological variable is not sufficient to discuss climate variability.

5. Summary and Conclusion

A comparative study of the trend of climate have been done with focus on the three stations in Nigeria namely Ogoja, Jos and Makurdi using thirty years worth of temperature and rainfall data. The following conclusions can be deduced from the results obtained from this study:

Mean monthly maximum temperatures exhibit a sinusoidal pattern at the three stations with two crests; one in March and the other around November while the trough is observed in July-August. Jos has all time low temperatures ranging between 24.5 - 30.6 ^{0}C compared to the Ogoja and Makurdi with 30.09-36.01^{0}C and 30.09 - 37.39 ^{0}C. Mean monthly minimum temperature rises from its minimum between January and April and then gradually plateau between May and October in Ogoja; June and October in Makurdi and July and October in Jos. Of all three stations, Makurdi recorded the highest monthly minimum temperatures while Jos has an all-time low minimum temperature. Although Jos is characterized by all-time low mean temperatures compared to the other two stations, Jos with the rate of increase in temperatures of 0.024 degree per year is warming up at a faster rate compared to Ogoja and Makurdi having 0.0155 degree per year and 0.0003 degree per year respectively. The implication of this is that Jos is most susceptible to warming which is capable of enhancing desertification and which according to BNRCC, 2011 report will reinforce existing patterns of water scarcity and increasing the risk of drought in that area.

Temperatures at the three stations did not show strong correlation with the sunspot number. This can be explained by the fact that solar radiation impinging the atmosphere and the earth are subject to extinctions and activities of the greenhouse gases which may be on the increase as a result of industrial activities. Thus the temperatures are not quite reflective of the solar radiation intensities. However the results on the variability in temperatures show that the greatest temperature variability is recorded in Ogoja. Rainfall has increasing trend in all the

three zones but the greatest in Ogoja (6.76 mm/year) and lowest in Makurdi. Ogoja also exhibits the greatest variability in rainfall compared to the other two stations. This result for Ogoja further confirms the findings by BNRCC, 2011 report for the delta regions of Nigeria. The implication of this for the southern/delta climatic region is that climate hazards related to abnormal rainfall, such as flooding, rainstorms and thunderstorms could be expected while the central climatic zones may be liable to drought. Also, the effect of climate variability which is reflective of the global climate change is different for different climate zones in accordance with the assertion of IPCC (2007).

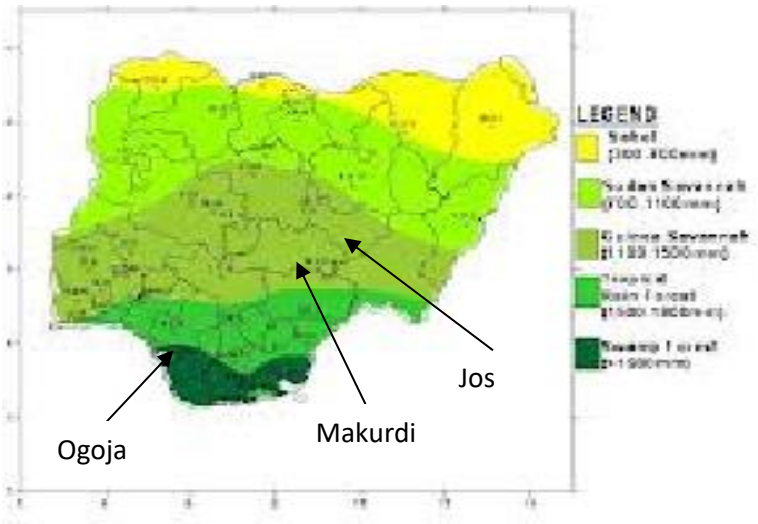
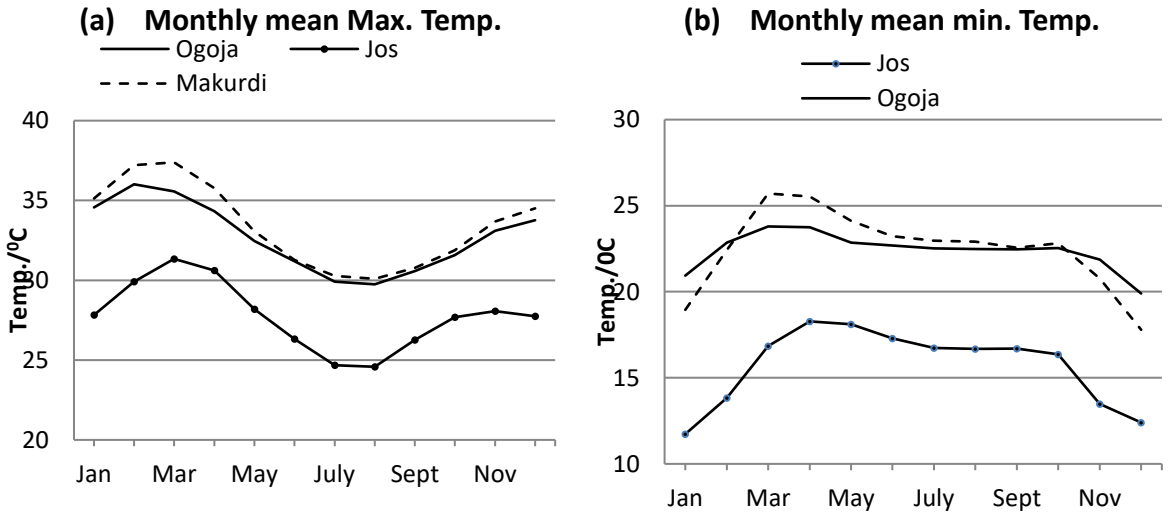


Plate 1.Climate map of Nigeria showing the five type of climate characterizing Nigeria.



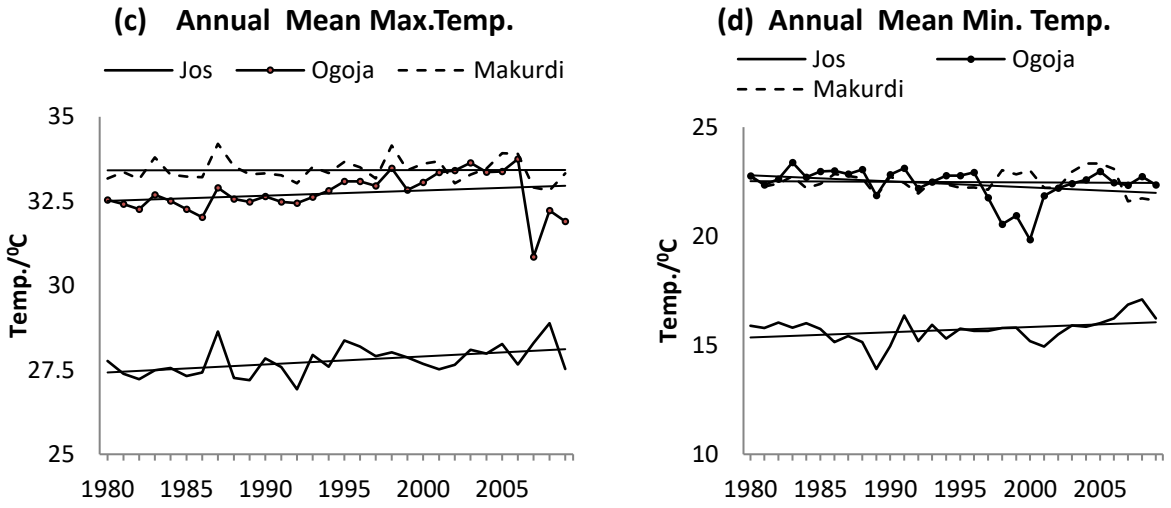
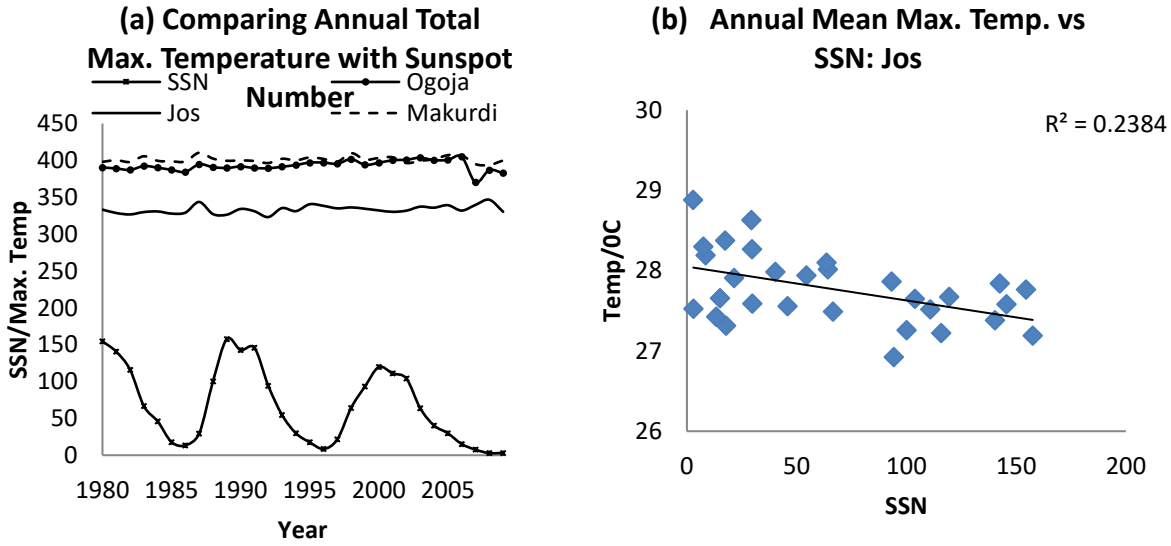


Fig.1: Plots showing the variation (a) monthly mean maximum temperatures (b) annual mean maximum temperatures and (c) annual mean minimum temperatures at the three stations of Jos, Ogoja and Makurdi.



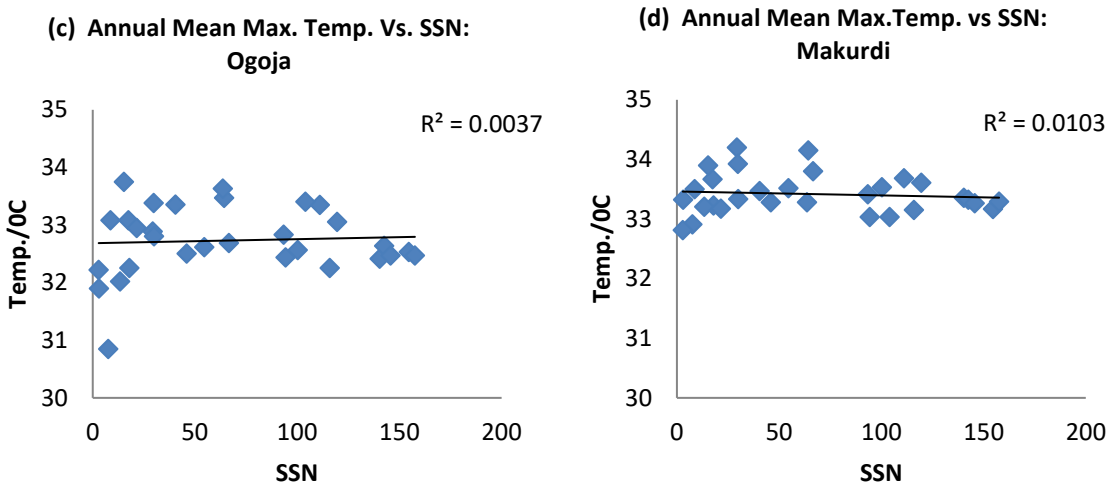


Fig. 2: Plots showing (a) the annual mean maximum temperature compared with sunspot numbers and the correlation plots for (b) Jos (c) Ogoja and (d) Makurdi.

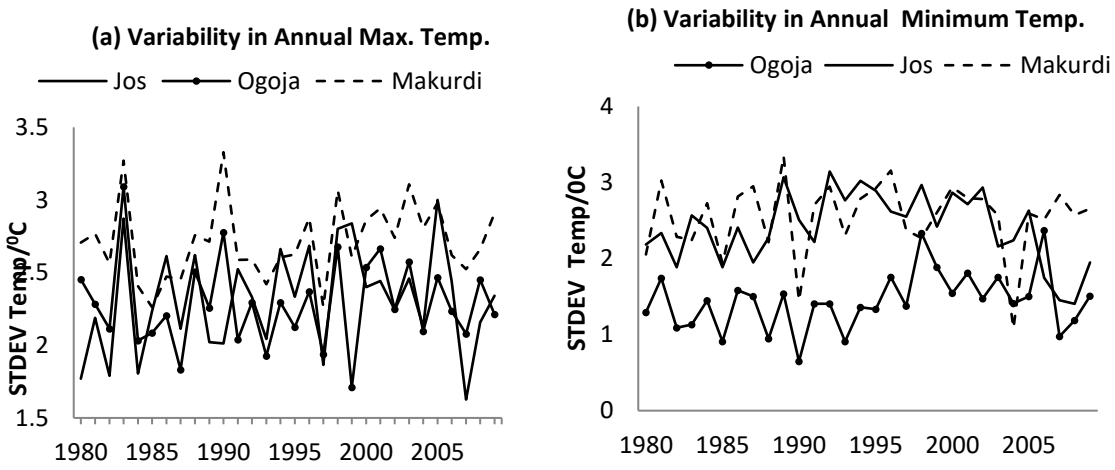


Fig. 3: Plots showing the variability in the (a) annual maximum temperatures and (b) annual minimum temperatures.

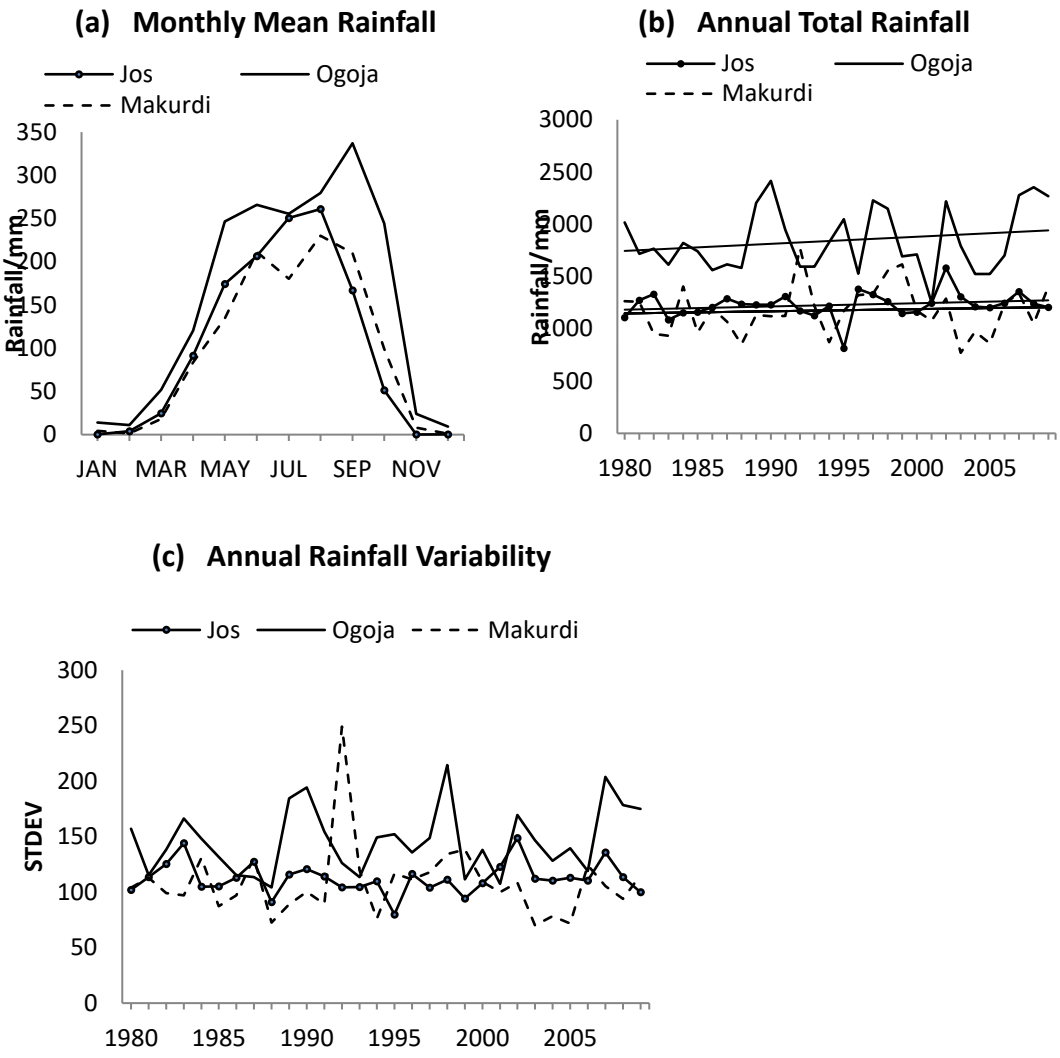
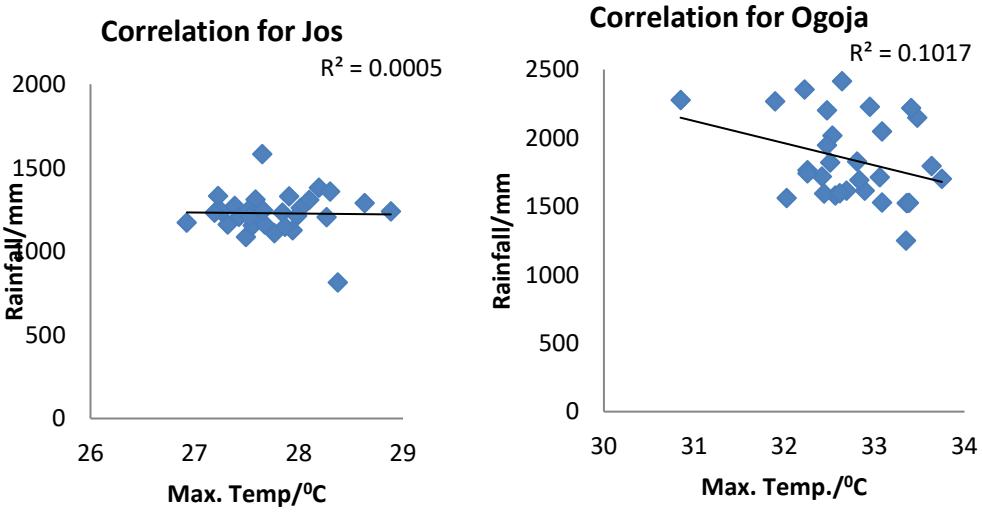


Fig.4: Plots showing variation in the (a) monthly mean rainfall (b) annual total rainfall and (c) variability in the total annual rainfall at the three stations of Jos, Ogoja and Makurdi.



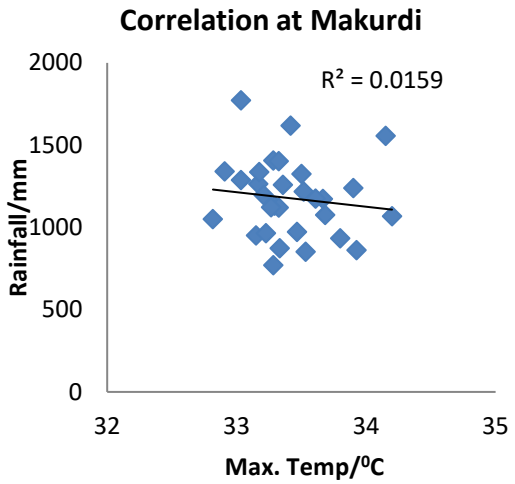


Fig. 5: Correlation between annual rainfall with the sunspot number at (a) Jos (b) Ogoja and (c) Makurdi

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