An Assessment of Spatio Temporal Variation of Rainfall and Temperature Using Different Weather Station Types in Zaria, Kaduna State

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Abstract

The concept of climate has gained much relevance because of its dynamic and complex nature and the significant influence it has on various aspects of the environment, including the threat of global climate change. Rainfall and temperature data for a period of 10 years (2006-2015) in three stations (A, B and C); Institute of Agricultural Research (IAR), Nigerian College of Aviation Technology (NCAT) and Federal College of Education (FCE), were statistically analysed. Analysis of variance (ANOVA) was also used to test for variation of monthly and annual rainfall-temperature distribution. In addition, the mean annual temperature shows that Institute of Agricultural Research (IAR) has the highest mean annual temperature in 2011, Federal College of Education (FCE) has its highest in 2013 and Nigerian College of Aviation Technology (NCAT) has its highest in 2012. For the rainfall variability, the mean monthly rainfall increases in an ascending manner from the month of March that has the lowest to August that has the highest peak. The study also reveal the mean annual rainfall for year 2006, 2008, 2010 and 2012 receives the maximum rainfall at the three stations while year 2011 receives the lowest rainfall at all stations. However, it is recommended that Standardized synoptic stations to give uniformed and accurate data in monitoring weather and climatic conditions should be put in place. Further studies should be carried out for continuous monitoring of the trend of rainfall and temperature to provide up to date information. Lastly, Government and private individuals should take the issue of climate change seriously so as to combat the negative effect it has on activities dependent on climate.

Keywords: Rainfall, Temperature, Weather Station, ANOVA, Zaria

INTRODUCTION

In recent times and across the globe, the concept of climate has gained much relevance because of its dynamic and complex nature and the significant influence it has on various aspects of the environment, including the threat of global climate change. The environment and biological system are similar in that on alteration in any component of the environmental system will lead to a disturbance in the whole system. A fundamental component of the environment is the climate. A change in climate will result to a change in the environment consequently affecting other components (Egbinola and Amobichukwu, 2013).

According to the Intergovernmental Panel on Climate Change (IPCC, 2015), global mean surface temperature has increased by 0.74^0C during the last century. Increasing temperature and changing patterns of precipitation, are among the many consequences that are attributed to climate change. Rainfall and Temperature are very important aspect in both climatic and geomorphologic studies. Rainfall and Temperature in Nigeria are the most variable climatic elements both in its spatial and temporal distribution. This is because the variabilities determine

the planning horizons of agriculture, water resources and many government and judicial processes (Yusuf, 2011).

Changes in individual weather events eventually contribute considerably to climatic variability, the environment will be greatly affected by climate change, which will affect the socio economic and other related sectors that include water resources, biodiversity, food security, human health, terrestrial and aquatic ecosystems. Changes in the pattern of rainfall will possibly lead to drought or flooding. Climate change will geometrically increase threats to food security. It will increase the frequency and intensity of natural disasters. It will result to scarcity of water and make lands difficult to access (Abaje, Ishaya and Usman, 2010).

The West African region has experienced a marked decline in rainfall from 15 to 30% depending on the area (Niasse, 2005). The trend was abruptly interrupted by a return of adequate rainfall conditions in 1994. This was considered to be the wettest year of the past 30 years and was thought to perhaps indicate the end of drought. Unfortunately, dry conditions returned after 1994 (McCarthy, Canziani, Leery, Dokken, & White, 2001). The rainfall in northern Nigeria (Zaria inclusive) is highly variable in spatial and temporal dimensions with inter annual variability of between 15 and 20% (Oladipo, 1993; FRN 2000) cited in (Abaje, et.al. 2010). As a result of the large inter-annual variability of rainfall, it often results in climate hazards, especially floods and severe widespread droughts with their devastating effects on food production, associated calamities and sufferings (Oladipo, 1993 (Okorie2003).

The global climate has changed rapidly with the global mean temperature increasing by 0.74^{o}C within the last century (IPCC, 2007). However, the rates of change are significantly different among regions (IPCC, 2007). This is primarily due to varied types of land surfaces, with different surface albedo, evapotranspiration and carbon cycle affecting the climate in different ways (Meissner *et al*, 2003; Snyder et al, 2004).

The variability in global climate indicates an alteration in either the mean state of climate or of its variability, occurring for many decades or more. Changes in individual weather events eventually contribute considerably to climatic variability, the environment will be greatly affected by climate change, will affect the socio economic and related sectors which include water resources, biodiversity, food security, human health, terrestrial and aquatic ecosystems. Changes in the pattern of rainfall will possibly lead to drought or flooding. Climate change will geometrically increase threats to food security. It will increase the frequency and intensity of natural disasters. It will result to scarcity of water and make lands difficult to access.

Several studies have been carried out at different temporal scales in different part of the globe. (Hasanean, 2001) examined trends and periodically of air temperature from eight meteorological stations in the east Mediterranean and observed positive significant trends in Malta and Tripoli, and negative trends in Amman. (Turkes *et al*, 2002) evaluated mean, maximum and minimum air temperature data in Turkey during 1929- 1999. Their analysis revealed spatio-temporal patterns of long term trends, change points and significant warming and cooling periods. Fan *et al* (2010) reported that diurnal temperature range (DTR) has been on the decrease in most region of the world. The implications of the impact of which are more immense in the poorest nations in Africa. According to Kolawole et al (2011) globally, the economic cost of extreme weather and flood catastrophes is severe and if it rises as a result of climate variability, it will hit the poorest nation the hardest.

Various aspects of the rainfall of Nigeria have been studied based on daily, weekly, monthly and annual rainfall values. These include the onset, advance, retreat, normality, trends and

periodicities of rainfall. This knowledge of variability, annual rainfall trends and periodicities have helped in predicting future incidents and probability of rainfall in Nigeria.

Other studies have identified the characteristics of extreme rainfall that are associated with flood frequency to include duration, intensity, frequency, seasonality, variability, trend and fluctuations. Studies in the Spatio-temporal variability and trend in temperature and rainfall are very limited in Nigeria. (Olaniran,1983, Ologunorisa, 2004). Eludoyin(2009) studied monthly rainfall distribution in Nigeria between 1985-1994 and 1994-2004, the study noticed some fluctuations in most months within the decades. The trends, both annual and seasonal, showed increasing tendency in temperature during the period.

Akinsanola & Ogunjobi (2014) studied rainfall and temperature variability in Nigeria using observations of air temperature and rainfall from 25 synoptic stations for a period of 30 years. Their studies revealed that air temperature indicated that in the first decade of 1971-1980, anomalies between -0.2 and -1.6 were predominant, in the second decade of 1981-1990, only five stations show positive anomaly while greater portion of the country were normal with evidence of warming the in third decade. Their result further indicated that there has been significant increase in precipitation and air temperature in vast majority of the country. (Ayansina & Ogunbo, 2009), also investigated the seasonal rainfall variability in guinea savannah part of Nigeria and concluded that rainfall variability continues to be on the increase as an element of climate change.

Egbinola & Amobichukwu (2013) also focused on the assessment of climatic variation in Ibadan region based on the variation of rainfall and temperature within the period 1970-2012. Times series analysis was used to determine the trend and the 5 year moving average was used to smoothen the time series and to eliminate fluctuations. The result revealed there is an upward trend in total rainfall within the period of study and there is an upward trend in average minimum temperature.

Dammo *et al* (2015) also studied the temporal and seasonal variation in north-eastern Nigeria, using a period of 30 years. Trends in diurnal and seasonal temperature series were analyzed using Mann-Kendall test, their investigation revealed the temperature ranged between 20.2-31.8^{o}C among all locations and over months and years. Abaje, et.al (2010) investigate the rainfall trend in Kafanchan from 1974-2008 using the relative seasonality index. Their investigation revealed rainfall regime for the area is markedly seasonal with long drier season.

The rainfall in northern Nigeria (Zaria inclusive) is highly variable in spatial and temporal dimensions with inter annual variability of between 15 and 20%, because of the large inter-annual variability of rainfall which will results in climate hazards, especially floods and severe widespread droughts with their devastating effects on food production, associated calamities and sufferings (Yusuf, 2011).

The great deal of research into rainfall and temperature variabilities has emphasized the spatial characterization on different temporal scale and the “meso-scale” has received considerable attention. Therefore, understanding of the spatio-temporal variation of rainfall and temperature amount and how it varies from point to point within smaller areas therefore becomes imperative (Yusuf, 2011).

This study assessed the spatial and temporal variation of rainfall and temperature in Zaria using different weather stations for a period of 10 years (2006-2015). These include Institute of Agricultural Research (Station A), Nigerian College of Aviation Technology (Station B) and Federal College of Education (Station C).

METHODOLOGY

Zaria is located between latitude $11^0$03' and $11^0$10' North, and between latitude $7^0$30' and $7^0$45'east of the Greenwich meridian. Zaria is 80km north of Kaduna city (See Fig 1).

Zaria belongs to the tropical continental type of climate corresponding to Koppen's tropical savannah or tropical wet and dry climate zone (AW), characterized by strong seasonality in rainfall and temperature distributions (Koppen, 1928). It has two distinct seasons: the dry or harmattan season (October to March) and wet season (April to September). The seasons generally coincide with the southward and northward movement of the surface transition between the hot, moist tropical maritime southeasterly air-mass (MTS) of southern hemisphere of Atlantic ocean origin and the cold, drier tropical continental air-mass (CTS) blowing out of the Sahara Desert known as Inter-Tropical Discontinuity (ITD). Mean annual rainfall is about 1,000mm, but inter-annual fluctuations may be high. Mean monthly temperature is about 27^0C but it is high between the months of March and May, which represent the hot dry period and low in December/January reaching about 22^0C (Yusuf, 2013).

Data on temperature and rainfall were collected for a period of 10 years, 2006-2015. These data were gotten from three synoptic stations, namely; Nigerian college of aviation technology (NCAT), Institute for agricultural research (IAR) and Federal college of education Zaria. Data collected were analysed into monthly and annual mean values for all the three stations.

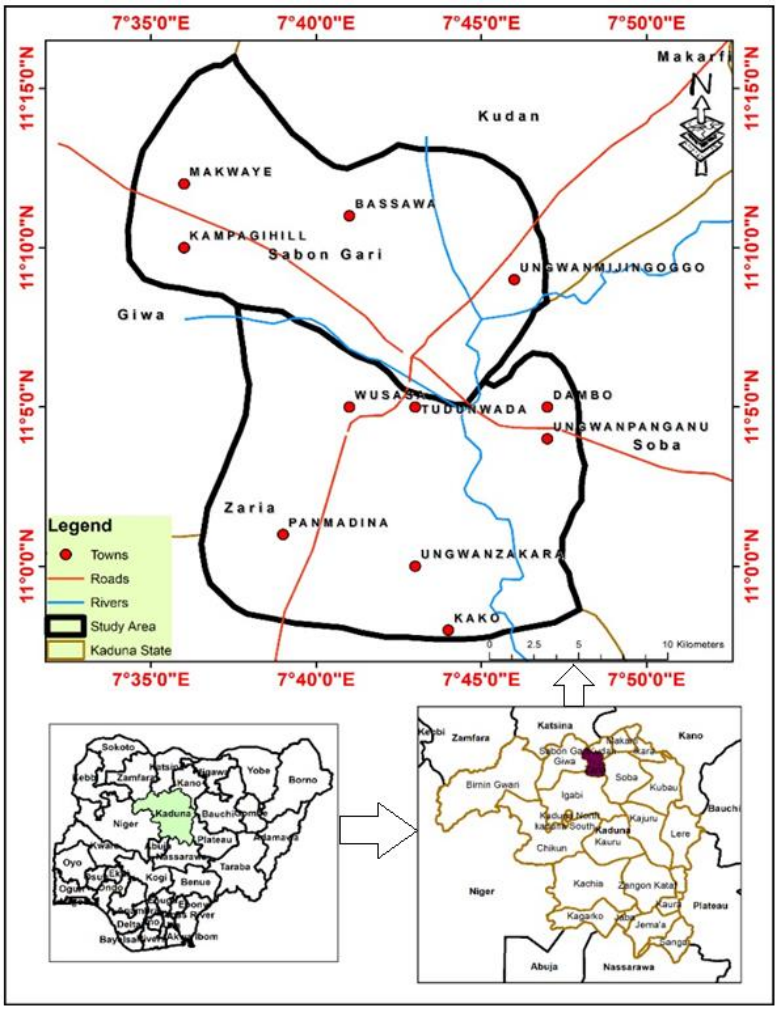

Fig 1. Study Area showing Nigeria, Kaduna State and Zaria.

The average rainfall and temperature data were use, after which it was subject to detail analyses. Analysis of variance (ANOVA) was used to test for variation of monthly, annual rainfall and temperature and to test for significant difference between both mean monthly and annual rainfall-temperature distribution.

RESULTS AND DISCUSSION

Temperature Variability

The results of statistical analysis performed on air temperature dataset on the selected area as shown in figure 2, over Zaria from 2006-2015 shows that the months of April and May at three synoptic stations shows the highest mean monthly temperature ranging from 29^0 C to 31^0 1.C, while the month of November December and January has the lowest mean monthly temperature ranging from 10^0 C to 22.3 ^{0} C at the synoptic stations. However, there is a little variation in air temperature in the month of June, July, August and September as there was abrupt increase and decrease in air temperature at the three stations. This is similar to the work of Akinsanola & Ogunjobi (2014) were they studied rainfall and temperature variability in Nigeria using observations of air temperature and rainfall from 25 synoptic stations for a period of 30 years. Their studies revealed that air temperature indicated that in the first decade of 1971-1980, anomalies between -0.2 and -1.6 were predominant, in the second decade of 1981-1990, only five stations show positive anomaly while greater portion of the country were normal with evidence of warming the in third decade. Their result further indicated that there has been significant increase in precipitation and air temperature in vast majority of the country.

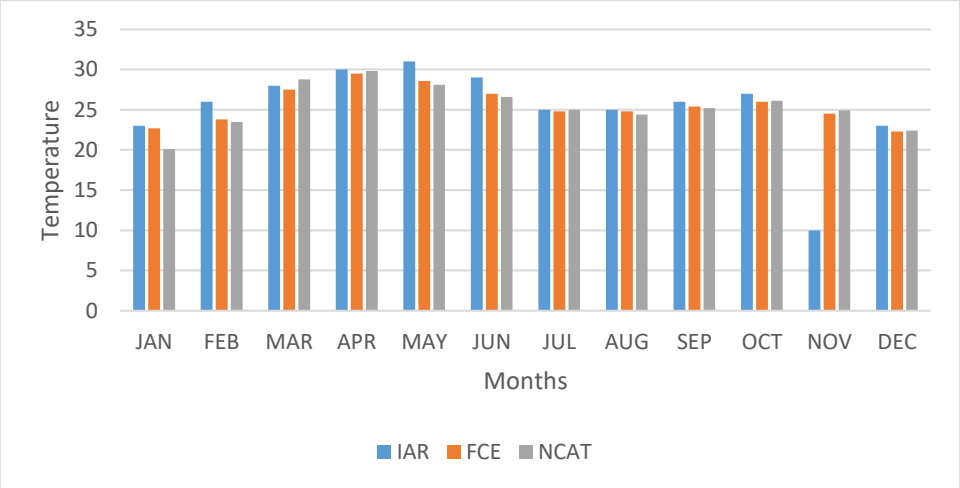

Fig 2: Mean Monthly Temperature

Mean annual temperature in figure 3, shows IAR has the highest mean annual air temperature in 2011, while FCE has its highest air temperature in the year 2013 at 26.7^0 C and NCAT has 23.5^0 C as its highest mean annual temperature in the 2012. The year 2007 and 2008 recorded the lowest mean annual air temperature at IAR, with a record of 23.7^0 C respectively. The year 2010 recorded air temperature 23.9^0 C at FCE stations which is a little higher than that of IAR with a difference of 0.2^0 C, while NCAT recorded among the three stations with a record of 10.3^0 C in 2006. This implies that there is a general increase in air temperature at IAR and decrease at NCAT. This could be because of effect from vegetation, surface cover, evapotranspiration, humidity etc. This justified the work of This is similar to the work of Akinsanola & Ogunjobi (2014) were they studied rainfall and temperature variability in Nigeria using observations of air temperature and rainfall from 25 synoptic stations for a period of 30 years. Their studies revealed that air temperature indicated that in the first decade of 1971-

1980, anomalies between -0.2 and -1.6 were predominant, in the second decade of 1981-1990, only five stations show positive anomaly while greater portion of the country were normal with evidence of warming the in third decade. Their result further indicated that there has been significant increase in precipitation and air temperature in vast majority of the country. In addition, the work justified the work of Dammo, Abubakar, & Sangodoyin(2015) who studied the temporal and seasonal variation in north-eastern Nigeria, using a period of 30 years. Trends in diurnal and seasonal temperature series were analyzed using Mann-Kendall test, their investigation revealed the temperature ranged between 20.2- 31.8^{o}C among all locations and over months and years.

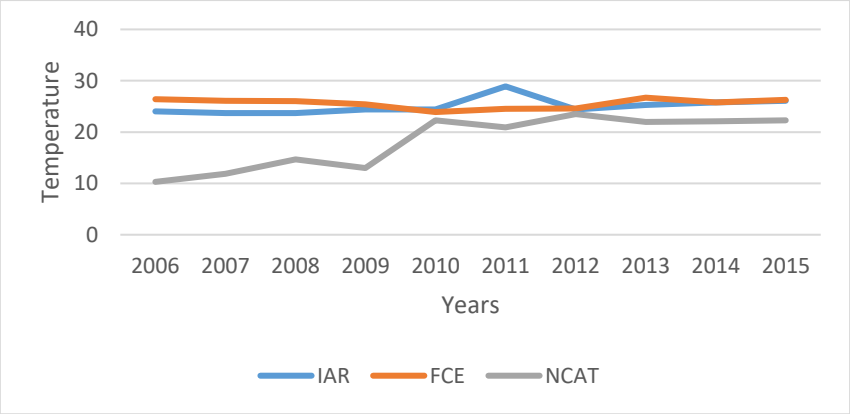

Figure 3: Mean Annual Temperature in ^{o}C.

Rainfall Variability

Rainfall series for the study area shows the mean monthly rainfall increases in an ascending manner from the month of march with a lower amount of rainfall of about 3.5mm, 0.8mm, and 4.92mm at all the three stations through April, May, June July with August as it highest peak receiving 350.5mm at IAR, 349.5mm at FCE and 348.3mm at NCAT. Records shows a declining rainfall from September to October with little or no rainfall in November, December, January and February at all the synoptic stations. This is similar to the work of (Ayansina & Ogunbo, 2009) were they investigated the seasonal rainfall variability in guinea savannah part of Nigeria and concluded that rainfall variability continues to be on the increase as an element of climate change.

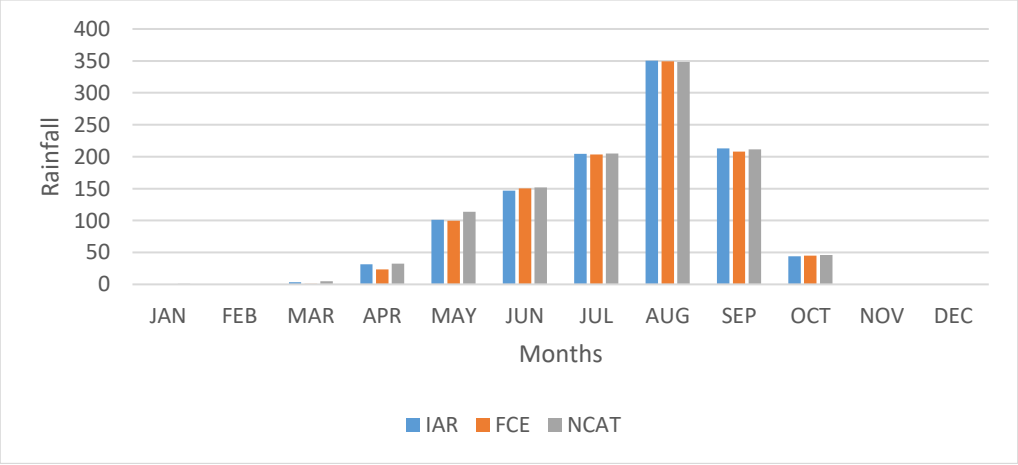

Fig 4: Mean Monthly Rainfall

Fig 5 shows graphical presentation of the mean annual rainfall. It is clear from the result that year 2006,2008,2010 and 2012 received maximum rainfall at IAR, FCE and NCAT stations, while year 2011, received the lowest amount of rainfall at all the stations. This justified the work Egbinola & Amobichukwu(2013) who focused on the assessment of climatic variation in Ibadan region based on the variation of rainfall and temperature within the period 1970-2012. Times series analysis was used to determine the trend and the 5 year moving average was used to smoothen the time series and to eliminate fluctuations. The result revealed there is an upward trend in total rainfall within the period of study and also there is an upward trend in average minimum temperature.

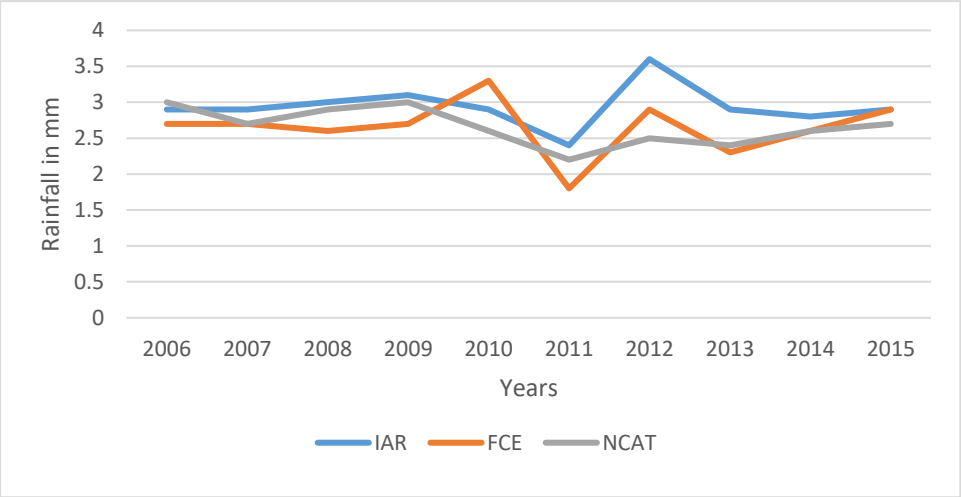

Fig 5: Mean Annual Rainfall

Spatial Variation of Annual and Monthly Rainfall Between the three Synoptic Stations

Table 1: Annual Rainfall Variation

Rainfall				
Source of variable	Sum of Squares	Df	Mean Square	F
Between Groups	0.542	2	0.271	2.6197637
Within Groups	2.793	27	0.1034444	
Total	3.335	29		

Table 2: Monthly Rainfall Variation

ANOVA				
Rainfall				
Source of variable	Sum of Squares	Df	Mean Square	F-ratio
Between Groups	45.832272	2	22.916136	0.00174487
Within Groups	433403.23	33	13133.431	
Total	433449.06	35		

The table 1 shows that there is a significant difference in annual rainfall between the three weather stations but no difference within the years. This is because the calculated F-ratio is greater than the critical table value. The table 2 on the other hand shows the monthly mean variation for rainfall between the three weather stations. The results shows that there is no

significant difference in monthly rainfall between the three weather stations but there is within the months this is because, the calculated F-ratio is greater than the critical table value for within three months and lower between the three stations therefore rejecting the hypothesis within means and accepting it for between means. This is similar in the work of Abaje, et.al (2010) who investigate the rainfall trend in Kafanchan from 1974-2008 using the relative seasonality index. Their investigation revealed rainfall regime for the area is markedly seasonal with long drier season. Also (Olaniran,1983, Ologunorisa, 2004). Eludoyin(2009) studied monthly rainfall distribution in Nigeria between1985-1994 and 1994-2004, the study noticed some fluctuations in most months within the decades. The trends, both annual and seasonal, showed increasing tendency in temperature during the period.

Spatial Variation of Annual and Monthly Temperature Between the three Synoptic Stations

Table 3: Annual Temperature Variation

Temperature				
ANOVA Source of variable	Sum of squares	Df	Mean square	F-ratio
Between Groups	347.56378	3	115.85459	11.922772
Within Groups	252.64422	26	9.7170855	
Total	600.208	29		

Table 4: Monthly Temperature Variation

ANOVA				
Temperature				
Source of variable	Sum of Squares	Df	Mean Square	F-ratio
Between Groups	0.6338889	2	0.3169444	0.0226614
Within Groups	461.54167	33	13.986111	
Total	462.17556	35		

The table 3 shows that there is statistical difference between the three weather stations but no difference between the years. This is because calculated F-ratio is higher than the critical table value in between means and lowers in within means therefore rejecting the hypothesis in case of between means and accepting it in case of within means for the years. The table 4 reveals that there is no significant difference between the three weather stations and within the months, this is because calculated F-ratio is less than the critical table value in both between and within means therefore accept hypothesis. This is also true in the case of Akinsanola & Ogunjobi (2014) who studied rainfall and temperature variability in Nigeria using observations of air temperature and rainfall from 25 synoptic stations for a period of 30 years. Their studies revealed that air temperature indicated that in the first decade of 1971-1980, anomalies between -0.2 and -1.6 were predominant, in the second decade of 1981-1990, only five stations show positive anomaly while greater portion of the country were normal with evidence of warming the in third decade. Their result further indicated that there has been significant increase in precipitation and air temperature in vast majority of the country. However, (Ayansina & Ogunbo, 2009) also investigated the seasonal rainfall variability in guinea savannah part of Nigeria and concluded that rainfall variability continues to be on the increase as an element of climate change. Egbinola & Amobichukwu(2013) also focused on the assessment of climatic variation in Ibadan region based on the variation of rainfall and temperature within the period 1970-2012. Times series analysis was used to determine the trend and the 5 year moving

average was used to smoothen the time series and to eliminate fluctuations. The result revealed there is an upward trend in total rainfall within the period of study and also there is an upward trend in average minimum temperature.

CONCLUSION

This study provides valuable insight on the spatial and temporal patterns of temperature and rainfall in Zaria. The results revealed that there is significant increase in temperature in Zaria. In addition, rainfall has been on increase within the year of consideration. The rainfall over all the stations revealed that there was a composite nature in which some of dry years were mixed with wet years and vice versa and these occurred in all seasons at the three stations. The decrease in rainfall may be due to failure of rain producing mechanism such as ITD, African easterly jets (AEJ), Tropical easterly jet (TEJ), to organize thunderstorm, squall line that are responsible for over 70% of the total annual rainfall. Lastly, the spatial analysis of the annual and monthly data for the three stations shows that there is no significant difference among the three weather stations. That is, weather stations have great similarities despite distance between them. This justified the studies of various scholars in Nigeria who have studied rainfall and temperature variability. For example, Sawa (2002), Yusuf and Attah (2009) and Yusuf (2011). Lastly, this knowledge of variability, annual rainfall and temperature trends and periodicities have helped in predicting future incidents in Nigeria.

The information on the variability of rainfall is very essential for general planning, and for obtaining a standard information and representation of the rainfall at Zaria. It is recommended that Standardized synoptic stations to give uniformed and accurate data in monitoring weather and climatic conditions should be put in place. Further studies should be carried out for further monitoring of the trend of rainfall and temperature to provide up to date information. Lastly, Government and private individuals should take the issue of climate change seriously so as to combat the negative effect it has on activities dependent on climate.

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