EVALUATING THE RELATIONSHIP BETWEEN RAINFALL, MAXIMUM TEMPERATURE AND CONVECTIVE SYSTEMS OVER SELECTED CITIES IN NIGERIA

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ABSTRACT

The convective systems and maximum temperature are key weather parameters that affect various sectors of the Nigerian economy, especially Agriculture, health and transportation. Agriculture which is the mainstay of the economy of Nigeria is weather driven. A balanced weather condition brings about good crop yield which in turn have a positive impact on the economy. The aim of this study was to evaluate the relationship between rainfall, maximum temperature and convective activities over Ikeja, Abuja and Kano cities in Nigeria. Monthly weather data of squall, thunderstorms, maximum temperature and rainfall were obtained from the archives of the Nigeria Meteorological Agency for the period between 1985 and 2015 (30years). Seasonal and inter-annual variations and relationships between the parameters were analyzed. Over Ikeja the result highlighted a gradual increase in these parameters from January to May/June, while the decrease began from October through to December. Further analysis revealed two separate peak periods for these parameters, with rainfall having its peaks in the months of June and September; Thunderstorm, June and October, and squall attaining its maxima in May and October. Over Kano, March, April and May (MAM) and September, October and November (SON) period indicated that the rain that fell during that period had positive correlation while December, January and February (DJF) and June, July and August (JJA) has a negative correlation. Over Abuja, DJF, MAM and SON showed positive while JJA shows a negative correlation. There will be a need for further studies which will consider the role(s) being played by the various triggering mechanisms and the extent to which the influence of the occurrence of these convective activities rainfall and maximum temperature. The utilization of modelling and mapping techniques may also give further insight into the variation of these systems and a clue to issuing more accurate forecasts and predictions.
Keywords: Convective system, Maximum Temperature and Maxima.

1. INTRODUCTION

Convective systems are characterized by the combination of one or more of heavy rain showers, lightning, thunder, hail-storms, dust-storms, surface wind squalls, downbursts and tornadoes. It is the towering cumulus or the cumulonimbus clouds of the convective origin and high vertical extent that are capable of producing lightning and thunder. Usually, these systems have the spatial extent of a few kilometres and a life span less than an hour. However multi-cell thunderstorms developed due to organized intense convection may have a life span of several hours and may travel over a few hundreds of kilometres. The systems mainly originate over the heated land masses that heats up the air mass above it and initiates convection and occurs mostly in the tropical belt. Convective systems are among the most dangerous atmospheric phenomena, frequently causing serious damages due to flash floods, strong gusts, and hail resulting sometimes in natural disaster **[1]**

In West Africa, these convective activities comprise majorly of thunderstorm and squall. However, as a weather system, a convective system has been observed to usually comprise fluctuating ensemble of “cells” and produces a contagious precipitation area of about ~100 km in horizontal scale in at least one direction [**2].** Within each of these cells are; updraft flows, precipitation showers and downdraft flows. While the updraft flows arise as a result of the formation of a gust front ahead of a thunderstorm cell, the low-level downdrafts arise from the flow of low theta-e (low θ_e - which is dry and cold) towards

the cumulonimbus cloud, at the level of the African Easterly Jet (AEJ). This air is driven by melting, evaporation and hydrometeor drag **[3, 4].**

Several definitions have been given about thunderstorm ranging from being merely a storm containing lightning and thunder **[5]** to being a convective storm that is accompanied by lightning, thunder and other variety of weather such as local heavy shower, hails gusty wind, sudden temperature change and occasionally tornadoes **[6].**

A thunderstorm is a convective storm accompanied by lightning. It develops when dense air overlays moist air that is less dense. A trigger such as solar heat, frontal weather, or rising terrain, causes the warm moist air to begin to rise through the cold air. Air current develops, and heat energy stored in the air and water vapour is then converted into the wind and electrical energy. The roaring and rumbling of the cloud and lightning associated with it had over the year invoked fear on millions. Many associate it to the gods, others to eventuality **[7].**

The associated cloud processes play an essential role in energy exchanges that influence the physical and chemical processes occurring in the atmosphere. The diurnal cycle of convection and cloud cover is a significant mode of the climate system variability, linked to the daily cycle of solar heating **[8].**

Squall is another convective storm accompanied by lightning, thunder, and variety of weather such as locally heavy rain shower, hails, high wind, sudden temperature, pressure and wind change. A squall is a sudden, sharp increase in wind speed that is usually associated with active weather, such as rain showers and thunderstorms [**9].**

Rainfall over West Africa is linked to the meridional migration of the Inter-Tropical Convergence Zone (ITCZ). Following the seasonal excursion of the sun, the monsoon develops over this part of the African continent during the northern spring and summer, bringing the ITCZ and the associated rainfall maxima to their northernmost location in August [**10].** Most studies on the subject have investigated the inter-annual time scale over West Africa through the role of surface characteristics **[11]** and in particular, the interactions between ocean and atmosphere **[12]** which are the base of seasonal forecasts of rainfall amounts **[13,14]** with potential benefits to agriculture **[15]**. However, the seasonal and intra-seasonal time scales are poorly documented in spite of their importance for agricultural strategy [**16]**. Studies on earth's global climate show an increasing trend on average air temperature. Consequently, the vegetation period is expected to become shorter and even more irregular distribution of rainfall is expected **[17]**. This has also been observed in Nigeria and it has been noted that the long dry spells incur heavy costs to the affected communities **[18]**.

Rainfall provides most of the needed water for agriculture in the tropics. The role of moisture in agriculture is even more spectacular in the tropics because of the relatively high temperature throughout the year, and the rate of evaporation is constantly high. On the other hand, rainfall is highly seasonal over most of the tropics. Since temperature is high throughout the year, to ensure the growth of crops over most parts of the tropics with exception of few mountain areas, the growing season/harvest unlike in temperate region is determined by the availability of rainfall **[19]**.

This study therefore aimed at evaluating the relationship between rainfall, maximum temperature and convective activities over Ikeja, Abuja and Kano cities in Nigeria. This will be achieved by determining the frequency of occurrence of convective activities associated with rainfall and maximum temperature over the study areas and; the lags between the peaks of variables

2. AREAS OF STUDY

This study was carried out in three major cities of Nigeria (Fig. 1), which are of utmost significance due to their economic importance and urban development. The cities are Ikeja, the capital of Lagos located at 6.6018° N, 3.3515° E in the south, Abuja, the capital city of Nigeria (9.0765° N, 7.3986° E) in the middle-belt, and Kano city in the Northern part of the Country (12.0022° N, 8.5920° E). The climate in Ikeja is tropical with the average temperature in Ikeja being 26.8 °C and an average precipitation of 1595 mm. There is a difference of 324 mm of precipitation between the driest and wettest months. During the year, the average temperatures vary by 3.5 °C. Abuja experiences three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season.

In between the two, there is a brief interlude of harmattan occasioned by the northeast trade wind, with the main feature of dust haze and dryness. The rainy season begins from April and ends in October when daytime temperatures reach 28°C to 30°C (and nighttime lows hover around 22°C to 23°C. In the dry season, daytime temperatures can soar as high as 40°C and nighttime temperatures can dip to 12°C. The high altitudes and undulating terrain of the FCT act as a moderating influence on the weather of the territory. Abuja falls within the Guinean forest-savanna mosaic zone of the West African sub-region Kano is situated in the Sahelian geographic region, south of the Sahara. Its 481m (1,578 feet) above sea level. Kano features a tropical savanna climate. The city sees on average about 980 mm (38.6 in) of precipitation per year, the bulk of which falls from June through September. Kano is typically very hot throughout the year, though from December through February, the city is noticeably cooler. Nighttime temperatures are cool during the months of December, January and February, with average low temperatures of 11 to 15 °C

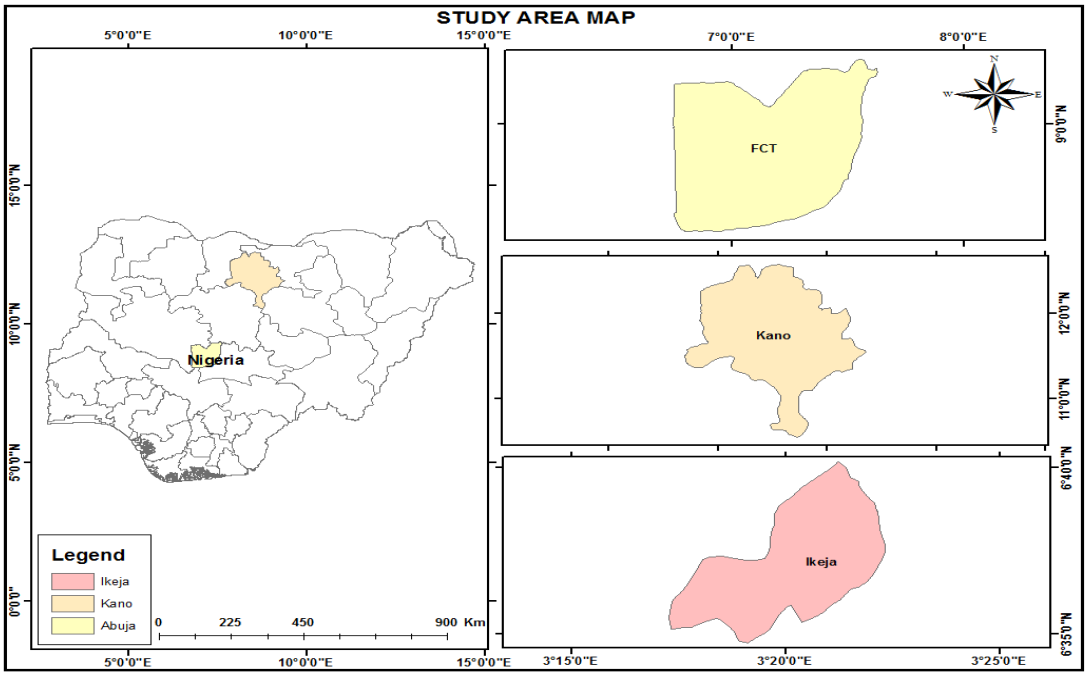


Fig 1: Map of the study areas

2.1 Observational Data

This study adopts monthly meteorological data for a period of 30years (1985 – 2015) over Ikeja, Abuja and Kano. The datasets obtained from the archives of Nigerian Meteorological Agency, Oshodi-Lagos which include: Rainfall, Maximum Temperature, Thunderstorm and Squall. The observation taken by this Agency has proven reliable, consistent, and a good representative of the tropical humid area with characteristics such as the double rainfall peak and short dry season in the south and a single peak of rainfall in the north (**Adejuwon, 1988; Odekunle, 2004) [20,21]**. All analyses for both the long-term mean and individual year were carried out using the acquired monthly data from 1985 to 2015.

2.2 Methodology

The data for weather parameters were analysed to determine their annual and monthly variations, thereby detecting their intra and interannual variability. The average peak period within a year for each weather parameter was noted while establishing the difference or lag between the peak of each weather parameter and rainfall. The relationship between the parameters of these convective activities and rainfall was also established using Pearson correlation approach as presented in equation (1).

..... (1)

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[\, n\Sigma x^2 - (\Sigma x)^2 \,][\, n\Sigma y^2 - (\Sigma y)^2 \,]}}$$

The Pearson correlation coefficient value falls between -1 and 1, where: 1 indicates a strong positive relationship, and -1 indicates a strong negative relationship.

3. RESULTS AND DISCUSSION

3.1 Seasonal and inter-annual variations of maximum temperature

The annual variation of maximum temperature over Ikeja, Abuja and Kano is shown in **figure 2.**

Throughout the years under study (1985 to 2015), Ikeja had the lowest average maximum temperature, while Kano had the highest maximum temperature. The highest maximum temperature value in Ikeja was observed in 1998 with a value of 32℃. The same was also witnessed in 2010. Kano had its highest maximum temperature in 2015 with a value if 34.9℃. A general increase in the value of maximum temperature was observed in that same year 2015. Kano's lowest maximum temperature value was witnessed in 1989 with a value of 32.4℃. Abuja had its lowest maximum temperature with a value of 32.8℃ in 1986 while its highest maximum temperature was seen in 1995 with a value of 33.9℃. This figure showed that in recent years maximum temperature values over the three cities had been increasing over the year which was due to climate change.

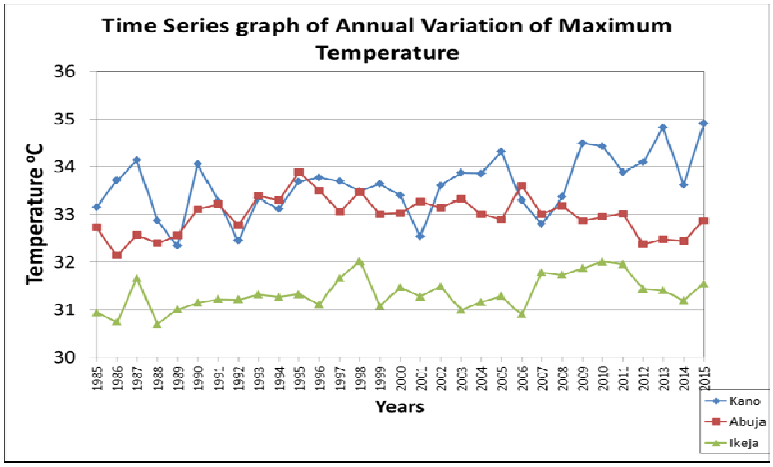


Figure 2: Annual Variation of Maximum Temperature over Ikeja, Abuja and Kano

Figure 3 shows the monthly variation of maximum temperature over Ikeja, Abuja and Kano. There was a bimodal regime of peak maximum temperature across the stations. It was observed that Kano recorded its lowest maximum temperature value of 29.1℃ in the month of January while having a sharp increase in maximum temperature to its peak in the month of April. Ikeja experienced its first

peak of maximum temperature in the month of February with a value of 33.3℃. This was followed by Abuja whose maximum peak was observed a month later in the month of March with a value of 36.9℃. This was followed by Kano afterwards whose peak maximum temperature was observed in the month of April with a value of 38.9℃.

Over the three cities, there was a huge reduction in the values of maximum temperature in the months of July and August with Kano, Abuja, Ikeja recording values of 30.8℃, 29℃ and 28.6℃ respectively. The maximum temperature was at their lowest for the stations (Ikeja, Kano and Abuja in August.

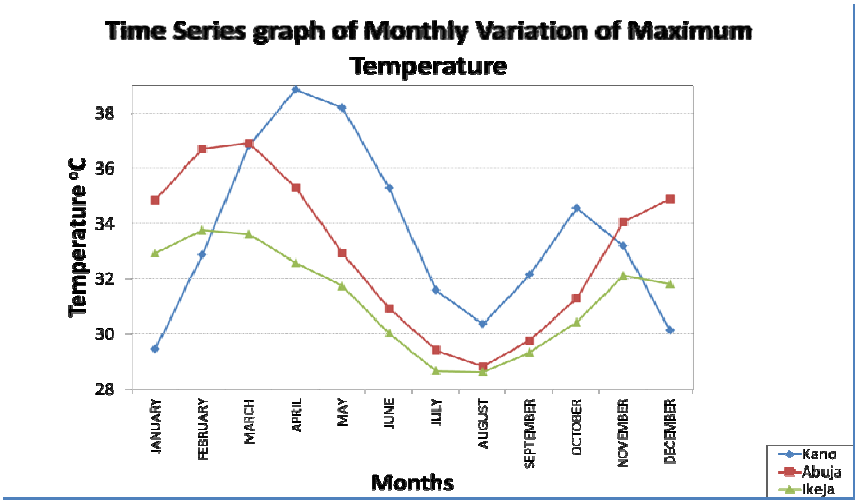


Figure 3: Monthly Variation of Maximum Temperature over selected cities

There was a general increase in maximum temperature from the month of September with Kano getting its peak before others in the month of October with a value of 34.8℃. Ikeja followed with its second peak month of November with a value of 32℃, while Abuja had its own second peak if the maximum temperature in December with a value of 35℃.

3.2 Seasonal and Inter-annual variations of Thunderstorm

Figure 4 shows the annual variation of a thunderstorm over Ikeja, Abuja and Kano. Averagely Abuja recorded the highest occurrence of a thunderstorm during this 30-year period. Initially, from 1985 to 1991, Ikeja had the highest thunderstorm occurrence followed by Abuja, Abuja had the highest in 1992, 1993, 1997 and 1998. The year 2007 marked a significant increase in the occurrences over the three cities compared to the previous years, though a little decline was witnessed in 2015 in the three cities.

Monthly variation of a thunderstorm over the three cities in Nigeria is shown in figure 5. There was a bimodal regime of peak thunderstorms across Ikeja and Abuja. Kano had a unimodal thunderstorm regime with its peak in August, and little or no thunderstorm event occurring in the months of January, February, March, November and December.

A critical look at Abuja's bimodal variation of a thunderstorm, shows that the first peak of a thunderstorm was witnessed in the month of May with when it occurred at an average of 16.9 times, while there was a little dip in the occurrence of a thunderstorm in the month of August. The second peak of thunderstorm occurred in the month of September at an average of 19 times, after which a sharp drop in the occurrence of a thunderstorm was seen between October and November.

Ikeja also has a bimodal occurrence with the first peak in the month of June with 15.8 times of occurrence and second peak occurred in October with 13.9 times. A sharp drop was observed between June, July and August, while it got its peak again in October.

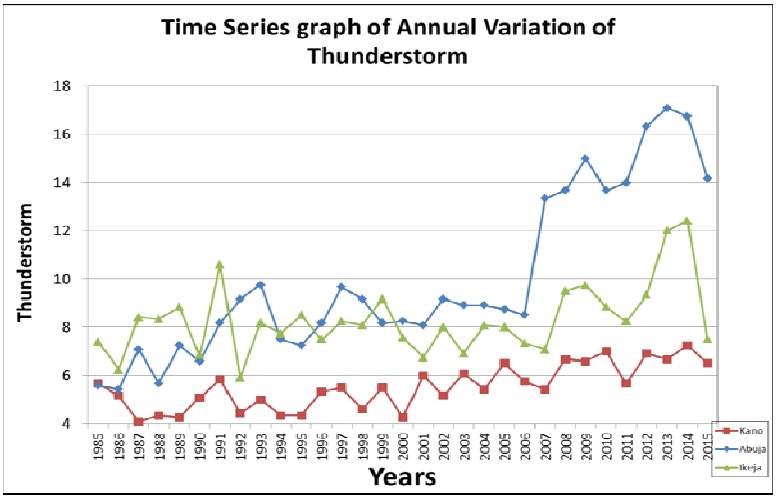


Figure 4: Annual Variation of thunderstorm over Ikeja, Abuja and Kano

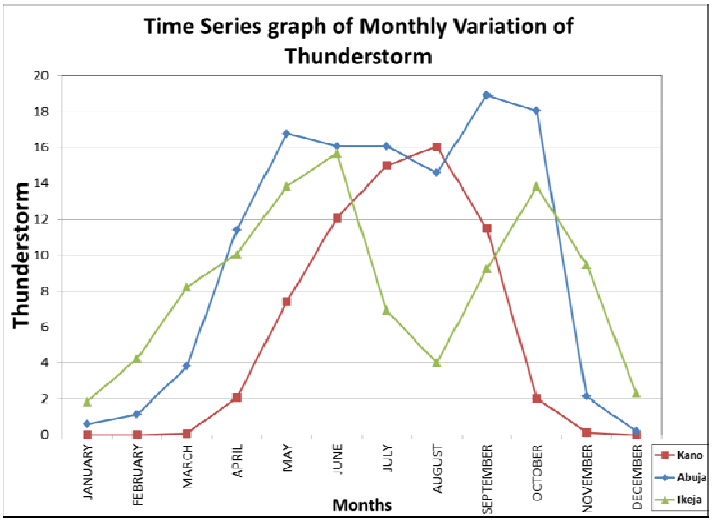


Figure 5: Monthly Variation of Thunderstorm over Ikeja, Abuja and Kano

3.3 Seasonal and inter-annual variations of Squall

Figure 6 shows the annual variation of squall over the three cities in Nigeria for a period of 30 years. A general decline in the average amount of squall occurrences across the stations was observed between 1985 and 1996, after which there was a general rise in the squall values from the year 2000 to 2014, then and a general dip in the values of average squall in 2015.

Initially, Kano city recorded the highest occurrences of squall from 1985 to 1991 while Ikeja had the least occurrences. From 2009 to 2015 Kano recorded the lowest occurrences of squall while Abuja had the highest number of occurrences. In 1999 Abuja witnessed the maximum number of

occurrences which was 4.9 times; Kano had highest occurrences in 1985 with a value of 4.3 times. Ikeja highest was observed in 2009 with 4 times of occurrences.

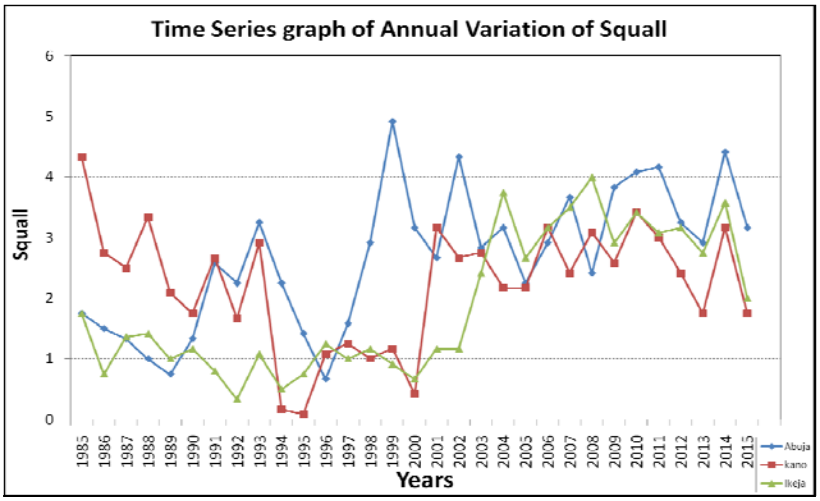


Figure 6: Annual Variation of Squall over Ikeja, Abuja and Kano

Monthly variation of squall over the three cities in Nigeria is shown in figure 7. There was a gradual increase of squall occurrences from the month of March, Ikeja first witnessed it in January with a value of 0.6 times while Abuja and Kano had zero value that is no squall activities was observed during this month. The three cities showed a bimodal peak of squall unlike what was observed in figure 4.6 where only Ikeja and Abuja had bimodal thunderstorm regime. Abuja and Ikeja had their peak squall occurrences of 6 and 4.3 times respectively in the month of May. Kano's first squall peak was observed in the month of June with a value of 6 times. Kano had lagged time of a month (June) after the two other cities witnessed their first peak of squall occurrence (in May). Kano's second squall peak of 5.6 times was in the month of August while Abuja and Ikeja with values of 5.2 and 3.3 times respectively had their second peaks in the month of October. Therefore, Kano, had a month lead time over Abuja and Ikeja during the second peak. Abuja (2 times) and Kano (5.1 times) recorded their lowest peak in the month of July while Ikeja (0.5 times) was in the month of July/August. In November, there was no significant squall occurrence in Kano and Abuja. And there was little or no occurrence for the three cities in the month of December.

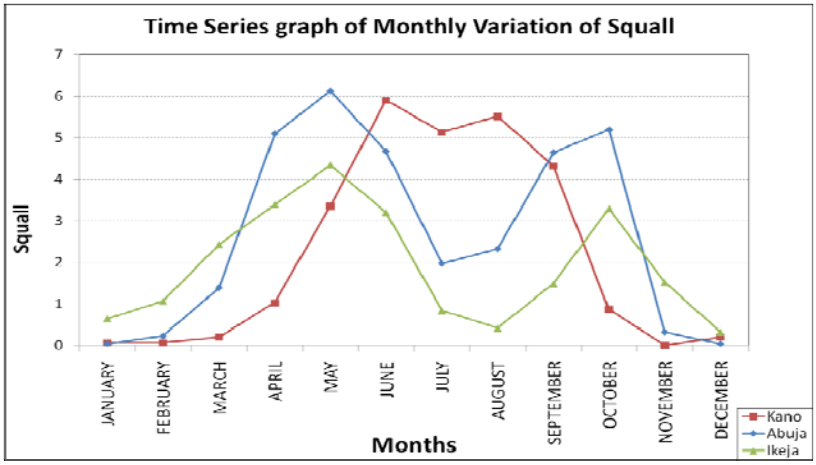


Figure 7: Monthly Variation of Squall over Ikeja, Abuja and Kano

3.4 Seasonal and Inter-annual variations of Rainfall

Figure 8 shows the annual variation of rainfall over Ikeja, Abuja and Kano. It shows an average general increase in rainfall amount from 1985 to 2015. On average, Kano had the lowest amount of rainfall with the highest variability, having its highest amount of 158mm in 1998. Abuja witnessed its highest amount of rainfall in 2002 with an amount of 172mm, while Ikeja had its own in 2004 with a value of 182mm.

Monthly variation of rainfall over the three cities in Nigeria is shown in figure 9. The bimodal variation of rainfall was only witnessed in Ikeja, unlike that of a thunderstorm that had two stations, and squall that all three stations experiencing bimodal situations. The first peak of rainfall in Ikeja was witnessed in the month of June with where 280mm of rainfall was recorded. The second occurred in the month of September with an offer of 195mm. There was a sharp drop in the rainfall amount from the month of June to August, a period known as the little dry season. The second peak of rainfall in Ikeja was observed in the month of September, after which a gradual reduction of rainfall until December was observed. Ikeja had bimodal occurrence with the first peak in the month of June with 15.8 times of occurrence and second peak occurred in October with 13.9 times. Kano had unimodal occurrence with the peak in the month of August with 16 times of occurrences.

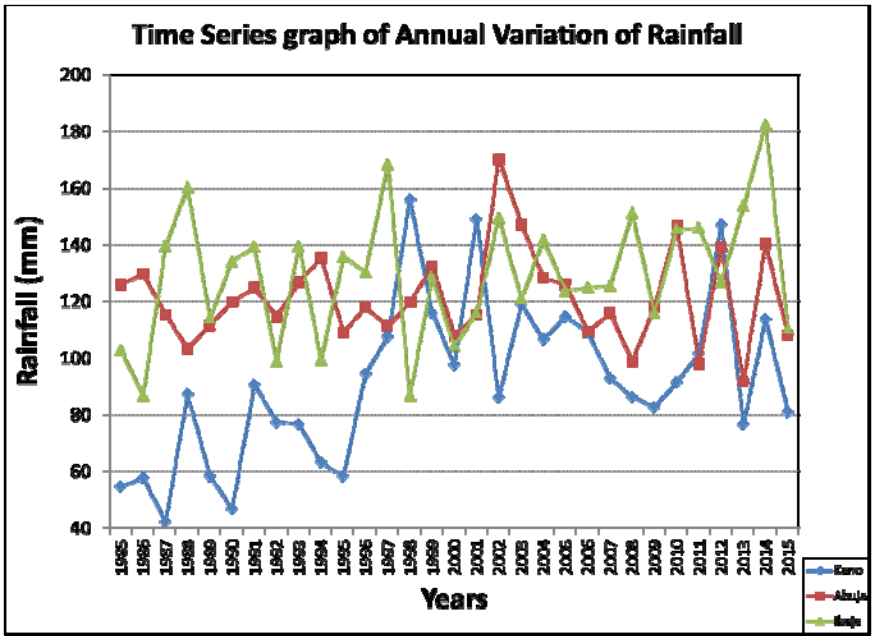


Figure 8: Annual Variation of Rainfall over Ikeja, Abuja and Kano

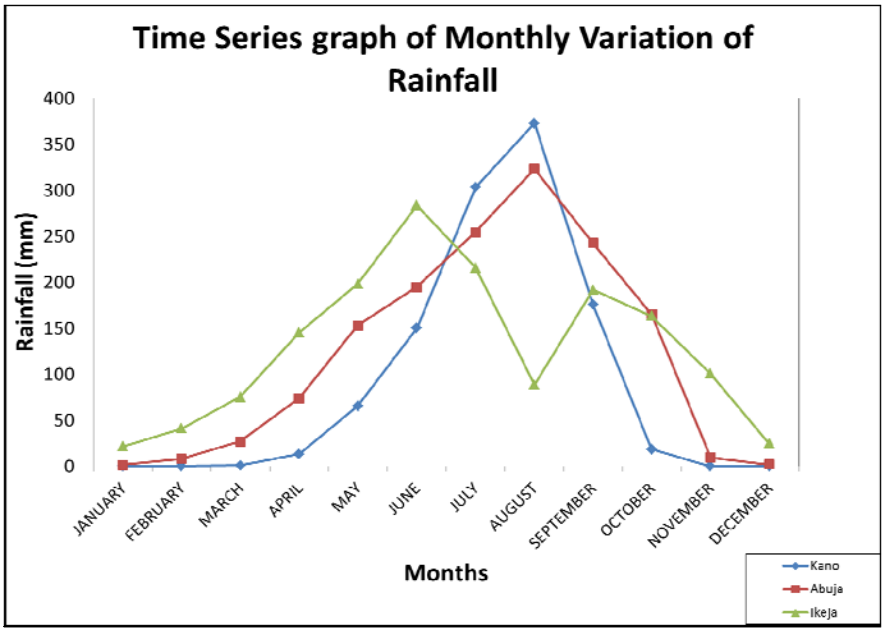


Figure 9: Monthly Variation of Rainfall over Ikeja, Abuja and Kano

3.5 Seasonal comparison of Maximum Temperature and Rainfall

Figure 10a shows the monthly variation of maximum temperature and rainfall over Kano. In Kano maximum temperature had bimodal peaks while rainfall had a unimodal peak of which the rainfall was in the month of August with a value of about 375mm during this month the maximum temperature was at one of its lowest value of about 30.3℃. The first maximum temperature highest was in the month of

April with the value of about 38.8℃ while the second highest was in the month of October with 34.7℃. It was observed in Kano that the hottest month was April which had the highest value of maximum temperature and coldest month was the month of January followed by December and August. Maximum temperature had a lead time of four month over rainfall which had its highest occurrence in August.

Figure 10b shows the monthly variation of maximum temperature and rainfall over Abuja. As in the case of Kano, the maximum temperature had bimodal highest value while rainfall had unimodal value. Rainfall highest valued which was observed in the month of August with the value of about 325mm started gradually from the month of February with a noticeable increase in the month of May and decrease rapidly after August with January and December recorded the lowest values. The first maximum temperature highest occurrence in Abuja station was in the month of March with a value of about 37℃unlike that of Kano which was in the month of April, there was a month lead time between Abuja and Kano maximum temperature highest peak. In Abuja, the maximum temperature highest which was recorded in March had five month lead time when compared with maximum rainfall occurrence which was observed in the month of August.

Figure 10c shows the monthly variation of maximum temperature and rainfall over Ikeja maximum temperature and rainfall exhibited bimodal highest occurrence. The first maximum temperature occurrence was recorded in the month of February with the value of about 34.8℃ and the second was recorded in the t6he month of November with the value of about 32.3℃. The lowest values of maximum temperature over Ikeja for the period under consideration were observed in the month of July with the value of about 28.7℃. At Ikeja station, the month of August served as the month of lowest maximum temperature as indicated in the figure with little rainfall and the highest maximum temperature value of about 33.8℃ was observed in February which served as the hottest month in Ikeja according to the years under review. The first rainfall maximum was observed in the month of June with the value of about 275mm and the second maximum was in the month of September with the value of about 180mm and the lowest rainfall value was recorded in the month of August with value less than 90mm, this period is usually referred to as the period of “Little dry season or rainfall decline (**Odekunle, 2004**) **[22]**. At Ikeja station, it was observed that there was five months lag time between maximum rainfall and maximum temperature occurrences.

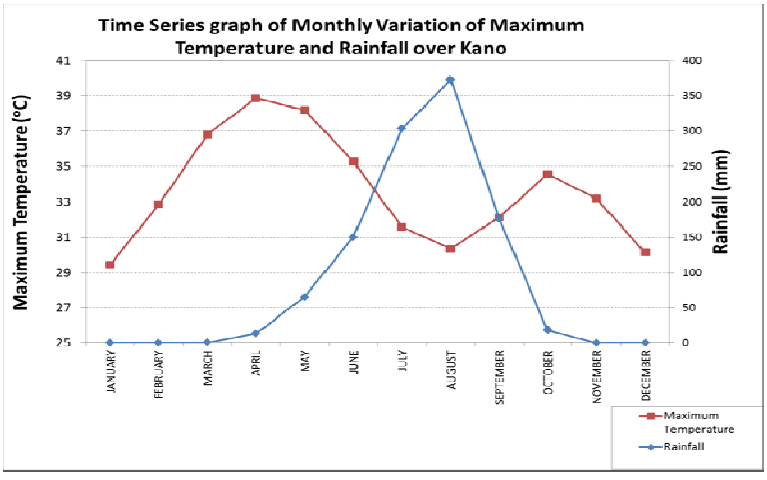


Fig. 10(a)

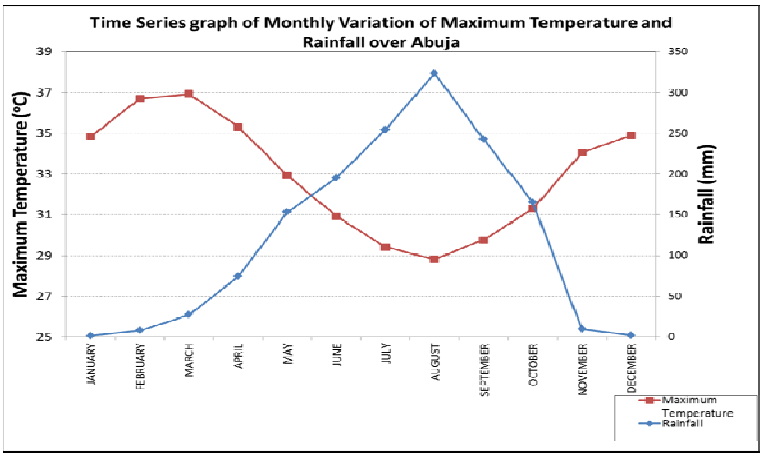


Fig. 10(b)

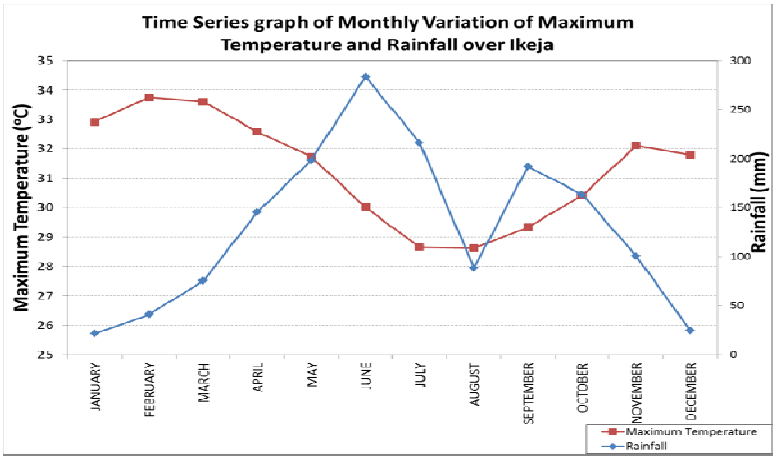


Fig. 10(c)

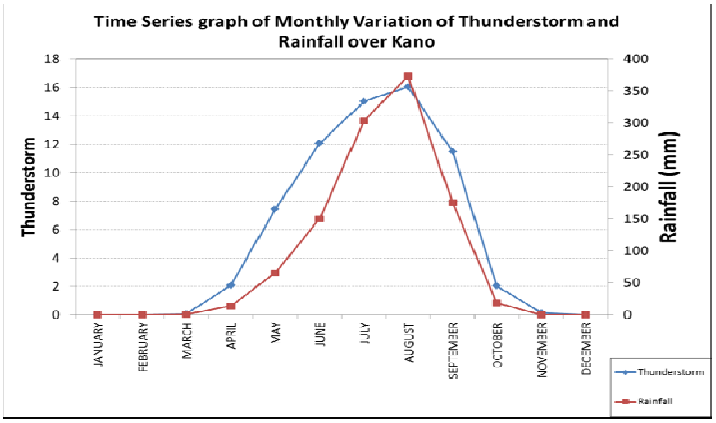
Figure 10: Seasonal comparison of Maximum Temperature and Rainfall over 10 (a) Kano 10(b) Abuja 10(c) Ikeja

3.6 Seasonal comparison of Thunderstorm and Rainfall

Figure 11a shows the monthly variation of thunderstorm and rainfall over Kano. During the months of January and February thunderstorm and rainfall had zero occurrences; there was a gradual increase of occurrences from the month of April with rainfall of about 10mm and thunderstorm of 2 times occurrences. Over Kano city, maximum rainfall and thunderstorm had only one month highest period throughout the year which was in the month of August with rainfall of about 375mm and thunderstorm of about 16 times, Gradual reduction for both weather parameters was noticed from the month of September (thunderstorm of 8 times and rainfall of 260mm) up till November, no occurrence was recorded in December like January and February This figure indicated that there was a strong relationship between occurrences of thunderstorm and rainfall over Kano.

Monthly variation of thunderstorm and rainfall over Abuja is shown in figure 11b. Thunderstorm had bimodal maximum occurrence while the third was not well pronounced which occurred in the month of July, the first maximum was observed in the month of May with the value of about 16.2 times (second highest occurrence) while the second was noticed in the month of September with the value of about 19 times (highest occurrence), it started to decrease from the month of October with 18 times of occurrences till November and no trace in December. Rainfall had unimodal maximum which did occur in the month of August in Abuja with a value of about 325mm. This figure shows that there was four-month lag time between the maximum occurrences of the first highest peak of thunderstorm and rainfall and one month lead time between the maximum occurrence of rainfall in August and thunderstorm in September.

Figure 11c shows the monthly variation of thunderstorm and rainfall over Ikeja. The month of January had the lowest rainfall amount of an average of 21mm and occurrence of a thunderstorm of 1.9. The month of December had the next lowest amount of rainfall and thunderstorm occurrences with the value of 24mm and 2.1 times respectively. There was a noticeable increase in the rainfall and thunderstorm amount in the month of March average of 70mm and 8.1 times respectively. It also shows the peak of rainfall which occurred in the month of June with an average of 280mm, this also coincided with that of a thunderstorm which also had its peak occurrence in the month of June which was16 times. A sharp reduction in rainfall was noticed from the month of July going into August with an amount of 218mm and then 87mm in the month of August. A similar trend was also noticed for thunderstorm which reduced considerably from 16times in June to 7 times in July.



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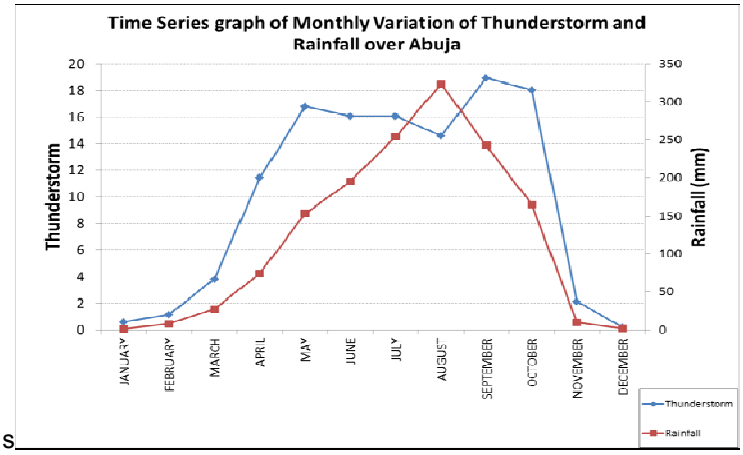

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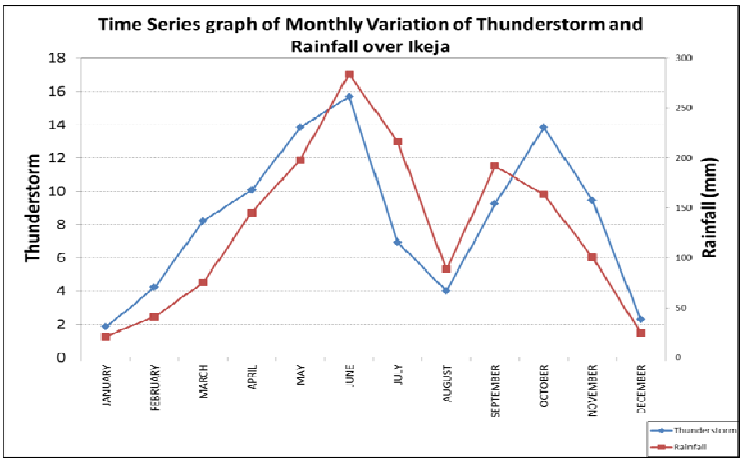


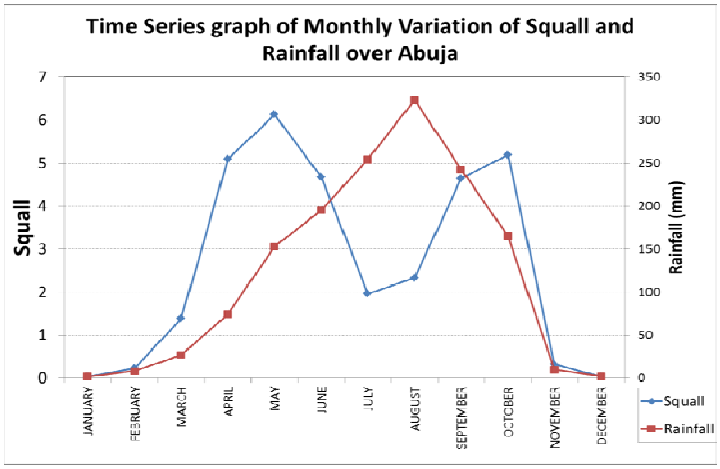
(c)

Figure 11: Seasonal comparison of Maximum Temperature and Rainfall over (a) Kano (b) Abuja (c) Ikeja

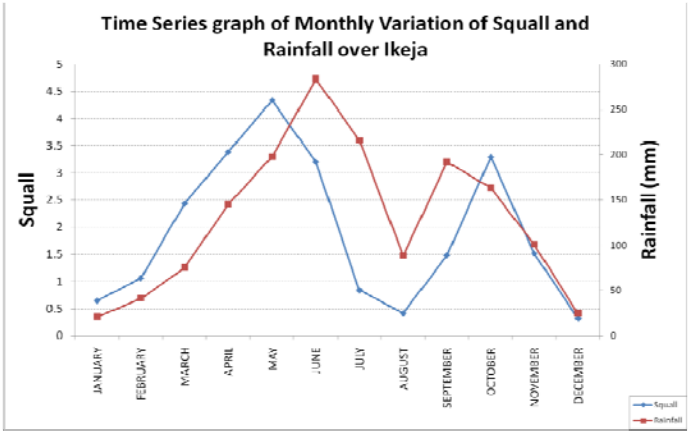
3.7 Seasonal comparison of Squall and Rainfall

In Figure 12a, the month of January and December had the lowest rainfall amount and squall occurrences of zero values over Abuja. The month of February had the next lowest squall and rainfall occurrences in Abuja with a value of less than 0.2 and 10mm respectively. There was an increase in the occurrences of squall and rainfall in the month of March and April with squall occurrences times of 2.3 and 5.2, rainfall of 25mm and 65mm respectively. Squall attained its peak in the month of May with 6 times occurrences and decline in the month of June to July with 4.8 times and 2 times respectively, it increased gradually to 2.2 times in August, 4.7 times in September and reached second peak in October with value of 5.1 times before it decline in the month of November to value less that one and zero in December. Rainfall attained its peak in the month of August with a value of averagely 325mm and decline to 240mm in September 160mm in October and less than 5mm in November. This indicated that there was three month lag time between the peak of squall and rainfall over Abuja, it also showed that Abuja witnessed its highest squall intensity three months before maximum rainfall in August.

The monthly variation of rainfall and squall over Ikeja is shown in figure 12b. The month of December had the lowest rainfall amount at an average of 21mm and squall of 0.32. The month of August had the next lowest thunderstorm occurrences with a value of 0.36, unlike that of a thunderstorm when the lowest was in January. This was followed by January with 0.4 thunderstorms. The peak squall occurrence was noticed in the first bimodal period, with 4.1 in the month of May while the second peak of squall was in October with 3.2. There was a steady rise in a squall with rainfall but the squall had peaked in May before the rainfall got to its peak in June. This indicates a one-month lag between the peak of squall and that of rainfall. This shows that Ikeja witnesses its highest intensity of squall before having its maximum amount of rainfall. The Little Dry Season witnessed a drastic reduction both in rainfall and squall, as noticed in the month of August. The steady rise in rainfall amount was accompanied with the rise in squall occurrence. Nevertheless, the second peak of rainfall was in September, while the squall occurrence peaked in October. This indicates a one-month lag between the second rainfall and that of squall and shows that Ikeja has its second maximum amount of rainfall before the second highest intensity of squall.



(a)



(b)

Figure 12: Seasonal comparison of Maximum Temperature and Rainfall over (a) Abuja (b) Ikeja

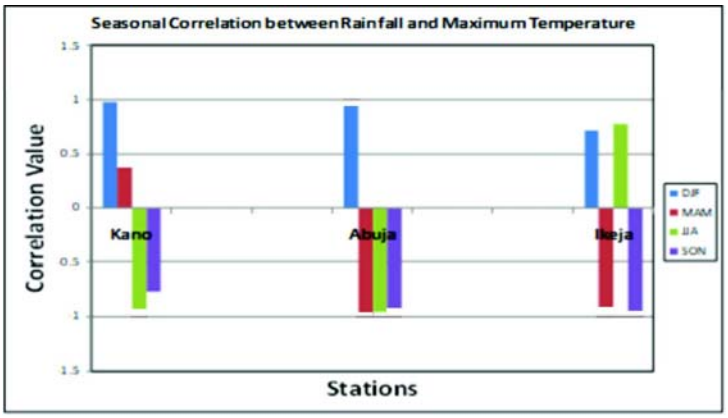
3.8 Relationship between Rainfall, Maximum Temperature, Squall and Thunderstorm.

Figure 13a shows the correlation between rainfall and maximum temperature over the three stations in Nigeria. The year was segmented into various seasons (DJF, MAM, JJA and SON) and relationship was detected across the various seasons and stations. In Kano, December-January-February (DJF) had the closest relationship between rainfall and maximum temperature with a correlation coefficient of about 0.9. This indicates a close relationship between rainfall and maximum temperature that may occur at this period of the year, thereby indicating that maximum temperature had a great role to play in any rain that fell within December, January and February in Kano. The period of the next closest relationship between rainfall and maximum temperature over Kano was observed in the month of March, April and May (MAM) where the correlation coefficient is 0.4. The June, July and August (JJA) had the lowest relationship between the occurrences of rainfall and maximum temperature with a correlation coefficient of 0.9, indicating that there was no relationship between the rain that fell during this period and maximum temperature that might have occurred over Kano.

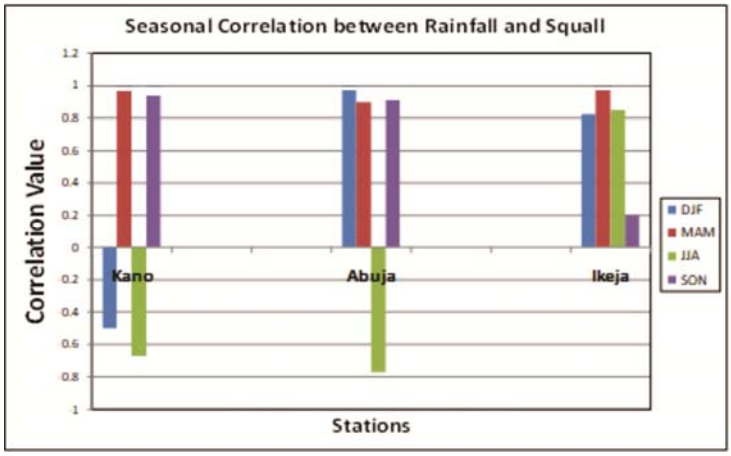
In Abuja, December, January and February period had the closest relationship between rainfall and maximum temperature with a correlation coefficient of 0.9. This indicates a very high close relationship between rainfall and maximum temperature that occurred at this period. The next period of the closest relationship between rainfall and maximum temperature over Abuja was JJA which show a negative relationship, it implied that most of the rain that fell under the review period had little or no relationship with the maximum temperature. During SON and MAM periods over Abuja, the effect of maximum temperature over the rain that fell was -0.8 (negative). This indicated that most of the rainfall at this period did not depend on heat caused by temperature. In Ikeja, DJF and JJA periods showed a positive relationship between the rainfall and maximum temperature which indicated that maximum temperature had an effect on rainfall, while MAM and SON showed a negative correlation which implied that rain that fell those periods did not depend on only on max temperature.

Figure 13b shows the seasonal correlation between rainfall and squall over Kano, Abuja and Ikeja. Over Kano, the MAM and SON period indicated that the rain that fell during that periods had positive correlation with the squall occurrences with the value of 0.95 and 0.9 respectively which show very strong relationship unlike the other two periods of DJF and JJA which show negative relationships of – 0.5 (negative) and – 0.7 (strong negative) respectively. Over Abuja, the following periods DJF,MAM and SON shows positive correlations between the occurrences of rainfall and squall that occurred during the years under review with the correlation coefficient values of 0.9 (Very strong),0.9(very strong positive relationship) and 0.9(Very strong positive relationship) respectively, while JJA period shows a negative correlation of about -0.75(strong negative relationship) which indicated that the rain that fell over Abuja during this period had less bearing with squall that occurred at the period.

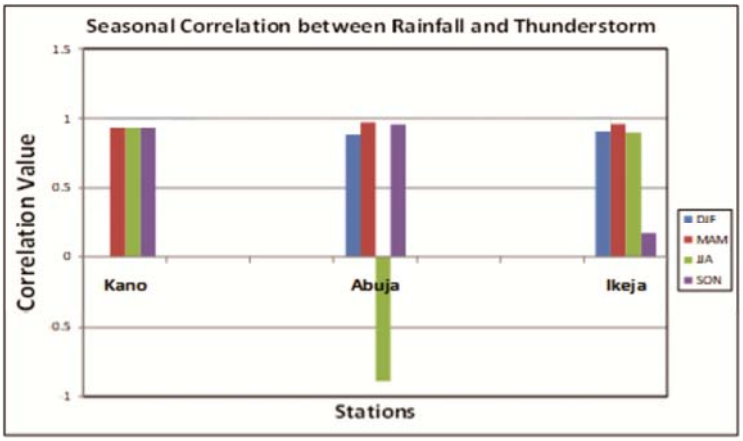
Over Kano, all the months/periods shows a very close relationship between rainfall and thunderstorm with the correlation coefficient of 0.9(very strong relationship) throughout the periods (Fig 13c). It means that thunderstorms that occurred during the period under consideration had a strong effect on the rain that fell that period over Kano. Over Abuja, the Figure 13c shows a strong correlation between rainfall and thunderstorm in DJF, MAM and SON periods with a correlation coefficient of about 0.8, 0.95 and 0.9 respectively, this implies that there was a close relationship between thunderstorm that occurred and rain that fell during the period. JJA period shows a negative relationship of about -0.8 which means that there was no close relationship between thunderstorm and rainfall at the period. There were a positive relationship between thunderstorm and rainfall over Ikeja throughout the periods with the following correlation coefficient DJF was 0.8 (very strong relationship), MAM 0.9 (very strong relationship), JJA 0.8(strong relationship) and SON 0.2 (strong relationship). This shows that there was a close relationship between occurrences of thunderstorm and rainfall over Ikeja.



(a)



(b)



(c)

Figure 13: Seasonal Correlation between Rainfall and (a) Maximum Temperature (b) Squall (c) Thunderstorm; over Kano, Abuja and Ikeja.

4. Conclusion

1. This study has examined the average monthly values of rainfall, maximum temperature and convective activities and the relationship between them over Ikeja, Kano and Abuja by using monthly rainfall, maximum temperature, thunderstorms and squall observations at the Forecast Office, Nigerian Meteorological Agency of the studied area.
2. It provided valuable insight into the temporal patterns of rainfall, maximum temperature and convective activities. Ikeja gradual increase in these parameters was observed between January and May, with squall attaining their own maximum in June and decreasing in July.
3. The Little dry season was conspicuously noticed with rainfall and the convective activities all having their minimal values between the bi-modal rainfall regimes. Thereafter, rainfall peaked up in the month of September, while the convective activities peaked up in October, as rainfall decreased.
4. The lag between rainfall and squall was noticed before the onset of rainfall, while rainfall was beginning to decrease, and this was with the maximum intensity of both thunderstorm and squall.
5. The relationship between rainfall and these convective activities was closest between March and May, while there was a very insignificant relationship between rainfall and these convective activities between December and February.

6. Over Kano, all the months/periods showed a very close relationship between rainfall, maximum temperature, squall and thunderstorm with correlation coefficient 0.9 (very strong relationship). It means that rainfall and convective activities that occurred during the period under consideration had a strong effect on the rain that fed with little decrease in maximum. There is only one peak for rainfall and convective activities over Kano, unlike Ikeja.
7. Over Abuja, a gradual increase in the correlation coefficient showed that occurrence of rainfall, squall, thunderstorm and maximum temperature was positive with a value of Pearson Correlation Coefficient of 0.9, therefore, rain that occurred in Abuja throughout the years were triggered by maximum temperature. It was shown that when rainfall was maximum at Kano during the month of August/September with convective activities leading to flooding and weather hazards associated with it, Ikeja will be having less rainfall with less thundering activities
8. Generally, most of the rainfall in Nigeria are triggered by temperature during the summer and movement of inter-tropical convergence Zone that favours the growth of convective activities.
9. During the winter, though there is a high/maximum temperature that triggered the development of cloud the Easterly trade wind with dry and haze weather does not allow it to grow and develop into the cloud that can form rain.

The study, therefore, suggests further research which will aid understanding of these convective systems, its dynamics, and their relationships with other weather parameters, especially in terms of their variation, more so that climate change effects are being experienced now more than ever before. The utilization of modelling and mapping techniques may also give further insight into the variation of these systems and a clue to issuing more accurate forecasts and predictions.

Ethical: NA

Consent:NA

REFERENCES

1. Christo Georgiev, Patrick Santurette, Karine Maynard. Applying Satellite Water Vapor Imagery and Potential Vorticity Analysis. Weather Analysis and Forecasting 2nd Edition.2016. ISBN: 9780128004951
2. Houze R. A. Jr. Cloud Dynamics. Academic, San Diego, California. 1993; 573 pp.
3. Srivastava, R. C. A simple model of evaporatively driven downdraft application to microburst downdraft. J. Atmos. Sci. 1985; 42, 1004 – 1023.
4. Knupp, K. R. Downdrafts within High Plains cumulonimbi. Part II: Dynamics and thermodynamics. J. Atmos. Sci.,1998; 45, 3965 – 3982.
5. Ahrens, D. C. Meteorology Today: An Introduction to Weather, Climate and the Environmen. 6th ed., Brooks/Cole.200. pp. 381-388.
6. Alexander, B. C. and Aloni, C. Adequate Environmental Monitoring, a Sinequanon for Sustainable Development. Journal of Economics and Sustainable Development. 2015; Vol.6, No.14. www.iiste.org
7. Alexander, B. C. Spatio-Temporal Variation of Thunderstorm Activity over Nigeria unpublished, M.Sc Thesis. 2005
8. Gettelman A., Salby, M. L., Sassi F. Distribution and influence of convection in the tropical tropopause region. Climate and Dynamics,2002; 6, 1-12.
9. The Weather Channel. Weather Glossary. 2006
10. Sultan B. and Janicot S. Abrupt shift of the ITCZ over West Africa and intra-seasonal variability. Geophysical Research Letters. 2000; vol. 27, no.20, pages 3353-3356
11. Zheng, X., and Eltahir, R. A soil moisture–rainfall feedback mechanism: 2. Numerical experiments. Water Resour. Res. 1998; 34, 777–785.
12. Janicot, S., Trzaska S., and Poccard I. Summer Sahel-ENSO teleconnection and decadal time scale SST variations, Climate Dynamics. 2001; 18, 303–320, doi:10.1007/s003820100172.

13. Ward, N. Diagnosis and short lead time prediction of summer rainfall in tropical North Africa at interannual and multidecadal timescales, J. Climate. 1998; 12, 3167– 3191.
14. Fontaine, B., Janicot S., and Roucou P. Coupled ocean-atmosphere surfacevariability and its climate impacts in the tropical Atlantic region, Climate Dynamics, 1999; 15, 451– 473.
15. Sivakumar, B., Berndtsson, R., Olsson, J., Jinno, K., and Kawamura, A.: Dynamics of monthly rainfall-runoff process at the Gota basin: A search for chaos, Hydrology and Earth System Sciences, 4, 3, 407–417, 2000
16. Sultan B., Christian B., Dingkuhnb M., Sarrc B., Janicot S. Agricultural impacts of large-scale variability of the West African monsoon. Agricultural and Forest Meteorology. 2005; 128: 93–110.
17. IPCC. Climate Change, summary for policymakers: A report of working group of the Intergovernmental Panel on Climate Change, Montreal, Canada. (available from http://www.ipcc.ch), 2008; 1009pp.
18. NIMET. Nigeria Climate Review Bulletin. A yearly publication of the Nigerian Meteorological Agency. 2015
19. Ayoade, J. O. Introduction to Climatology for the Tropics. Spectrum Publisher.1998
20. Adejuwon, S. A. An assessment of the patterns of rainfall fluctuations between 1922 and 1985 in Nigeria. Unpublished Ph.D. Thesis, Obafemi Awolowo University, Ile-Ife. 1988
21. Odekunle, T.O. Rainfall and the Length of the Growing Season in Nigeria. International Journal of Climatology, 24, 467-479. 2004