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SPATIAL AND TEMPORAL VARIABILITY OF 40 YEARS TEMPERATURE AND PRECIPITATION IN THE SAVANNA REGION, NIGERIA

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ABSTRACT
The fact that climate is varying globally and across regions and within drainage basins are no longer disputable, the causes of these variability have been attributed to natural and anthropogenic (human activities on the earth) factors, In the last four decades, the anthropogenic factors have become more dominant. Temperature and precipitation record in the savanna region for 40 years of six synoptic weather stations were obtained from Nigerian Meteorological Agency (Nimet). The obtained data covered two stations from each vegetation zone namely; Sahel Savanna (Maiduguri and Sokoto), Sudan Savanna (Katsina and Kano) and Guinea Savanna (Kaduna and Niger). Coefficient of variance (CV), mean, standard deviation kurtosis and skewness were used to assess the inter annual variability across the savanna regions. The result obtained from the analysis revealed that, there is moderate variability of Precipitation in the Guinea, Sudan and Sahel savanna and low variability in temperature in the whole of savanna region.

***Keywords*: ** Variation, Time, Space, Temperature, Rainfall and Savanna.

INTRODUCTION

Temperature and rainfall variability, its impacts and vulnerabilities are growing concerns worldwide. The climate of Nigeria, and in particular the study area, is changing and it is becoming more unpredictable every year. Global warming induced changes in temperature and rainfall are already evident in many parts of the world, as well as Nigeria (Odjugo, 2010) including the study area. The terms climate variability and climate change are sometimes used interchangeably just as weather and climate though they represent different phenomena. They are often distinguished based on the time scale. Generally, there are three categories of climate change and these are: long term, short-term and fluctuations depending on the timescale. Climate Changes occurring over time scales shorter than those associated with the orbital forcing frequencies are defined as short-term while climate fluctuations on time scales less than 100 years are usually considered as climate variability (Matondo *et al.,* 2004). Climate variability, therefore, is the fluctuations and variations experienced on shorter time scales (less than 100 years) such as years or decades whereas climate change refers to variations on longer time scales (greater than100 years).

The consequence of climate variability on the world climate system is global warming which has been recognized since 1970s of the 20th century (Gruza and Rankova, 2004). The public and policy-makers understand climate variability as being synonymous with global warming. The number of researches concerning climate variability due to both natural and anthropogenic forcing has increased sharply since then. The science has become more irrevocable than ever. The evidence of climate change or variability is all around us and unless we act, we will see catastrophic consequences including sea level rise, drought and famine and the loss of plant and animal species. It is now becoming evident that the monitoring of the current climate variables is required.

The fact that the world climate is varying globally and across regions and within drainage basins are no longer disputable (Hengeveld, 2000; IPCC, 2001), the causes of these variability have been attributed to natural and anthropogenic (human activities on the earth) factors (IPCC, 2007; Le Trent *et al*, 2007; UNDP, 2007). In the last four decades, the anthropogenic factors have become more dominant. The increase in the generation and emission of greenhouse gases (GHG) through industrial activities and the burning of fossil fuels, deforestation and urbanization are some of the human activities that have continued to increase the temperature regimes in the lower atmosphere (IPCC, 2007; USAID, 2005). These have led to the occurrence of extreme weather events such as floods, droughts, cyclones and tornadoes and increase in their frequencies of occurrence (Marx *et al,* 2005). The distribution of rainfall globally and across continents and within drainage basins has continued to change due to climate variability (Chaponniere and Smakhtin, 2006; UNDP, 2007). Since most developing countries like Nigeria depend heavily on agriculture, the effects of global warming on productive croplands is likely to threaten both the welfare of the population and the economic development of the countries. Tropical regions or countries of the developing world are particularly vulnerable to potential variations in climatic variables because the poor soils that cover large areas of these regions already have made much of the land unusable for agriculture (Robert and Ariel, 1999; DFID, 2004; UNDP, 2007).

Hazards such as floods and droughts which are aggravated by climate variability are being experienced more frequently than ever before in Nigeria and in particular the study area. Rapid population growth and movement into areas exposed to floods, landslides, coastal storm surges, tornadoes or drought have produced increasing loss of life and economic losses in many countries during the recent decades. The increases in the frequency of these extreme weather events have been attributed to climate variability due to human activities which led to increases in the green house gas emissions. In recent decades, Kaduna River within the study area had experienced a number of flood events along the floodplain which led to loss of lives, property, farmlands and livestock (Alayande and Agunwamba, 2010). Also, a number of earth dams across some of the tributaries of Kaduna River, within Kaduna State, had been overtopped and collapsed pre-maturely in recent decades. Recent study had attributed the increase in the frequency of the flood events in the study area to urbanization and encroachment on the floodplain by residents (Alayande and Agunwamba, 2010). However, from literature, several incidences of flood in many countries and basins, in recent decades, had been attributed to climate variability due to increases in the green house gas emissions. It is obvious that the capacity of Nigerian government and Nigerians to manage these hazards associated with climate variability is far from being perfect due to lack of awareness and understanding of the mechanism and the level of climate variability among the population and policy makers. Effective mitigation of these hazards associated with climate variability will thus require continued development of our understanding of the magnitude of climate variability and its effects on such resources as water and the responses of the human communities to the climate related hazards.

Extreme temperature events, through the occurrence of prolonged hot or cold spells, can have serious impacts on our environment and society. In recent years investigations of observed temperature in many regions of the world have already shown some important changes in the extremes. This warming may not be spatially or temporally uniform, but it is projected to continue and will likely be accompanied by more extreme climate events (Folland *et al*., 2001). Prolonged exposure to high temperature can cause heat-related illness, including heat cramps, heat syncope, heat exhaustion, heat stroke and death (Kilbourne, 1999). Heat events can result in increased deaths and emergency hospital admissions, especially among vulnerable groups such as elderly people, young children and patients with chronic diseases. Example, European drought and heat waves in 2018 where much of Europe experienced above-average temperatures and drought which resulted in wildfires in Sweden and wildfires in Greece, Japan heat wave in mid-July 2018 which arrived after a major flood and it caused over 22,000 hospitalization and 80 deaths, 2018 North American heat wave etc.In the study area, there is general lack of awareness and knowledge of the effects of climate variability. This study analyzed temperature and rainfall variability through measure of dispersion and central tendency.

Study area Description

Nigeria, a West African country located in the tropical zone of Africa, lies on latitude 4^{o} to 14^{o}N of the equator and longitude 3^{o} and 15^{o} on the east of the Greenwich meridian. Nigeria vegetation is divided into forest and savanna region, this study covered the savanna area which is found in the northern region covering about 79% of the entire landmass of the country. In 2018, the estimated population of the country is over 185.88 million based on the annual growth rate of the country by Nigerian Bureau of Statistics. The Northern Nigeria which covers the Savanna region composed of the 19 states of the country's 36 states. It is inhabited by over 50% of the country's 167million people (Pate and Dauda, 2013) sparsely distributed across 79% of the country's total land mass. The savanna region is home to over Two-third of the country's 250 ethnic group (Pate and Dauda, 2013).

Nigeria is found in the Tropics, where the climate is seasonally damp and very humid. Nigeria is affected by four climate types; these climate types are distinguishable, as one moves from the southern part of Nigeria to the northern part through Nigeria's middle belt. The tropical savanna climate or tropical wet and dry climate is extensive in area and covers most of Western Nigeria to central Nigeria beginning from the Tropical rainforest climate boundary in southern Nigeria to the central part of Nigeria, where it exerts enormous influence on the region.

The single Dry season experienced in this climate, the tropical savanna climate in central Nigeria beginning from December to march, is hot and dry with the Harmattan wind, a continental tropical (CT) airmass laden with dust from the Sahara Desert prevailing throughout this period. With the Intertropical Convergence Zone (ITCZ) swinging northward over West Africa from the Southern Hemisphere in April, heavy showers coming from pre-monsoonal convective clouds mainly in the form of squall lines also known as the north easterlies formed mainly as a result of the interactions of the two dominant airmasses in Nigeria known as the Maritime tropical (south westerlies) and the Continental tropical (north easterlies), begins in central Nigeria while the Monsoons from the south Atlantic ocean arrives in central Nigeria in July bringing with it high humidity, heavy cloud cover and heavy rainfall which can be daily occurrence lasting till September when the monsoons gradually begin retreating southward to the southern part of Nigeria.

Rainfall totals in central Nigeria varies from 1,100 mm in the lowlands of the river Niger Benue trough to over 2,000 mm along the south western escarpment of the Jos Plateau. The Sahel climate or tropical dry climate is the predominant climate type in the northern part of Nigeria. Annual rainfall totals are lower compared to the southern and Guinea Savanna region of Nigeria. The rainy season in the Sudan Savanna last for only three to four months (June–September), the rest of the year is hot and dry with temperatures climbing as high as 40°C. Nigeria's seasons are determined by rainfall with rainy season and dry season being the major seasons in Nigeria. The rainy season of Nigeria brings in cooler weather to the country as a result of an increased cloud cover that acts as a blockage to the intense sunshine of the tropics by blocking much of the sun's rays in the rainy season; this in turn cools the land, and the winds above the ground remains cool thereby making for cooler temperatures during the rainy season. But afternoons in the rainy season can be hot and humid, a feature of tropical climates. In the rainy season it is damp, and the rainfalls are usually abundant.

The dry season of Nigeria is a period of little cloud cover in the southern part of Nigeria to virtually no cloud cover in the northern part of Nigeria. The sun shines through the atmosphere with little obstructions from the clear skies making the dry season in Nigeria a period of warm weather conditions. In the middle of the dry season around December, a dusty wind from the Sahara Desert called the harmattan enters Nigeria from the north eastern part of the country blocking sun rays partially from shining and also creating haze in the atmosphere, this activities of the wind lowers temperatures considerably saving inhabitants for sometime, from the scorching heat that would have occurred as a result of clearer skies during the dry season. But with the withdrawal of this wind around March to April following the onset of the rainy season, temperatures can go as high as 44°C in northern parts of Nigeria.

The Coast: Nigeria's southern coastline runs approximately 835 km (519 mi) alongside the Gulf of Guinea. Along the coast, a swath of low-lying mangrove forests and swamps extend inland. In most places, these areas are 15 km (9 mi) wide, but in the Niger Delta, they may stretch as far as 100 km (62 mi) from the coast. Waterways and lagoons intersect these areas, portions of which are heavily developed and populated.

The Forest Belt: Inland from the coastal region is a belt of tropical and transitional forests that ultimately merges into the savanna of northern Nigeria. A portion of this region in the southwest is one of the most densely populated areas in Africa. Not surprisingly, human development has led to severe deforestation in many areas, leaving the region's existing forests fragmented and threatened by further activity.

The Savanna: The West Sudanian Savanna covers a broad swath of northern Nigeria. Typically hot and dry, the savanna supports scattered trees ranging from tall to stunted and a variety of grasses.8 Areas of this vast plain are dotted with outcroppings of granite. Overall, the region is the site of significant agricultural activity, leaving many areas degraded.

The Sahel: Covering a small portion of northeastern Nigeria, the Sahel region represents a dry transitional stage between the savanna and the Sahara to the north. The greater Sahel region stretches east to west across Africa from the Atlantic Ocean to the Red Sea. This area sees only small amounts of rainfall from 10 to 20 cm per year and is sparsely vegetated. Because only a few crops will grow, such as peanuts and millet, many people here earn their livelihood as nomadic herders.

In conclusion, the savanna zone's three categories are divided into mm' Guinean forest-savanna mosaic, made up of plains of tall grass which are interrupted by trees, the most common across the country; Sudan savanna, similar but with shorter grasses and shorter trees; and Sahel savanna patches of grass and sand, found in the northeast.

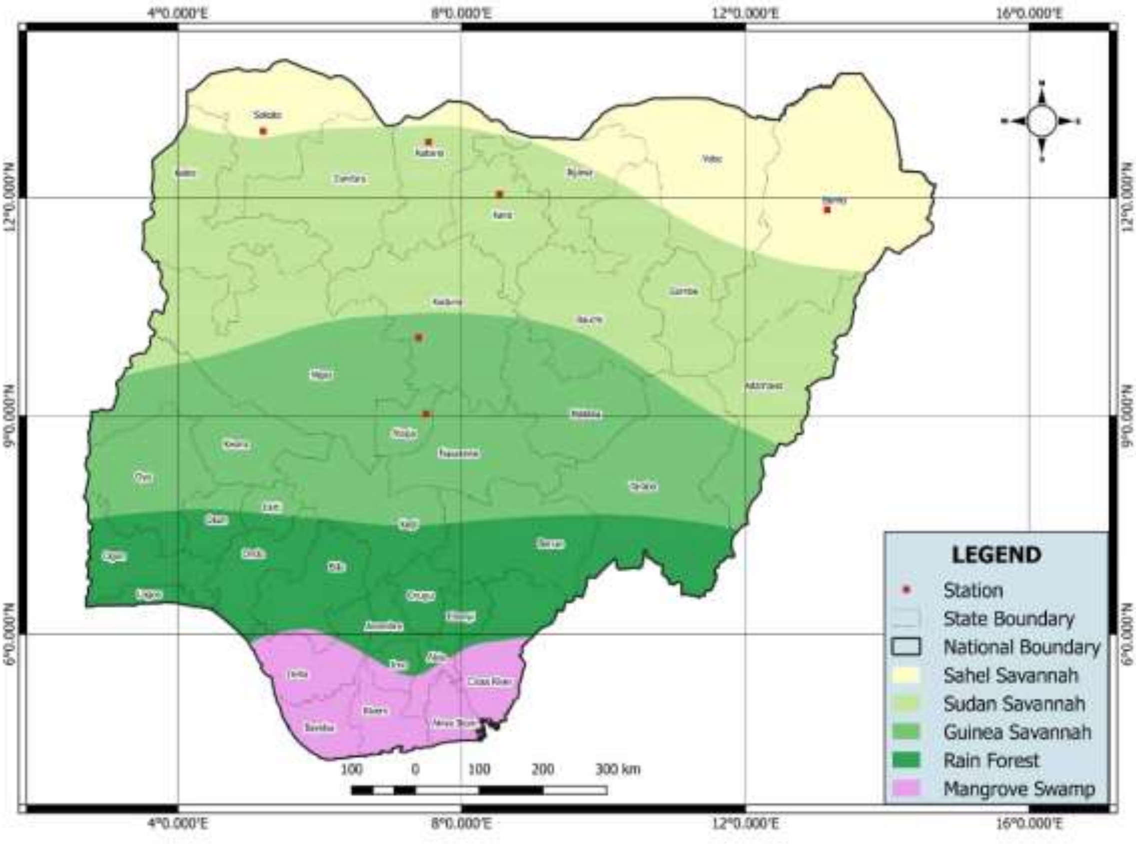

Fig. 2: Nigeria showing selected stations for the study

MATERIALS AND METHOD

The records of the daily maximum and minimum temperature and daily precipitation data of 6 stations from the vegetation regions (2 stations from each 3 vegetation zones) in Nigeria for 40years was collected from the achieve of the Nigerian Meteorological Agency (NIMET), a governmental organisation in charge of all weather stations across the Country. Data homogeneity was assessed using an R-based program, RHtest, also developed by ETCCDI. This program is capable of identifying multiple step changes at documented or undocumented change points. It is based on a two-phase regression model with a linear trend for the entire base series (Wang, 2003). The data quality (QC) and homogeneity test procedures will identify some apparent problems in the data such as, duplicates dates, out-of-range values based on a defined threshold, outliers, coherence between maximum and minimum temperatures (Tmax>Tmin), and consecutive days with equal values. Each potential outlier will be manually validated using information from the days before and after the event along with expert knowledge about the climate (for example, Aguilar *et al.,* 2009).

World Meteorological guidance (WMO) guidance on developing long-term, high-quality and reliable instrumental climate records is provided in Brunet (2008). This involves basically, the quality control (QC) of the obtained data, which usually involves a variety of graphical and statistical analyses. The three (3) Vegetation zones are Sahel, Sudan and Guinea Savanna.

Table 1: The Selected Stations and their Locations

S/NO	VEGETATION ZONE	STATION NAME	WMO ID	STATION ELEVATION (meters)	LAT.	LONG.	STATE
1.	Sahel Savanna	Maiduguri	65082	354	11º50'N	13º09'E	Borno
		Sokoto	65010	351	12º55'N	05º12'E	Sokoto
2.	Sudan Savanna	Kano	65046	476	12º03'N	08º32'E	Kano
		Katsina	65028	427	13º01'N	07º41'E	Katsina
3.	Guinea Savanna	Minna	65123	262	09º04'N	07º32'E	Niger
		Kaduna	65019	645	11º04'N	07º42'E	Kaduna

Investigation of Interannual variability of selected element

Descriptive statistical techniques such as the mean, standard deviation, variance, skewness, kurtosis and the Coefficient of variance was used to determine the inter-annual variability of temperature and precipitation of vegetation zone in the savanna region in Nigeria (Adejuwon, 2006). Addin Soft XlStat Excel tool software was used for the analysis. The result of Inter-annual variability of selected element was presented using Charts, Tables and graphs.

RESULTS AND DISCUSSION

Inter Annual Variability of Rainfall, and Temperature in the Savanna Regions

In this section the characteristic of rainfall and maximum and minimum temperature was analysed by the used of measure of central tendency, dispersion and coefficient of variance.

Inter Annual Variability of Rainfall Distribution

The result of descriptive statistical analysis of precipitation over 40 year's record is presented in Table 2. In Guinea Savanna the result revealed that the precipitation had a mean of about 3.254mm with variance of 0.387 and standard deviation of 0.622 in Kaduna. Niger had a rainfall distribution with a mean of about 3.261mm with variance of 0.198 and standard deviation of 0.445. The coefficient of variations (CV) which measure the variability is therefore, 0.191 (19.1%) in Kaduna and 0.137(13.7%) in Niger. According to Durdu (2009) when (CV <= 0.1 or 10%) indicate low variability, (CV <= 0.4 or 40% and > 10%) indicating moderate variability while when (CV >0.4or 40%) indicated high variability. Therefore, from the analysis it indicated that the rainfall had a low variability in Guinea savanna vegetation zone.

In Sudan savanna, Kano has the rainfall variability of 2.712mm, a variance of 0.898 and a standard deviation of 0.947 and the coefficient of variance are 0.349 (34.9%). Katsina has a mean of 1.564, variance of 0.290, standard deviation of 0.539 and the coefficient of variance of 0.344 (34.4%). The rainfall variability in the Sudan savanna still revealed a moderate variability (Durdu, 2009). In the Sahel savanna, Maiduguri has a rainfall mean variability of 1.577mm, variance of 0.156, the STD of 0.492 and Sokoto has a mean rainfall variability of 1.816, the variance is 0.156 and the STD is 0.395. 0.312 (31.2%) in Maiduguri and Sokoto has a coefficient of variance of 0.218 (21.8%). According to Durdu, 2009, Sahel savanna falls under moderate rainfall variability.

Table 2: Inter Annual Variability of Rainfall Distribution in Savanna Vegetation Zone, Nigeria

Vegetation zone	Station	Min	Max	Range	Mean	Var	STD	CV	Skewness	Kurtosis
GUINEA	KADUNA	1.440	4.535	3.095	3.254	0.387	0.622	0.191	-0.342	0.547
	NIGER	2.242	4.216	1.974	3.261	0.198	0.445	0.137	-0.202	-0.383
SUDAN	KANO	1.294	4.902	3.608	2.712	0.898	0.947	0.349	0.384	-0.618
	KATSINA	0.710	3.590	2.880	1.564	0.290	0.539	0.344	1.271	3.073
SAHEL	MAIDUGURI	0.642	2.942	2.300	1.577	0.242	0.492	0.312	0.204	0.363
	SOKOTO	1.022	3.142	2.120	1.816	0.156	0.395	0.218	0.664	1.496

Note: Min: - Minimum, Max: - Maximum, Var: - Variance, STD: - Standard Deviation and CV: - Coefficient of Variance.

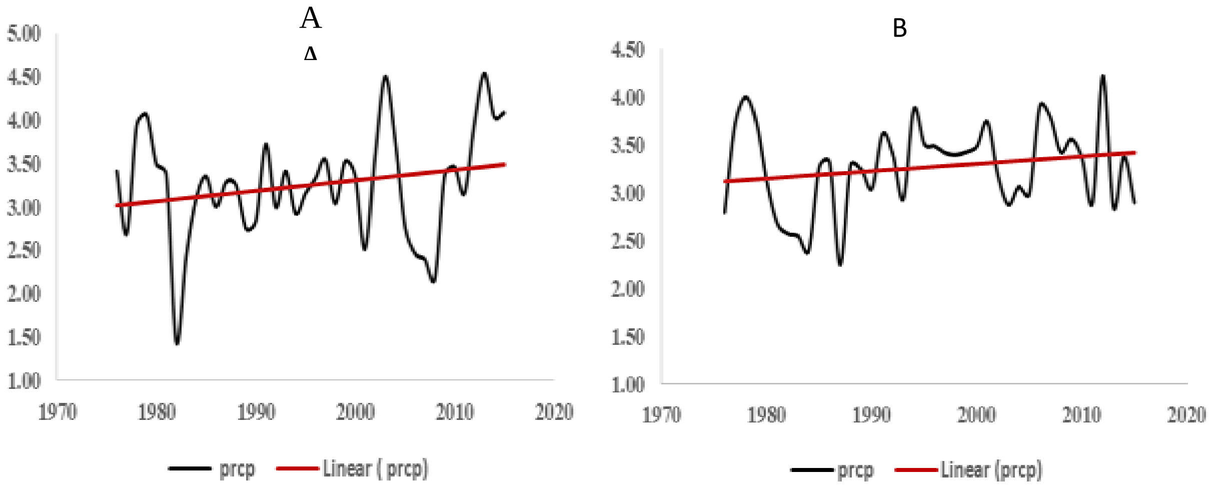

Figure 1: Inter Annual Rainfall Distribution in Guinea Savanna Vegetation Zone (A) Kaduna Station and (B) Niger Station

Figure 1 showed a temporal distribution of inter annual rainfall in Guinea Savanna vegetation region of Nigeria. The result revealed that in Figure 1A (Kaduna) 1981 the region experienced decline or low rainfall during the period of study while 2013 recorded the high amount of rainfall in the region. From 1982 the rainfall pattern in the region experienced raised and falling in the range. This temporal pattern continues until 2000 where it experienced decreased and then increased around 2002. Similarly, in Figure 1B (Niger) unless around 1994 to 2004 showed a stable rainfall distribution, this implies that the variability was minimal compared to that of other years as well as that of Kaduna. The rainfall distribution showed that there is two year cyclical pattern in Guinea Savanna vegetation region of Nigeria. It indicated an upward linear slope in the region, which showed a positive trend. That is the tendency of increased of the amount of rainfall in the near future.

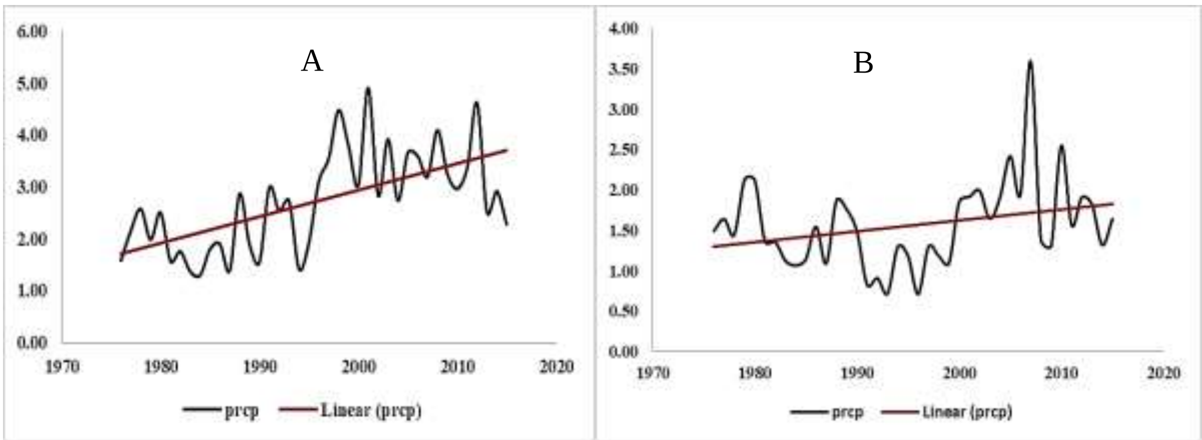

Figure 2 showed a temporal distribution of inter annual rainfall in Sudan savanna vegetation region of Nigeria (A) Kano (B) Katsina. The result revealed that in Figure 2A (Kano) from 1972 the region experienced fluctuation of rainfall distribution until 2001 were it reach the highest amount of rainfall recorded during the period of study. Similar pattern was observed from 2002 to 2012 then the rainfall continues declined from 2013 to 2015. In Figure 2B (Katsina) from1980 there is declined of rainfall amount until 2000 were the amount increased compared with that of 1980 despite the fluctuation characteristic of the rainfall distribution in the region, the continual increased of rainfall was recorded until it reach the peak i.e. the highest recorded amount of rainfall (2008). The rainfall distribution showed that there is one year cyclical pattern in Sudan savanna vegetation region of Nigeria this implies that in every one the region experienced increased rises of rainfall. It indicated an upward linear slope in the region i.e. but from Kano and Katsina, this implies a positive trend. There is tendency of increased of the amount of rainfall in the near future.

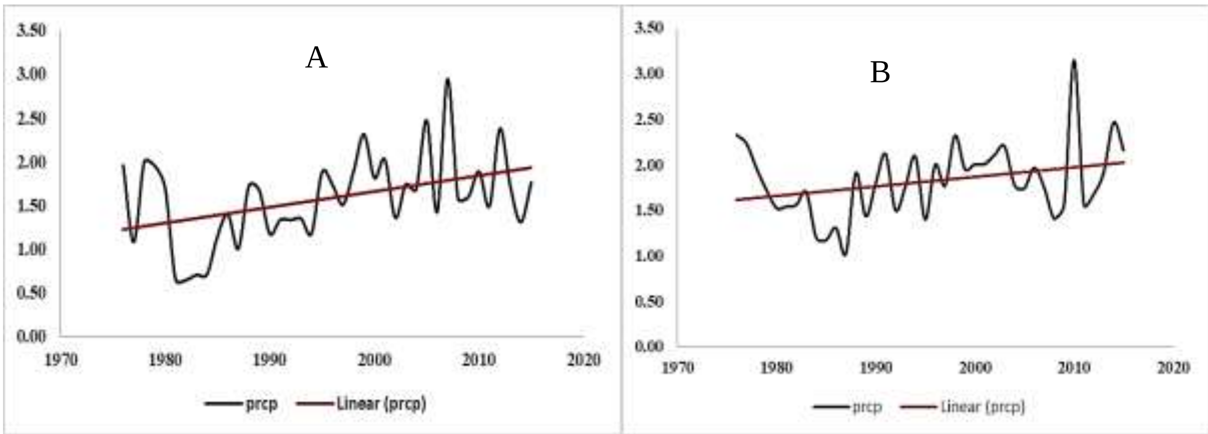

Fig. 3: Inter Annual Rainfall Distribution in Sahel Savanna Vegetation Zone (A) Maiduguri Station and (B) Sokoto Station

Figure 3 showed a temporal distribution of inter annual rainfall in Sahel savanna vegetation region of Nigeria. The result revealed that in Figure 3A (Maiduguri) 1981 the region experienced decline or low rainfall during the period of study while 2007 recorded the high amount of rainfall in the region. From 1983 the rainfall pattern in the region experienced fluctuation to 2007. Similarly, in Figure 3B (Sokoto) the rainfall distribution continues rising up to the 2010 were it recorded the highest amount of rainfall with the rising and falling pattern the region. 1998 recorded the lowest amount of rainfall during the period of study. The rainfall distribution showed that there is one year cyclical pattern in every three year then two year cyclic pattern was experienced in the region. It showed an upward linear slope in the region, which indicated positive trend. There is tendency of increased of the amount of rainfall in the near future.

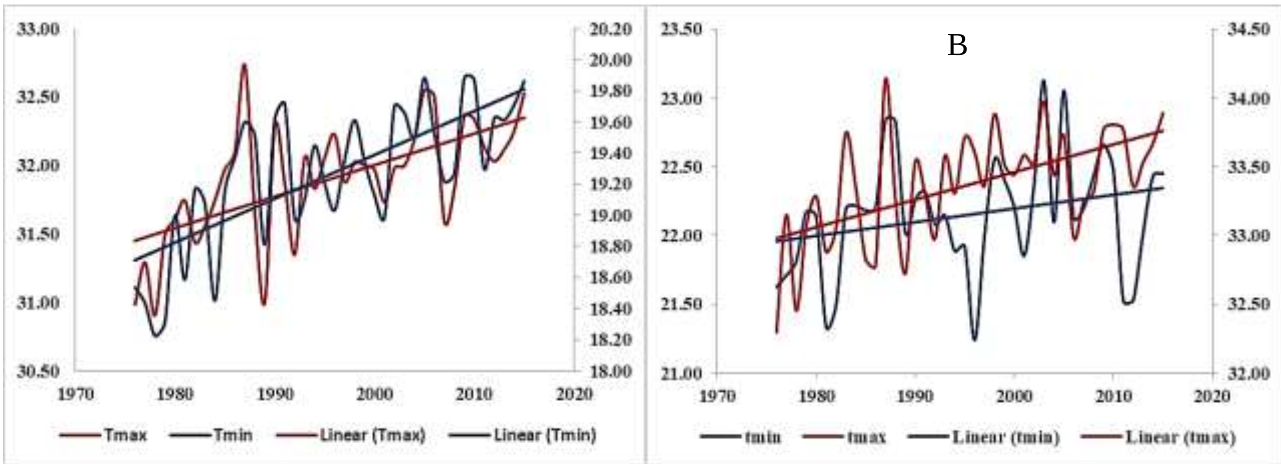

Fig. 4: Inter Annual Maximum and Minimum Temperature Distribution in Guinea Savanna Vegetation Zone, Nigeria (A) Kaduna Station and (B) Niger Station

Figure 4 showed a temporal distribution of inter annual Tmin and Tmax in guinea savanna vegetation region of Nigeria. The result revealed that in Figure 4A (Kaduna) the Tmin and Tmax had a similar distribution pattern during the period of the study. In Figure 4B (Niger) the Tmax and Tmin had a gain said pattern of distribution in this station. During the period of study, especially between 1990 and 2000 when Tmin is low the Tmax is high. The guinea savanna region experienced fluctuation of the Tmin and Tmax. The temperature distribution showed a one year cyclical pattern in the region. It also showed an upward linear slope in the region both the Tmin and Tmax, which indicated positive trend. There is tendency of increase of the amount of temperature in the near future.

Inter Annual Variability of Temperature Distribution

Table 3: Inter Annual Variability of Temperature Distribution in Savanna Vegetation Zone, Nigeria

Vegetation Zone	Station	Climate variable	Min	Max	Range	Mean	Var	STD	CV	Skewness	Kurtosis
GUINEA	KADUNA	Tmax	30.905	32.732	1.827	31.897	0.179	0.422	0.013	-0.469	-0.047
		Tmin	18.225	19.882	1.658	19.259	0.200	0.447	0.023	-0.658	-0.384
	NIGER	Tmax	32.297	34.137	1.840	33.371	0.165	0.407	0.012	-0.592	0.034
		Tmin	21.240	23.126	1.885	22.154	0.180	0.425	0.019	0.060	-0.001
SUDAN	KANO	Tmax	32.340	34.447	2.107	33.590	0.196	0.442	0.013	-0.209	0.536
		Tmin	18.470	21.052	2.582	20.094	0.262	0.512	0.025	-0.635	1.246
	KATSINA	Tmax	32.748	34.600	1.852	33.777	0.230	0.480	0.014	-0.230	-0.854
		Tmin	17.437	21.340	3.903	19.913	0.723	0.850	0.043	-0.953	0.572
SAHEL	MAIDUGURI	Tmax	34.058	36.123	2.065	35.413	0.171	0.414	0.012	-0.847	1.011
		Tmin	18.995	21.650	2.656	20.499	0.294	0.542	0.026	-0.159	0.227
	SOKOTO	Tmax	34.271	36.580	2.309	35.405	0.314	0.560	0.016	-0.100	-0.907
		Tmin	21.011	23.627	2.616	22.540	0.337	0.581	0.026	-0.396	-0.177

Note: Min: Minimum, Max: Maximum, Var: Variance, STD: Standard Deviation and CV: Coefficient of Variance

Table 3 showed inter annual variability of maximum and minimum temperature of savanna region of Nigeria. The result revealed that the maximum temperature of Kaduna, Niger, Kano, Katsina, Borno and Sokoto are; 31.897, 33.371, 33.590, 33.777, 35.413 and 35.405 respectively. While for minimum temperature are; 19.26, 22.15, 20.09, 19.91, 20.49 and 22.54. The minimum temperature (Tmin) CV within the region ranges from 0.01 to 0.04. The result revealed that the selected Kaduna, Niger, Kano, Katsina, Sokoto and Borno had a low variability of minimum temperature within the savanna vegetation region of Nigeria. Similarly, maximum temperature (Tmax) CV of the region showed a low variability.

Also the result revealed that all the station in the savanna region had a negative skewness only that of Niger accounted for positive skewness of the Tmin. The regional average of the skewness indicates the negative. Similarly, the Tmax of the region revealed left distribution skewness. This implies that the station in the savanna region had a right distribution and pattern of Tmin and Tmax. Furthermore, the result showed that only Tmin had a negative kurtosis in guinea savanna region while the remaining region in the savanna region of Nigeria had a positive kurtosis. The negative kurtosis of guinea savanna indicated a flat distribution (not clear for readers) while positive kurtosis of remaining region indicated a peaked distribution of Tmin. The Tmax of the savanna region showed a peak distribution.

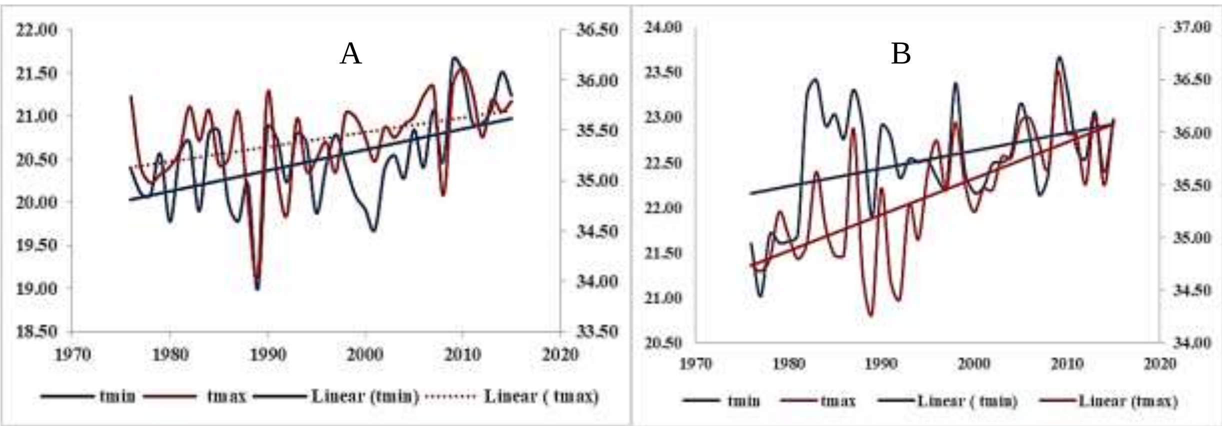

Fig. 5: Inter Annual Maximum and Minimum Temperature Distribution in Sudan Savanna Vegetation Zone, Nigeria (A) Kano Station and (B) Katsina Station

Figure 5 showed a temporal distribution of inter annual Tmin and Tmax in Sudan savanna vegetation region of Nigeria. The result revealed that in Figure 5A (Kano) the Tmin and Tmax had a similar distribution pattern during the period of the study. It showed that 1990 accounted for low amount of low Tmax while 2015 recorded the high amount of Tmax. In addition the Tmin had low amount in 2014 with the high amount in 1997. It showed a decreased amount of Tmin since the linear trend line showed downward while the Tmax was increased. In Figure 5B (Katsina) showed that the Tmin had low pattern and distribution. This implies that there is low variability in the Katsina. The Tmax recorded a low value 1977 while in 1988 the highest recorded amount of Tmax was experienced, although the amount of Tmax rises during the period of study. Despite that the nature was fluctuation pattern. This showed a one year cyclical pattern of Tmax in the region. It also showed an upward linear slope of Tmax in the region but the Tmin was stable. There is tendency of increase of the amount of maximum temperature in the near future.

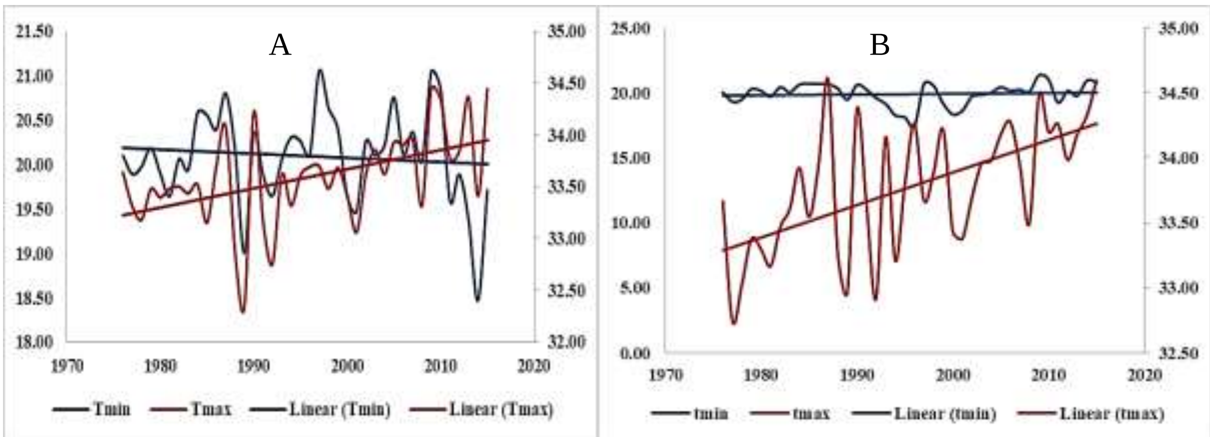

Fig. 6: Inter Annual Maximum and Minimum Temperature Distribution in Sahel Savanna Vegetation Zone, Nigeria (A) Maiduguri Station and (B) Sokoto Station

Figure 6 showed a temporal distribution of inter annual Tmin and Tmax in Sahel savanna vegetation region of Nigeria. The result revealed that in Figure 6A (Maiduguri) the Tmin and Tmax had a similar distribution pattern during the period of the study. In Figure 6B (Sokoto) the Tmax and Tmin had a gainsaid pattern of distribution in this station especially between 1980 and 1990 when Tmin is rising the Tmax is falling. The Sahel savanna region experienced rising and falling pattern of the Tmin and Tmax. The temperature distribution showed a one year cyclical pattern in the region. It also showed an upward linear slope in the region both the Tmin and Tmax, which indicated positive trend. There is tendency of increase of the amount of temperature in the near future.

DISCUSSION

Result of the analysis indicated that the rainfall had a moderate variability in Guinea, Sudan and Sahel savanna vegetation zone. The rainfall distribution showed that there is two year cyclical pattern in guinea savanna this can be related to the amount of the rainfall experienced in the region and compared with the one year cyclical pattern in Sudan savanna and Sahel savanna region of Nigeria where the inter tropical continent is more prevailing and experienced dryness more than the guinea savanna. The trend analysis of annual rainfall distribution in savanna region of Nigeria revealed that all the station within the region had a positive trend (showing an upward linear slope in the region). This indicated that the annual rainfall had increased over the study period with the tendency of increasing in the near future. Although, the annual rainfall trend showed insignificant at 0.05 level of significant only in Kano and Borno (Maiduguri). The finding is similar to the study by Abdussalam (2015) in the Northwestern region of Nigeria and also Akande et al. (2017) in Nigeria.This variability can be as result of anthropogenic activities such as burning of fossil fuels, deforestation and urbanization which have continued to increase in the region that help in generation and emission of greenhouse gases (GHG). These have led to the occurrence of extreme weather events in the region such as floods, droughts and increase in their frequencies of occurrence

Also low variability of minimum temperature within the savanna vegetation region of Nigeria was experienced across the savanna region respectively. Similarly, Tmax of CV of the region showed a low variability as indicated by Durdu (2009) when (CV <= 0.1 or 10%) indicate low variability. The temperature distribution showed a one year cyclical pattern in Guinea, Sudan and Sahel region of Nigeria of both Tmax and Tmin in the Savanna region of Nigeria. The temperature distribution showed a one year cyclical pattern in the entire savanna region. The result of the trend analysis of annual maximum and minimum distribution in savanna region of Nigeria revealed that all the stations within the region had a positive trend of maximum and minimum temperature. This indicated that the maximum and minimum temperature had increased over the study period with the tendency of increasing in the near future, only the Tmin had experience a negative trend in Kano. The finding matches well with the study by Abdussalam (2015) in the Northwestern region of Nigeria. Although, the Tmax and Tmin trend showed significant at 0.05 level of significant only Tmin of Kano, Katsina and Sokoto are insignificant.

Evidence has shown that northern Nigeria is particularly vulnerable to climate extremes because of its physical and socioeconomic characteristics, such as widespread poverty, desertification, ecological disruption, high population growth rate and extreme weather events. The region lies in areas identified as "hotspots" of climate change (Collier, 2008) and which are projected to be disproportionately affected by an increasing disease burden and extreme climate events. The region has the highest population in the country and a large proportion of the area is vulnerable to flooding, desert encroachment, poverty and prevalence of infectious diseases. It has been observed that in past decade extreme weather events were common and occurred regularly.

CONCLUSION

The results reveal that the rainfall showed a moderate variability in the Guinea, Sudan and Sahel savanna while the min and max temperature showed a low variability in the whole savanna region. The result also revealed a significant increase in maximum and minimum temperature in the region. The rainfall distribution showed two year cyclical pattern in guinea savanna, one year cyclical pattern in Sudan savanna and Sahel savanna region of Nigeria. This revealed a tendency of rainfall return period in the respected regions. As such climate daily indices should be considered for further research since it give an account of extreme weather event more than the daily rainfall and temperature data.

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