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Spatial and seasonal variations in rainfall and temperature across Nigeria

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Key words: Climate dynamics, Climate variability, Climatic zones, Environmental zones, Trends analysis

Abstract

This research investigated spatial and seasonal variations in the rainfall and temperature in Nigeria. The study utilised the ex-post facto research design, on the existing 8 climatic zones in Nigeria. Archival data on rainfall and temperature from 1901 to 2017 used for this study were got from Climate Research Unit, University of East Anglia, via Google Earth Version 7.3.2, using 5° x 5° high-resolution gridded CRUTEM 4.03. Statistical analyses of data were carried out using Analysis of Variance (ANOVA) and Mann-Kendall tests. Results indicate that significant differences exist in: rainfall within Nigerian states as determined by ANOVA test at $F(35, 4176) = 1596.76$ and $p = 0.000$; temperature within Nigerian states as determined by ANOVA test at $F(35, 4176) = 310.73$ and $p = 0.000$; seasonal variations in rainfall within Nigerian states as determined by ANOVA test at $F(11, 50532) = 7776.36$ and $p = 0.000$; seasonal variations in temperature within Nigerian states as determined by ANOVA test at $F(11, 50532) = 4575.79$ and $p = 0.000$; trends of rainfall across Nigeria; and trends of temperature across Nigeria. While rainfall showed increasing trends, temperature trends were alternately increasing and decreasing. Rainfall and temperature vary spatially and seasonally within Nigeria. The environmental regions have their peculiar rainfall and temperature characteristics. Therefore, this study is of significant importance to agricultural production because understanding regional climatic attributes is an essential environmental part for effective agricultural productivity.

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Introduction

Rainfall and temperature elements of climate vary spatially and seasonally. This is because; different localities and regions experience variant rainfall and temperature distributions within different seasons (International Panel on Climate Change report, 2013). However, the IPCC (2013) report upholds that the present-day warming and the increased variability of precipitation are likely to be exacerbated in future climate with high regional variations and different degrees of confidence. Climate variability explains the dynamics in the mean and other statistics of the climate variables on every temporal and spatial scale, which is beyond that of the individual weather events (Daramola, Eresanya and Erhabor, 2017).

It has long been observed that there is variability in climate in addition to the possibility of significant variations within comparatively short periods of time. However, due to lack of appropriate means for predicting such variations, their relevance to regional planning were not noticed. Our present ability to predict these variations is still very limited thus; any prediction made is highly debated. The current interest and urgency in climate variability issues is due to the fact that man himself may be the cause of such variations in climate.

Climate variability occurs generally, and has varied gradually over the past millennia to date. This inconsistency in climate signifies variations in patterns of rainfall and temperature, and will continue in the nearest future (Okorie, Okeke, Nnaji, Chibo and Pat-Mbano, 2012). According to Okorie *et al.* (2012), variation in climate is motivated by the irregular circulation of solar heating; distinctive feedback of the land surface, atmosphere and oceans; the interactions between these mechanisms and the physical environment together with the physiognomies of the regions. In the same vain, Daramola, *et al.* (2017) opined that variability in climate signifies a disagreement between climatic parameters of an area with its long-term mean. In each season of the year with specific time period, climatic conditions of any given locality differ significantly. While some years will have below average rainfall and temperature, other years may have within average and sometimes above average. Regional climate is always varied; these continuous variations do not normally arise on a time scale that is instantaneously noticeable. Changes in everyday weather can be observed, but subtle climate variations are not as immediately noticeable (IPCC, 2013). With respect to variability, temperature varies strikingly across locations and over time at a given location on the globe. Never in history of mankind different location has given the same temperature, these variations in temperature are influenced by several factors such as ocean current, nature of the prevailing wind, relief, distance from water bodies, nature of surface, and the amount insulations received. In the same vain, the distribution of rainfall over the world is considerably more complex than that of temperature because practically all rainfall results from adiabatic cooling of ascending air masses. Rainfall is highest in areas of the air mass ascent. The major ones are the zones of convergence, atmospheric disturbances of the middle latitudes as well as areas along the windward side of different mountain ranges. The distribution pattern over the world is therefore influenced by several factors such as topography, distance from large water bodies' direction and character of the predominant air mass (Rahman, Jiban and Munna, 2015).

Seasonal variation occurs in rainfall. The time of commencement of rainy season, period it lasts, and when the rainy season gets to an end has great implications on agricultural activities in Nigeria. The raining season also ushers in lower temperature which in one way affects outdoor activities of the people and also reduces their income. Because rainfall, temperature and other elements of climate are considerably more uniform, seasonal rainfall distribution are used as a basis for the classification or subdivision of Tropical climates (Daramola *et al.*, 2017). In the Tropics people depend on rainfall for plant cultivation anytime it rains, rainfall in the Tropics tends to extra seasonal on its prevalence likened to the extra-tropical areas of the world.

In the light of impact, Africa is considered the most vulnerable region in the world in terms of climate variations and change, due to its physical and socio-economic characteristics (Akinsanola and Ogunjobi, 2014). Warmer and drier conditions within the African Sahel region have constantly reduced the length of time for crops cultivation thus detrimental to crops productivity. According to Slaughter and Odume (2017), the 2012 Nigerian heavy flood disaster which claimed about 360 human lives and displaced approximately 2 million people was due mainly to heavy local rainfall coupled with release of excess water from Lagdo dam, Cameroon. Study by Slaughter and Odume (2017) further revealed that flooding remains a recurring phenomenon in most parts of Nigeria, and can be attributed mainly to change in climate which has contributed more to extreme storms as well as rainfall. Although other factors like poor settlement planning lead to flooding, the implications of climate change on flood occurrence is paramount.

Expectedly, several studies have been carried out in Nigeria with respect to climate variability. While some of such studies were localised to particular regions with short period of climatic data set, other studies involved only rainfall data sets without the aspect of temperature data. Okorie *et al.* (2012) examined evidence of climate variability in Imo State of South-eastern Nigeria, and employed data for rainfall and temperature covering a period of 30 years (1980-2009) from Nigerian Meteorological Department.

Results from this study showed marked fluctuations in the rainfall and temperature regimes within the period under study, which were the reasons for the variations in climate of the region. Ogunrayi, Akinseye, Goldberg, and Bernhofer (2016) carried out a descriptive analysis of the temperature and rainfall trends in Akure, Nigeria, and utilised monthly records for 1980-2011 from the Nigerian Meteorological Agency (NIMET), and the Climatic Research Unit (CRU). Findings from this study showed alternating wet and dry trend of rainfall periods; with increasing temperature within the region.

Oluwatobi and Oluwakemi (2016) carried out an analysis of annual average trend and variability of atmospheric temperature in Ijebu-Ode, South west Nigeria, and involved 31 years air temperature data collected from NIME for 1982-2013. From the results, the trend of air temperature has been on the increase since 1983. A gradual increase was observed between 1991 and 2013, with slight reduction in trend between 1984 and 1985. Owolabi (2016) investigated “trend analysis of rainfall and temperature” in Ado-Ekiti, South-west Nigeria, and employed data for temperature and rainfall collected from NIMET for the period between 2001 and 2011. Results revealed that there is no particular trend in the rainfall and temperature within the study period. Uko and Tamunobereton (2013) studied the variability of climatic parameters in Port Harcourt, South-South Nigeria, and utilised Meteorological data for rainfall, humidity, temperature, solar radiation and evaporation between 2001 and 2010. Findings revealed a mean annual value of maximum temperature at 31.03^{o}C, with a corresponding minimum temperature of 22.54^{o}C. While the monthly rainfall amount is 203.03mm, the annual rainfall amount is 200.45mm.

Other studies involved only rainfall data sets without the aspect of temperature as carried out by Ukhurebor and Abiodun (2018) on variation in annual rainfall records for 40 years (1978-2017), South-South Nigeria. Data were got from the NIMET. Data collected were tested using coefficient of variability, t-test statistics, Sen’s estimator slope and Mann Kendall test. Findings showed that rainfall varied, with variability of 7.00mm. While less rainfall was recorded in 21 years, more rainfall was recorded within 19 years. Igweze, Amagoh, and Ashinze (2014) carried out an analysis of rainfall variations within Niger Delta region of Nigeria and utilised rainfall data from 1981-2008; Analysis of Variance and descriptive statistics were used to analyse the data. Results revealed observed variability of rainfall within the study area. Egor, Osang, Uguetan, Emeruwa, and Agbor (2012) investigated the inter-annual variability of rainfall in some states of Southern Nigeria and employed rainfall data from 1972-2012.

The results revealed an increase in rainfall supply over the period of study, with continuous annual increase in the amount of rainfall in all the locations. While Calabar and Uyo indicated the possibility of flood occurrence, other stations indicated a possibility of drought occurrences.

In all these studies conducted, information regarding temperature and rainfall between 1901 and 1970 were left out, leaving the periods in the dark. Therefore, the primary aim of this study is to find out the spatial and seasonal variations of the rainfall and temperature within the different environmental regions of Nigeria, using a broader spectrum of weather stations across the country, as well as weather data covering a broader time period (1901-2017). The present study is an attempt to fill the gap created by inadequate literature regarding spatial and seasonality characteristics of rainfall and temperature within Nigeria. In order that the stated aim of the study was achieved, the specific objectives of the study were to: (i) investigate if there are significant spatial variations in rainfall and temperature within the different environmental regions in Nigeria; (ii) examine if there are significant seasonal variations in the rainfall and temperature within the different environmental regions in Nigeria; and (iii) ascertain if there is any significant increase or decrease in the trends of rainfall and temperature in Nigeria.

Materials and methods

The Study Area

This study was carried out in Nigeria, a region geographically located between, Latitudes 4°00'N and 14°00'N, and also between Longitudes 3°00'E and 15°00'E (Fig. 1). The area coverage of this region duly extends the land area to about 910770 sq. Km. Defined in this way; the study area is made up of 36 states and a capital territory. This study area falls within the tropical climate with varied rainy and dry seasons, depending on location. The four climate types which prevail across this study region are the equatorial monsoon or tropical climate, tropical Savannah climate, tropical dry climate and Alpine climate. The natural vegetation types are the tropical rainforest, riparian vegetation, the montane forest, the savanna/grassland and the desert. The study area has eight (8) major climatic zones: Sudan Savannah, Northern Guinea Savannah, Southern Guinea Savannah, Montane Forest, Dry Lowland Rainforest, Fresh Water Swamp, Mangrove Swamp and Wet Lowland Rainforest (Fig. 1).

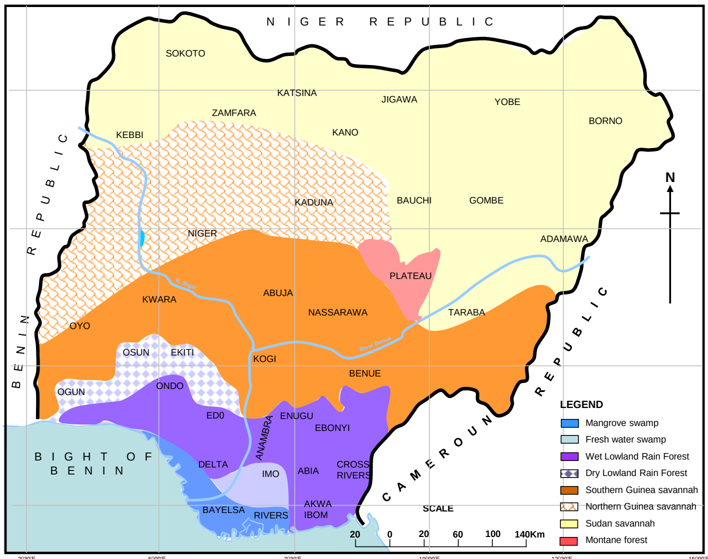

Fig. 1. Map of Nigeria showing climatic regions.

Research Methods

The study utilised the ex-post facto design. However, the study area was stratified into 8 regions following the existing climatic regions in the study area (Fig. 1): Sudan Savannah (Sokoto, Kano, Zamfara, Jigawa Gombe, Katsina, Yobe, Borno, Yola, Taraba, Kebbi and Bauchi), Northern Guinea Savannah (Niger and Kaduna), Southern Guinea Savannah (Nasarawa, Abuja, Kogi, Kwara, Oyo, Benue), Montane Forest (Plateau), Dry Lowland Rainforest (Ekiti, Osun and Ogun), Fresh Water Swamp (Owerri), Mangrove Swamp (Bayelsa and Port Harcourt) and Wet Lowland Rainforest (Cross River, Anambra, Enugu, Ebonyi, Delta, Edo, Ondo, Akwa Ibom and Abia). The used for this study were monthly archival rainfall and temperature data for 117 years (1901–2017). The data were got from the Climate Research Unit (CRU), University of East Anglia, via Google Earth Version 7.3.2, using 5° x 5° high-resolution gridded CRUTEM 4.03. The CRUTEM data have been used in many studies such as carried out by Jones, Lister, Osborn, Harpham, Salmon and Morice (2012), Osborn and Jones (2014), Hadi and Tombul (2017), Ogunrayi, Akinseye, Goldberg and Bernhofer (2016). Details of temperature and rainfall stations with data are given in Table I. Data collected were statistically analysed using the mean, graph, ANOVA and modified non-parametric Mann-Kendall statistics. The mean statistics was used to ascertain the mean values of the data collected; graph was used to show the spatial and seasonal variations in the temperature and rainfall; ANOVA was used to test research question (i) on the spatial variations in rainfall and temperature across Nigeria; ANOVA was also used to test research question (ii) on the seasonal variations in rainfall and temperature across Nigeria; while Mann-Kendall statistics was used to test research question (iii) on the trends of rainfall and temperature across Nigeria using the Addinsoft's XLSTAT 2018 software.

Results and discussion

Spatial Variations in Temperature and Rainfall amount across Nigeria (1901-2017).

Rainfall and temperature varied spatially within the study area. Table 1 presents the descriptive analysis of spatial variations in the amount of temperature and rainfall across Nigeria between 1901 and 2017. The highest rainfall of 291504.3mm was observed in Akwa Ibom State within the wet lowland rain forest region, while the lowest rainfall of 69103.11mm was recorded in Yobe state within the sudan savannah region. While the highest temperature of 28.2°C was recorded in Sokoto and Kebbi states within the Sudan Savannah region, the lowest temperature of 25.4°C was recorded in Plateau State within the montane forest region.

Table 1. Descriptive Analysis of Spatial Variations in the amount of Temperature and Rainfall across Nigeria between 1901 and 2017.

Environmental Regions	Stations	Rainfall (mm)	Temperature (°C)	Stations	(mm)	(°C)
Mangrove Swamp	Bayelsa	265801.4	26.6			
	Port Harcourt	278511.6	26.6			
Wet Lowland Rain Forest	Cross River	267245.8	26.7	Delta	252614.1	26.5
	Anambra	231159.5	26.6	Edo	213494.1	26.5
	Enugu	222799.8	26.6	Ondo	187851.4	26.7
	Ebonyi	228958.7	26.6	Abia	260328.4	26.0
	Akwa Ibom	291504.3	26.6			
Dry Land Rainforest	Ekiti	169302.1	25.8			
	Osun	165258.3	26.4			
	Ogun	159282.2	27.2			
Southern Guinea Savanna	Nasarawa	150214.2	26.8	Kwara	136404.8	27.1
	Abuja	147099.6	26.8	Oyo	136369.9	26.9
	Kogi	171486.6	26.9	Benue	189085.2	27.0
Northern Guinea Savanna	Niger	128997.3	27.6			
	Kaduna	129967.3	25.7			
Sudan Savanna	Sokoto	81249.31	28.2	Yobe	69103.11	27.6
	Katsina	94046.72	26.5	Adamawa	104057.3	26.3
	Kano	98368.06	26.3	Gombe	101528	27.4
	Bauchi	104716.5	26.3	Tarab	181117.2	26.7

Environmental Regions	Stations	Rainfall (mm)	Temperature (°C)	Stations	(mm)	(°C)
				a		
	Jigawa	79692.24	27.5	Kebbi	102365.3	28.2
	Borno	74261.2	27.9	Zamfara	99661.25	27.1
Montane Forest	Plateau	150773.9	25.4			
Fresh Water Swamp	Imo	260594.3	26.9			
	Mean				5985271	26.8

Source: Authors' Computation (2020).

The higher rainfall amount within the wet lowland rainforest region corroborates with results of the study by Okorie *et al.* (2012) which reported highest rainfall in Calabar; while the low rainfall amount within sudan savannah region corroborates with the findings in study by Adakayi, Oche and Ishaya (2016) which reported lowest mean amount of annual rainfall in Katsina within sudan savannah region.

In the same vain, findings in this study corroborate findings in studies by Yusuf, Okoh, Musa, Adedoja and Said (2017) which reported highest temperature distribution within the Sudan Savannah region, and lowest temperature in Jos, Plateau State within the montane forest region. Fig. 2 shows the spatial variations in rainfall and temperature across Nigeria. The distributions of temperature and rainfall shows a marked spatial variation, while the higher temperature distribution observed in the Northern part of Nigeria could be attributed to the influence of the Sahara desert which has less cloud cover and therefore more transparent to solar radiation.

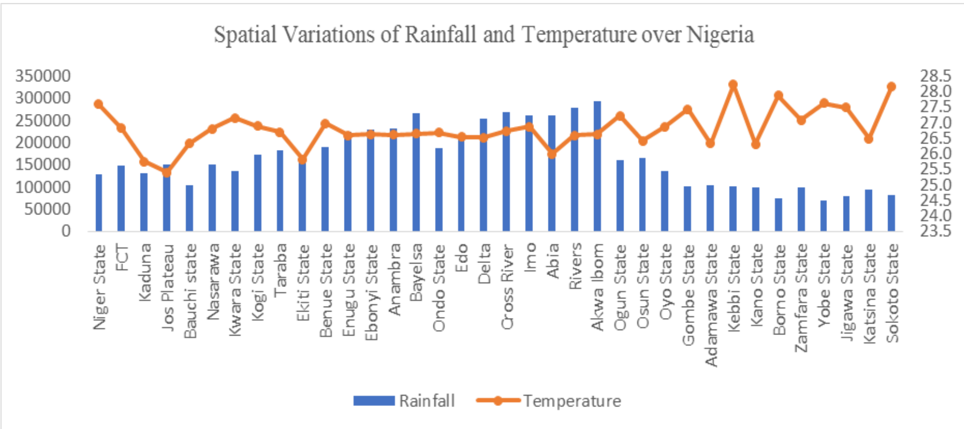

Fig. 2. Spatial Variations in Rainfall and Temperature across Nigeria.
Source: Authors' Computation (2020).

Table 2 presents the results of One-way ANOVA for the spatial variations in rainfall and temperature across Nigeria between 1901 and 2017. Results revealed that spatial variations in rainfall and temperature are significant as determined by one-way ANOVA at F (35, 4176) = 1596.76, p = .000; and F (35, 4176) = 310.73, p = .000 respectively.

This result is in consonance with observations in study by Dammo, Ibn Abubakar and Sangodoyin (2015) which reported that Taraba State received significantly higher amount of rainfall than the other locations in North-Earthen Nigeria. The result also corroborates with findings in study by Akinsanola and Ogunjobi (2014) which reported that there have been statistically significant increase in air temperature across almost every part of the study area.

Seasonal Variations in Rainfall and Temperature across Nigeria from 1901 to 2017

The mean values of rainfall and temperature distribution varied across all the states in Nigeria.

Table 3 presents the mean seasonal variations in rainfall and temperature across Nigerian states. The highest mean amount of rainfall (43,828.53mm) was recorded in Akwa Ibom State within the Wet Lowland Rain Forest in September, while the lowest mean amount of rainfall (21,198.75mm) was recorded in Ogun State within the Dry lowland Rainforest in September. The highest mean temperature value (32.8°C) was recorded in Sokoto State within the Sudan Savannah region in April, while the lowest temperature value (27.8°C) was recorded in Cross River within the Wet Lowland Rainforest in March.

Table 2. Summary of ANOVA results for the spatial variations in rainfall and temperature across Nigeria (1901-2017).

		Spatial variation in rainfall				Spatial variation in temperature			
Source	DF	Adj SS	Adj MS	F-Value	P-Value	Adj SS	Adj MS	F-Value	P-Value
Stations	35	1338726116	38249318	1596.76	0.000	1603.3	45.8077	310.73	0.000
Error	4176	100032992	23954			615.6	0.1474		
Total	4211	1438759108				2218.9			

Table 3. Mean Seasonal Variations in Rainfall (RF) and Temperature (TM) across Nigeria (1901-2017).

Environmental Regions	Stations	RF	Months	TM	Months
Mangrove Swamp	Bayelsa	35,830.6	September	28.0	February
	Port Harcourt	41,358.97	September	28.0	February
Wet Lowland Rain Forest	Cross River	43,519.33	September	27.8	March
	Anambra	38,325.6	September	28.5	March
	Enugu	38,325.6	September	28.6	March
	Ebonyi	39,331.25	September	28.8	March
	Delta	37,834.72	September	28.6	March
	Edo	34,337.34	September	28.7	March
	Ondo	30,792.35	September	28.7	March
	Abia	41,828.4	September	28.4	March
	Akwa Ibom	43,828.53	September	28.0	March
Dry Lowland Rainforest	Ekiti	29,621.65	September	28.2	March
	Osun	25,944.05	September	28.6	March
	Ogun	21,198.75	September	29.2	March
Southern Guinea Savanna	Nasarawa	29,199.26	September	28.2	March
	Abuja	29,289.8	September	29.8	March
	Kogi	32,013.29	September	29.5	March
	Kwara	25,922.3	September	30.0	March
	Oyo	22,836.34	September	29.3	March
	Benue	34,386.34	September	29.7	March
Northern Guinea Savanna	Niger	26,688.6	August	30.8	April
	Kaduna	31,544.87	August	29.2	April
Sudan Savanna	Sokoto	25665.44	August	32.8	April
	Zamfara	29073.14	August	31.6	April
	Katsina	29415.82	August	30.9	April
	Kano	30291.71	August	30.5	April
	Jigawa	27078.9	August	31.9	May
	Yobe	24003.12	August	32.1	May
	Borno	23763.32	August	31.8	May
	Gombe	27851	August	31.3	April
	Adamawa	27132.2	August	30.5	April
	Taraba	31131.73	August	29.6	March
	Kebbi	27760.95	August	32.6	April
	Bauchi	30151.67	August	30.1	April
Montane Forest	Plateau	30,369.57	August	28.4	March
Fresh Water Swamp	Owerri	41,061.73	September	28.2	March

Source: Authors' Computation (2020).

The seasonal northward and southward oscillatory movement of the Inter-Tropical Discontinuity (ITD) largely dictates the weather pattern of Nigeria (Odjugo, 2010). The south-westerly winds from South Atlantic Ocean prevail across every part of this study region during the rainy months (April – October). On the other hand, north-easterly winds which rise from the Sahara Desert while moving along with dust particles from the north to the southern part of Nigeria during the harmmattan period (November – March).

The overall changes in the rainfall and temperature, together with other meteorological variables determine the climate of Nigeria. Also, temperature and rainfall varied amongst the different environmental regions, as well as within the different months of the year, thereby accounting for the seasons within the study areas. Table 4 presents the seasonal variations in rainfall and temperature in different environmental regions of Nigeria between 1901 and 2017. The highest amount of rainfall (41061.73mm) was observed in the fresh Water Swamp zone (FWS) in September, while the lowest rainfall amount (8.1625mm) was observed within Northern Guinea Savanna (NGS). Rainfall amount was generally high between June and September in all the zones. Fresh water swamp, southern guinea savanna, mangrove swamp, wet low land rainforest and dry land rainforest zones get the peak of their rainfall in September, with a fall in August due to August hiatus (August Break) which accounts for the double rainfall maxima between July and September within these ecological zones. The sudan savanna, Northern Guinea Savanna and Montane forest get the peak of their rainfall in August thus accounts for the single rainfall maximum pattern. This finding corresponds with result of study by Okorie *et al* (2012) which reported that "August Break" brought in the seasonal north and southward movement of the ITCZ (Inter-Tropical Convergence Zone). The double maxima phenomenon exhibited in this study within some of the zones is a marked characteristic of rainfall within the southern Nigeria (NIMET, 2012), and it is in agreement with findings in a study by Adejuwon (2012) which reported a marked drop in rainfall amount in August. The highest amount of temperature (30.0ºC) was observed within Northern Guinea Savanna and Sudan savanna zones in April and May respectively; while the lowest temperature (23.3ºC) was observed within Sudan savanna zone. Temperature reduction between December and January can be attributed to the effect of harmattan within the period.

Table 4. Seasonal Variations in Rainfall and Temperature in Different Environmental Regions of Nigeria between 1901 and 2017.

	Environmental Regions							
	SS		NGS		DLRF		FWS	
Months	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)
January	14.85	23.3	52.31583	25.2	1108.692	26.7	3011.267	26.6
February	159.01	26.2	188.0846	27.5	3501.1	28.4	5471.2	28.0
March	821.24	29.6	1616.078	29.6	9449.383	28.7	13634.57	28.2
April	3241.04	31.3	6555.79	30.0	15011.11	27.9	20799.47	27.8
May	8623.74	30.7	14416.44	28.4	20294.48	26.9	28270.13	27.0
June	13491.31	28.7	18540.85	26.5	25635.84	25.6	33452.6	26.0
July	21975.62	26.7	24269.89	25.2	23455.62	24.7	37906.13	25.3
August	27776.58	25.7	29121.74	24.6	15926.23	24.4	33031.00	25.3
September	18005.10	26.6	25858.39	25.3	25588.15	25.1	41061.73	25.6
October	4835.59	27.6	8684.772	26.3	19513.65	25.8	30788.17	26.1
November	260.49	26.0	169.7904	26.0	3947.261	26.9	10287.13	26.7
December	16.08	23.8	8.1625	25.1	1182.689	26.6	2880.933	26.4

	Environmental Regions							
	SGS		MF		MS		WLRF	
Months	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)
January	368.4906	26.5	71.24444	24.0	5621.525	26.9	2137.003	26.5
February	1174.19	28.7	229.1778	26.4	7625.563	28.0	4556.08	28.2
March	5248.679	29.7	3263.067	28.4	16443.05	28.0	11874.7	28.5
April	11313.47	29.1	9571.911	28.2	23025.26	27.7	19092.42	28.0
May	18974.82	27.5	17399.57	26.4	29601.18	27.0	26121.1	26.9
June	22423.68	26.2	21691.04	25.1	32393.24	26.1	31741.7	26.0
July	24303.09	25.3	27603.86	24.0	34534.9	25.4	35321.76	25.2
August	24090.2	25.0	30369.57	23.7	30263.91	25.4	31353.12	25.0
September	28941.22	25.5	27905.89	24.3	38594.78	25.7	38688.11	25.5
October	16306.99	26.4	12053.31	25.3	33869.48	26.1	28191.52	26.1
November	1658.043	26.8	575.0111	25.0	14639.38	26.8	8231.693	26.7
December	307.1644	26.2	40.22222	23.9	5544.225	26.8	2241.433	26.3

The two seasons as observed from the rainfall and temperature distributions are determined by the ITCZ that is controlled by two prevailing air masses, which are the Northeast Trade Winds which brings the harmattan and the South West monsoon winds which brings rainfall. Findings in this study corroborates with reports in the studies by Ati, Stigter, Iguisi and Afolayan (2009), who observed that rainy season lasts about 7 months (April to October) in the southern part and last for 3 months (July to September) in the northern part of this study area; while rainfall intensity is very high between July and August. Also, findings in this study are in consonance with findings reported in study by Ayanlade (2009) which observed that the peak of rainy season in northern Nigeria occurs in August.

Generally, rainfall and temperature distributions varied amongst the different ecological zones. While the pattern is similar within the sudan savanna, Northern Guinea savanna and Montane forest zones; marked similarities were also observed within the Fresh water swamp, southern guinea savanna, mangrove swamp, wet low land rainforest and dry land rainforest zones (Figs. 3-10).

Figs. 3, 4, 5, 6, 7, 8, 9, and 10 present the spatial variations of rainfall and temperature in the Sudan savanna, Northern Guinea Savanna, Dry Lowland Rain Forest, fresh water swamp, Southern Guinea Savanna, Montane Forest, Mangrove Swamp and Wet Lowland Rain Forest respectively. Figs. 3, 4 and 8 representing the seasonal variations in rainfall and temperature within the sudan savanna, Northern Guinea Savanna and Montane forest zones, share similar characteristics in the distribution of rainfall and temperature.

The highest amount of rainfall was recorded in August, while the lowest amounts were observed in December and January within the dry season months; in the same vain, these zones observed their highest temperature between March and May, while their lowest temperatures were observed between December and January. The rainfall patterns within these zones are all single maximum.

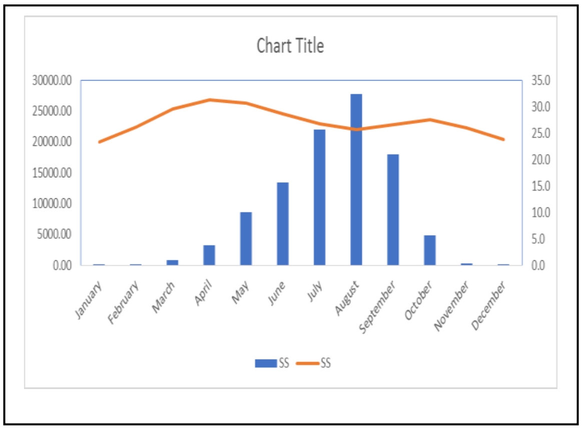

Fig. 3. Seasonal Variations in Rainfall and Temperature in Sudan Savanna.

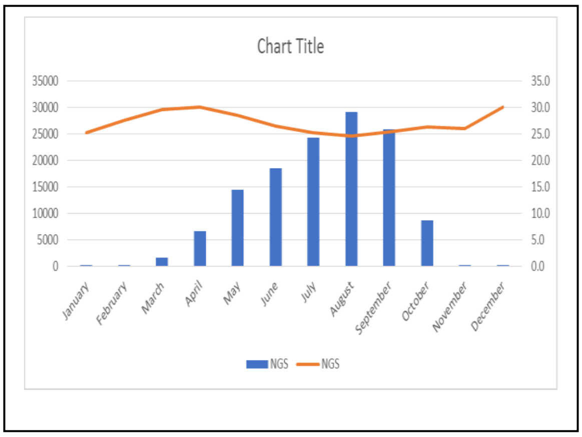

Fig. 4. Seasonal Variations of Rainfall and Temperature in Northern Guinea Savanna.

Also, Figs. 5, 6, 7, 9 and 10 representing the seasonal variations in rainfall and temperature within the dry land rainforest, Fresh water swamp, southern guinea savanna, mangrove swamp and wet lowland rainforest zones share similar characteristics in the distribution of rainfall and temperature. The highest amount of rainfall was recorded in September except for the dry land rainforest where the highest rainfall was recorded in June; while the lowest amounts were observed in December and January within the dry season months. In the same vain, these zones observed their highest temperature in March, while their lowest temperatures were observed between July and August. The rainfall patterns within these zones reflect double maxima with a drop in rainfall amount in August. However, while rainfall amount and pattern reflect a marked difference between the northern and southern zones, the rainfall pattern shows a marked similarity among the zones in recording the lowest rainfall between December and January thereby defining the season as dry.

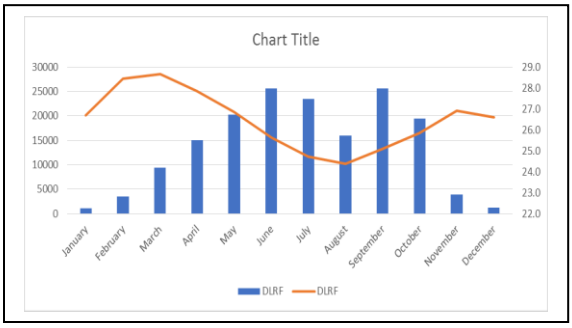

Fig. 5. Spatial Variations of Rainfall and Temperature in Dry Lowland rain forest.

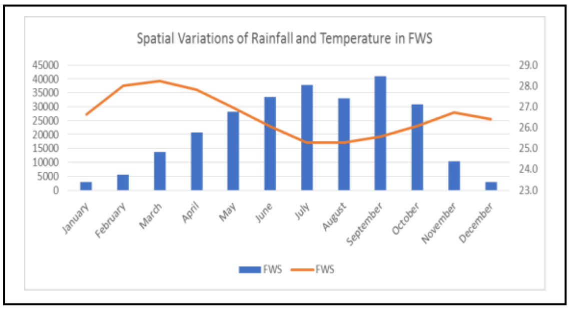

Fig. 6. Spatial Variations of Rainfall and Temperature in Fresh Water Swamp.

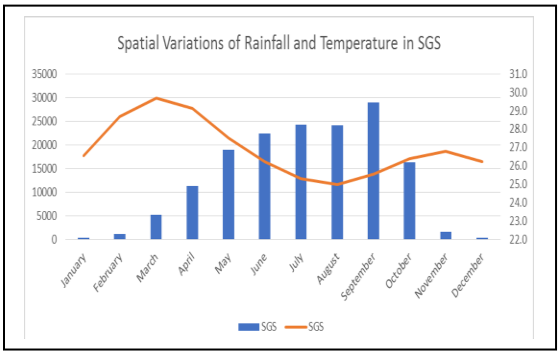

Fig. 7. Spatial Variations of Rainfall and Temperature in Southern Guinea Savanna.

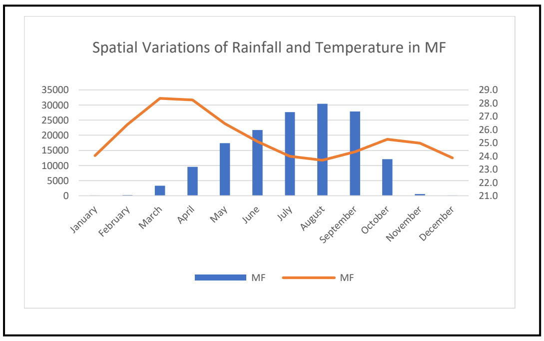

Fig. 8. Spatial Variations of Rainfall and Temperature in Montane Forest.

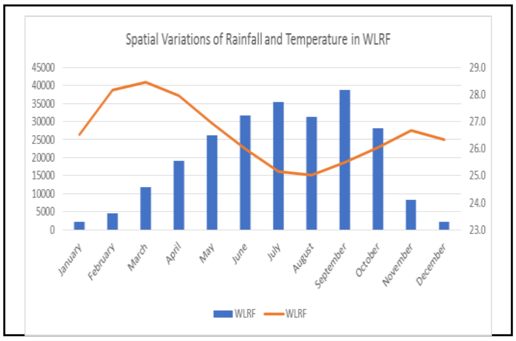

Fig. 9. Spatial Variations of Rainfall and Temperature in Mangrove Swamp.

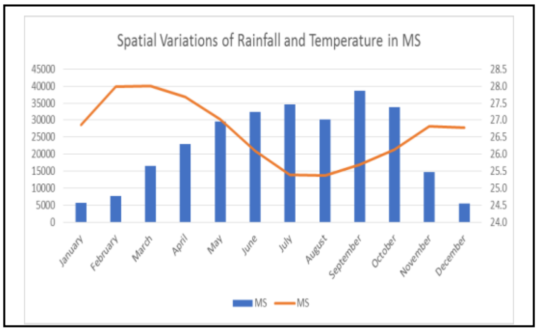

Fig. 10. Spatial Variations of Rainfall and Temperature in Wet Lowland Rain Forest.

Table 5 presents the ANOVA results for the seasonal variations in rainfall and temperature across Nigeria. The results showed that the differences in seasonal variations in rainfall and temperature across Nigeria are statistically significant at $F (11, 50532) = 7776.36$, $p = .000$; and $F (11, 50532) = 4575.79$, $p = .000$ respectively for rainfall and temperature.

Trends of rainfall and temperature across Nigeria

Rainfall across Nigeria shows marked increasing trend. While increasing trend in temperature was observed in some stations, other stations showed decrease in trend, and in some others there were no trends observed.

Table 6 presents the results of Mann Kendall analysis for the trends of rainfall across Nigeria. Statistically significant increasing trends were found in 35 stations, while the trend in one station was not statistically significant. This result corroborates with findings in a study by Akinsanola and Ogunjobi (2014) where increasing trends in mean annual precipitation in Nigeria were reported.

Table 5. Summary of ANOVA results for the seasonal variations in rainfall and temperature across Nigeria (1901-2017).

		Seasonal variation in rainfall				Seasonal variation in temperature			
Source	DF	Adj SS	Adj MS	F-Value	P-Value	Adj SS	Adj MS	F-Value	P-Value
Months	11	397583041	36143913	7776.36	0.000	100782	9162.02	4575.79	0.000
Error	50532	234868710	4648			101179	2.00		
Total	50543	632451751				201961			

Table 6. Results of Mann Kendall Analysis for the trends of Rainfall across Nigeria.

Stations	Numbers of Years	Calculated Z	Upward P-Value	Downward P-Value	Significance
Bayelsa	117	15.1153	0	1	Increasing
Port Harcourt	117	13.0366	0	1	Increasing
Cross River	117	10.6276	0	1	Increasing
Anambra	117	12.0231	0	1	Increasing
Enugu	117	12.1954	0	1	Increasing
Ebonyi	117	11.1166	0	1	Increasing
Delta	117	12.1128	0	1	Increasing
Edo	117	11.6885	0	1	Increasing
Ondo	117	11.7994	0	1	Increasing
Abia	117	11.8753	0	1	Increasing
Akwa Ibom	117	12.4438	0	1	Increasing
Ekiti	117	11.5285	0	1	Increasing
Osun	117	12.0804	0	1	Increasing
Ogun	117	11.3369	0	1	Increasing
Nasarawa	117	10.2091	0	1	Increasing
Abuja	117	9.67448	0	1	Increasing
Kogi	117	11.4064	0	1	Increasing
Kwara	117	10.0753	0	1	Increasing
Oyo	117	11.2521	0	1	Increasing
Benue	117	10.5504	0	1	Increasing
Niger	117	7.71050	0.0000000	1	Increasing
Kaduna	117	5.31275	0.0000001	1.00000	Increasing
Sokoto	117	3.37135	0.0003740	0.999626	Increasing
Zamfara	117	4.09797	0.0000208	0.999979	Increasing
Katsina	117	2.73942	0.0030774	0.996923	Increasing
Kano	117	2.21674	0.0133203	0.986680	Increasing
Jigawa	117	3.53370	0.0002049	0.999795	Increasing
Borno	117	2.31394	0.0103354	0.989665	Increasing
Gombe	117	3.52433	0.0002123	0.999788	Increasing
Adamawa	117	2.51265	0.0059914	0.994009	Increasing
Taraba	117	9.48103	0	1	Increasing
Kebbi	117	3.79205	0.0000747	0.999925	Increasing
Bauchi	117	2.067630	0.0193374	0.980663	Increasing
Plateau	117	7.07923	0.0000000	1	Increasing
Owerri	117	12.2330	0	1	Increasing
Yobe	117	1.36925	0.0854608	0.914539	No Trend

Source: Author's Computation (2020).

Table 7. Results of Mann Kendall Analysis for the trends of Temperature across Nigeria.

Months	Numbers of Years	Calculated Z	Upward P-Value	Downward P-Value	Significance
Owerri	117	-6.13132	1.00000	0.0000000	Decreasing
Bayelsa	117	-8.00681	1	0.0000000	Decreasing
Cross River	117	-2.24115	0.987492	0.0125082	Decreasing
Anambra	117	-6.44519	1.00000	0.0000000	Decreasing
Enugu	117	-4.75918	1.00000	0.0000010	Decreasing
Delta	117	-7.15280	1	0.0000000	Decreasing
Abia	117	-4.21906	0.999988	0.0000123	Decreasing
Ekiti	117	-6.13480	1.00000	0.0000000	Decreasing
Abuja	117	-4.40783	0.99999	0.0000052	Decreasing
Kwara	117	-3.83358	0.999937	0.0000631	Decreasing
Oyo	117	-5.25188	1.00000	0.0000000	Decreasing

Months	Numbers of Years	Calculated Z	Upward P-Value	Downward P-Value	Significance
Niger	117	-1.71283	0.956628	0.0433723	Decreasing
Port Harcourt	117	-7.12763	1	0.0000000	Decreasing
Edo	117	-6.54953	1.00000	0.0000000	Decreasing
Ondo	117	-6.33840	1.00000	0.0000000	Decreasing
Akwa Ibom	117	-5.32546	1.00000	0.0000001	Decreasing
Osun	117	-5.05026	1.00000	0.0000002	Decreasing
Ogun	117	-5.91620	1.00000	0.0000000	Decreasing
Kogi	117	-4.91371	1.00000	0.0000004	Decreasing
Kaduna	117	3.55636	0.001880	0.999812	Increasing
Sokoto	117	7.92334	0.0000000	1	Increasing
Zamfara	117	7.12684	0.0000000	1	Increasing
Katsina	117	7.18874	0.0000000	1	Increasing
Kano	117	7.06909	0.0000000	1	Increasing
Jigawa	117	7.71251	0.0000000	1	Increasing
Borno	117	7.35222	0.0000000	1	Increasing
Gombe	117	6.84987	0.0000000	1.00000	Increasing
Adamawa	117	6.12532	0.0000000	1.00000	Increasing
Kebbi	117	5.54663	0.0000000	1.00000	Increasing
Bauchi	117	7.42106	0.0000000	1	Increasing
Plateau	117	2.13814	0.0162529	0.983747	Increasing
Yobe	117	8.03038	0.0000000	1	Increasing
Nasarawa	117	-1.21607	0.888193	0.111807	No Trend
Ebonyi	117	-1.44643	0.925972	0.0740278	No Trend
Benue	117	-1.29752	0.902774	0.0972262	No Trend
Taraba	117	-1.31005	0.906575	0..0934251	No Trend

Source: Author's Computation (2020).

Table 7 presents the results of Mann Kendall analysis for the trends of temperature across Nigeria. Statistically significant increasing trends were recorded in 13 stations. While 4 of the stations were not statistically significant, statistically significant decreasing trends were recorded in the remaining 19 stations. However, this result corroborates with findings in a study by Akinsanola and Ogunjobi (2014) where mean annual air temperature was alternately increasing and decreasing in trends within Nigeria.

Conclusion

This study examined the spatial and seasonal variations in rainfall and temperature across Nigeria. Indeed, several studies have been carried out in Nigeria with respect to climate variability, but some of them were localised to particular regions with short period of climatic data set, while others involved only rainfall data sets without involving temperature data.

The primary aim of this study was to investigate the spatial and seasonal variations in rainfall and temperature across the different environmental regions of Nigeria, using a broader spectrum of weather stations that spread across every parts of the country, as well as weather data covering a broader time period (1901-2017); with a view to fill the gap created by inadequate literature on the rainfall and temperature seasonality in the study area. However, findings revealed that rainfall and temperature vary spatially and seasonally across Nigeria, while the trends of rainfall and temperature were statistically significant.

Recommendations

Since the rainfall and temperature across Nigeria varied spatially and seasonally, the knowledge of this trend could give understanding to the prevailing climatic conditions in the different environmental regions. This variation has implications on the environment thus, could determine the favourable climatic requirements for effective agricultural productivities, by defining the seasons and locations where certain agricultural crops can be produced.

Crops thrive better at certain period of the year within a given location when and where the climatic conditions are favourable to their requirements. Therefore, this study is of importance to agricultural production by giving insight to the climatic attributes of the study area.

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