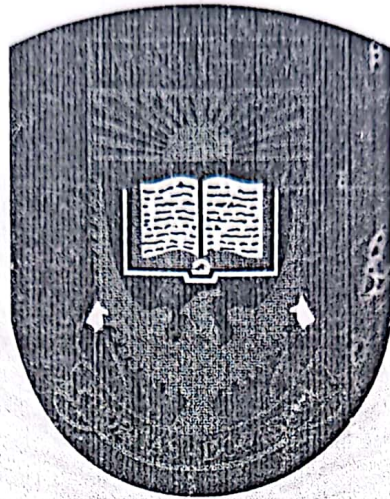


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RAINFALL PATTERNS IN A CHANGING CLIMATE: EXAMPLE OF KANO AND DELTA STATES, NIGERIA

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Abstract

Climate is the accumulated and average weather patterns of a locality or region; the statistical properties of atmospheric variables including temperature, precipitation, and wind. The full description is based on long term statistics and includes extremes or deviations from the norm. There is increasing evidence that precipitation patterns have changed worldwide as a result of atmospheric responses to climate change (UNEP, 2007). Data required for this work is rainfall amount measured in millimeters (mm) for twelve months of each year. The rainfall data spanned thirty-five years between 1975 and 2010 for each of the states i.e. Kano and Delta states. The data were sourced from the archival records of the Nigerian Meteorological Agency (NIMET) headquarters in Oshodi, Lagos state. In order to analyze the obtained data, both descriptive and inferential statistics will be used for this study. Rainfall was found to be negatively skewed for Kano and positively skewed for Warri. It was observed that rainfall pattern at Warri was heterogeneous, while that of Kano was homogeneous with 89.5 per cent and 10.7 per cent respectively, thus, there is significant evidence of Climate change in the areas that would cause more rainfall in annual totals and consequently reinforce present increasing trends. Since temperature varies in this region, further study is necessary, using temperature and other climatic parameters, to assess climate change and give a more vivid understanding of the weather pattern of the areas.

Key words: Rainfall, Climate Change, Variability, Atmosphere

Introduction

Climate is the consistent, long-term behavior of weather over time, including its variability (Christopherson, 2001). Climate is the accumulated and average weather patterns of a locality or region; the statistical properties of atmospheric variables including temperature, precipitation, and wind. The full description is based on long term statistics and includes extremes or deviations from the norm (Robert et al., 2009; Edward

& James, 2007). Ayode (2003) defined climate as the synthesis of weather at a given location or area over a period of at least 30 years.

Thus, climate is more than just the average value of year to year variations, seasonal variations, and the tendency for above or below the normal values, its occurrences in sequence are also a major component of climate (Edward & James, 2007). Hence variability is an inherent attribute of climate as the global climate has never been static (Ayode, 2003; Tilakasiri, Olanrewaju & Salami, 2016). There is irrefutable evidence that since the industrial revolution, human activities have resulted in the release of new or increased amount of greenhouse gases and substances which destroy ozone (Alison et al., 1995). The Intergovernmental Panel on Climate Change, IPCC (2007) contends that human activity is the main cause of the change; seen in climate. This it does through activities that cause emissions of greenhouse gases (IPCC, 1995).

However, when fluctuation in climate constitutes persistent and statistically significant departures from the normal climate, or becomes prolonged, it constitutes a new climate state (Ayode, 2003; Olaniran, 2002). Thus, a change in climate usually takes place over a long period of time of at least 150 years with clear and permanent impact on the ecosystem (Ayode, 2002).

One important factor that accounts for the prominence now given to the issue of climate change in the global scene is the frequency of occurrence of extreme weather events such as flood, drought, heat and cold waves. These are experienced in different parts of the world in recent years and have devastating effects on human lives and properties as well as national economies (Ayode, 2003). Except in the highest areas which comprise a very small part of the tropics, tropical precipitation consists almost entirely of rainfall (Nievwolt, 1982; Ayode, 2003a; Ayode, 2004; Alison et al., 1995).

The main cause of rising air is convection, which is responsible alone or in combination with other factors, for most tropical rainfall, as indicated by the omnipresence of cumulus clouds and thunderstorms (Nievwolt, 1982; Ayode, 2004). Rainfall is the most variable element of tropical climate, hence rainfall is the main factor used in the delimitation of tropical climates (Nievwolt, 1982; Olaniran, 2002). Almost everywhere in the tropics, annual totals, seasonal and diurnal distribution, intensity, duration and frequency of rain days differ widely with respect to both time and place (Alison et al., 1995). Rainfall regime in the tropics has traditionally been linked to the seasonal north-south migration of the zenithal sun as well as the inter-tropical convergence zone (Nievwolt, 1982). Tropical rainfall is characterized by strong seasonality. In the absence of pronounced temperature changes over the year in the humid tropics, rainfall becomes the determinant of season. Humid tropical rainfall is also characterized by torrential downpours of short duration and little spatial extent which occur mostly in the afternoon and late evenings (Alison et al., 1995; Ayode, 2002). Rainfall variability and seasonality exact an overall control on water availability in the humid tropics. It is also the most controlling factor of the calendar of agricultural activities in most tropical climates. In many part of the tropics, the times of

the start, duration and end of the rainy season are decisive in the struggle for sufficient food supply (Niewol, 1982).

There is increasing evidence that precipitation patterns have changed worldwide as a result of atmospheric responses to climate change (UNEP, 2007). As climate changes, several direct influences alter precipitation amount, intensity, frequency and type (IPCC, 2007). Precipitation has increased by about 1 to 2 per cent over the world's continent in the last century. For high and mid-latitude regions, there has been a 2 to 4 per cent increase in the frequency of heavy precipitation events over the second half of the 20th century (IPCC, 2001). Global warming due to climate change accelerates land surface drying and increases the potential incidence and severity of droughts (IPCC, 2007). The decreasing rainfall and devastating droughts in the Sahel since the 1970s are among the least disputed and largest recent climate changes by the global climate research community (Dar et al, 2004; IPCC, 2007). It is likely that rainfall has increased by 0.2 to 0.3 per cent per decade over the tropical (10oN to 10oS) land areas. Increases in the tropics are not evident over the past few decades. It is also likely that rainfall has decreased over much of the Northern hemisphere sub-tropical (10oN to 30oN) land areas during the 20th century by 0.3 per cent per decade (IPCC, 2001). IPCC (2007) also estimates that due to climate change, wet areas will get wetter and dry areas drier.

The Study Area

The study area is Kano state in the North and Delta State in the southern part of Nigeria. Kano State is located in Northern Nigeria, in the Sahel geographic region of South of the Sahara. It was created on May 27, 1967 from part of the Northern Region. Kano State borders Katsina State to the Northwest, Jigawa State to the Northeast, Bauchi State to the Southeast and Kaduna State to the Southwest. The area covers a total of 20,131km² and comprises of forty four (44) local Government Areas (LGAs) with a population of about 9,383,682 people. Kano State is located at longitude 5.5000°N, and latitude 8.5000°E. All the same, Delta State is located on longitude 5.5000°N, and latitude 6.0000°E. It was created on 27 August 1991 out of the former Bendel State. Delta is an oil and agricultural producing state of Nigeria. It is bounded in the North by Edo State, the east by Anambra State, South-east by Bayelsa State, and on the Southern flank is the Bight of Benin which covers about 160km of the states coastline. It spans a total area of 17,698km² with an estimated population of about 6,710,181 in 2005.

The mean annual rainfall in Kano ranges from over 1,000mm in the extreme south to a little less than 800mm in the extreme North. The rains last for three to five months. Mean temperature ranges from 26°C to 35°C. There are four seasons: the dry and cool season, Kaka, (mid-November to February) marked by cool and dry weather plus occasional dusty haze; the dry and hot season, Bazara, (March to mid-May) when temperatures climb up to 40°C and which is a transition period between the harmattan (dry season) and

the wet season; the wet and warm season, Damina, (mid-May to September) is the proper wet season when the lowest diurnal temperature is recorded; and the dry warm season, Rani, (October to mid-November) marked by high humidity and high temperature next to Bazara in hotness.

Temperature increases from the south to the north. The vegetation varies from the mangrove swamp along the coast, to the evergreen forest in the middle, and the savannah in the northeast (Nigeria Physical Setting-www.onlineinigeria.com/links). The entire Delta State is a region built up by the sedimentation of the Niger Delta and consists of the delta in various stages of development. Geologically, more than four-fifth of Kano is underlain by quartzite, undifferentiated meta-sediments and basement complex rocks of the pre-Cambrian upper Cambrian origin.

According to the 2006 census figures, Kano State had a population totaling 9,383,682. Agriculture is one of the most important pillars of the state's economy with about 75 per cent of the total working population engaged directly or indirectly in this activity. In the 2006 Population and Housing census, Delta state accounted for about 4,112,445 people. Apart from abundant crude oil in the state, the state has developed a non-oil economy that includes agriculture, tourism and fisheries industries. Agriculture is the backbone of the state's economy as it provides food for the people and raw materials for industries, which are mostly in the cities. Food crops such as cassava, yam, maize, plantain, groundnut, palm oil and beans are produced in the state.

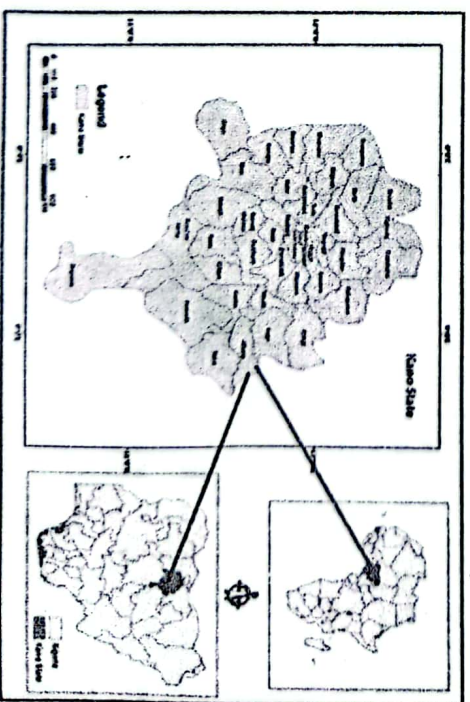


Figure 1: A map of Kano State

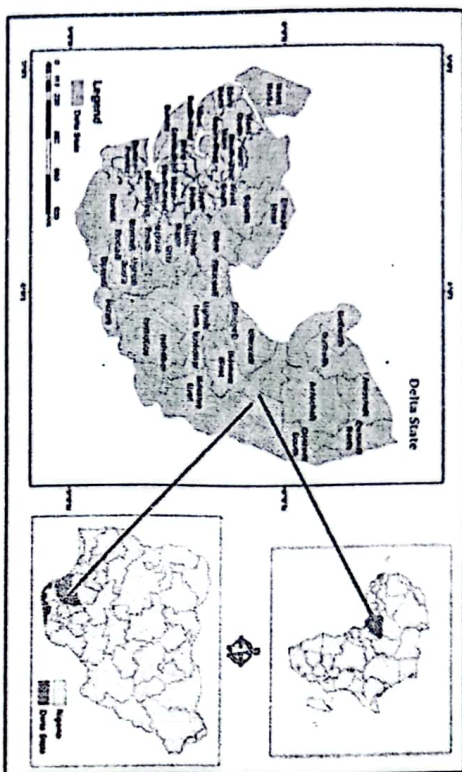


Figure 2: A map of Delta State

Methodology

Data required for this work is rainfall amount measured in millimeters (mm) for twelve months of each year. The rainfall data spanned thirty-five years between 1975 and 2010 for each of the states i.e. Kano and Delta States. The data were sourced from the archival records of the Nigerian Meteorological Agency (NIMET) headquarters in Oshodi, Lagos State. In order to analyze the obtained data, both descriptive and inferential statistics will be used for this study.

Descriptive statistics for this study entailed the use of statistical tools such as mean, standard deviation, variance, coefficient of variability and, coefficient of skewness.

Inferential Statistics include Test for Normality, Trend Analysis, Simple Linear Regression Analysis and Correlation Analysis.

Results and Discussions

As shown in Table 1, Warri station recorded an approximate mean annual rainfall of (236mm) over a period of 37 years. The station also recorded a standard deviation of (29.93) from the mean annual rainfall within the station. It also recorded a relatively high coefficient of variance of about 89.5 per cent.

Table 1: Descriptive Rainfall Datasets at the Warri Station (1976-2012)

Observations		37 years (1976 - 2012)
Minimum		172.7mm
Maximum		294.711mm
Range		122.011mm
Sum		8722.846
Mean		233.7526
Median		233.875
Quartile 1		209.3375
Quartile 3		255.8591
Standard Deviation		29.93109
Variance		895.8702
Skewness		0.1881916
Kurtosis		2.249361

Source: Authors' analysis (2017)

The minimum amount of rainfall (172.7mm) and the maximum amount of rainfall (294.7mm) recorded showed a wide range gap of 122mm. this implied that if it was not raining in some parts of Warri, some other areas will record rainfall to the tune of 122mm. Since the coefficient of variation in rainfall within the Warri station is >33 per cent, it therefore means that rainfall at Warri is heterogeneous in nature. Rainfall at the Warri station was also found to be positively skewed with (0.19) coefficient of skewness.

Table 2: Descriptive Rainfall Datasets at the Kano Station (1976-2012)

Observations		37 years (1976 - 2012)
Minimum		39.89167mm
Maximum		162.6727mm
Range		122.7811mm
Sum		3168.605
Mean		85.63796
Median		86.325
Quartile 1		58.025
Quartile 3		108.3083
Standard Deviation		32.71498
Variance		1070.27

Skewness	-0.06300227
Kurtosis	2.467309

Source: Authors' analysis (2017)

As shown in Table 2, the mean annual rainfall at the Kano station is 85.64mm over a period of 37 years with a standard deviation of 32.71. It also recorded a 10.7 per cent coefficient of variance which indicates that the data is homogeneous in nature since the coefficient of variance is <33 per cent. Rainfall at this station was also found to be negatively skewed with a (-0.06) coefficient of skewness.

Table 3: Trend Line Analysis Of Rainfall at the Warri Station.

Variable	Warri
Included Observation	37
Linear Trend Equation	$Y_t = 226.7 + 0.47663 * t$
R	0.172368
R-Squared	0.029711
R-Square Adjusted	0.094515
Sum Square Error (SSE)	31293.114120
Mean Squared Error (MSE)	894.088975

Source: Authors' analysis (2017)

From the Table 3, the trend line equation generated from the Warri station is: $Y_t = 226.7 + 0.47663 * t$. From this equation, it is evident that rainfall in Warri experienced a significant increase of (0.47mm). It shows a gently climbing rise in rainfall values albeit a uniform and constant increase. The correlation coefficient ($r = 0.17$) shows that there is a weak positive relationship between rainfall and time (years).

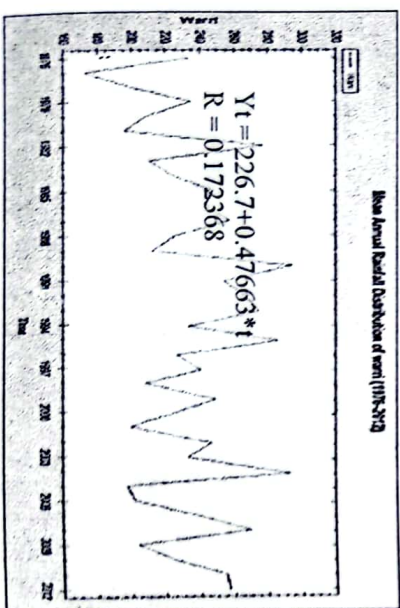


Fig 1: Linear Trend in Rainfall at the Warri station (1976-2012)
Source: Authors' analysis (2017)

Table 4: Trend Line Analysis of Rainfall at the Kano Station

Variable	Kano
Included Observation	37
Linear Trend Equation	$Y_t = 45.052 + 2.1361 * t$
R	0.706772
R-Squared	0.499527
R-Square Adjusted	0.996396
Sum Square Error (SSE)	19283.093064
Mean Squared Error (MSE)	550.945516

Source: Authors' analysis (2017)

From the Table 4, rainfall at Kano shows a linear trend equation of $Y_t = 45.052 + 2.1361 * t$ over a period of 37 years. The correlation analysis shows a strong positive relationship between rainfall and time (years) with a correlation coefficient of (0.71).

However, an annual increase of (2.14mm) of rainfall is expected at Kano. Comparatively, it shows a greater rate of increase in mean annual rainfall as obtainable in the Warri station. Here, a sharp and steady increase is noticeable in the rainfall values obtained at the Kano station.

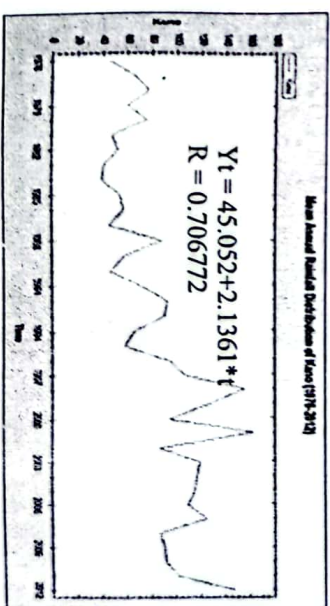


Fig 2: Linear Trend in Rainfall at the Kano Station. (1976-2012).
Source: Authors' analysis (2017)

Table 5: Predicted Rainfall.

YEAR	PREDICTED MEAN ANNUAL RAINFALL (MM)	PERCENTAGE INCREASE FROM BASE YEAR (%)
2013	245	-
2014	245	0.41
2015	246	0.41
2016	246	0.41
2017	247	0.82
2018	247	0.82
2019	248	1.22
2020	248	1.22
2021	249	1.63
2022	249	1.63
2023	250	2.04
2024	250	2.04
2025	251	2.44
2026	251	2.44
2027	252	2.86
2028	252	2.86
2029	253	3.27
2030	253	3.27
2031	254	3.67
2032	254	3.67
2033	255	4.08
2034	255	4.08
2035	256	4.49
2036	256	4.49
2037	257	4.90
2038	257	4.90
2039	258	5.31
2040	258	5.31
2041	259	5.71
2042	259	5.71

Source: Authors' analysis (2017)

The forecast of rainfall using trend line equation: ($Y_t = 226.7 + 0.47663 \cdot t$) of the Warri station shows an average increase of (0.47mm) in mean annual rainfall values.

Using 2013 as the base year, a predicted increase of (0.82%) is expected in the mean annual rainfall of Warri by the year 2018.

Consequently, an overall increase of (5.71%) is expected in the region by the year 2042.

This however shows a steady increase in rainfall values over a period of 30 years at Warri, Delta State with a percentage of 5.3 per cent from the base year (2013) to 2042.

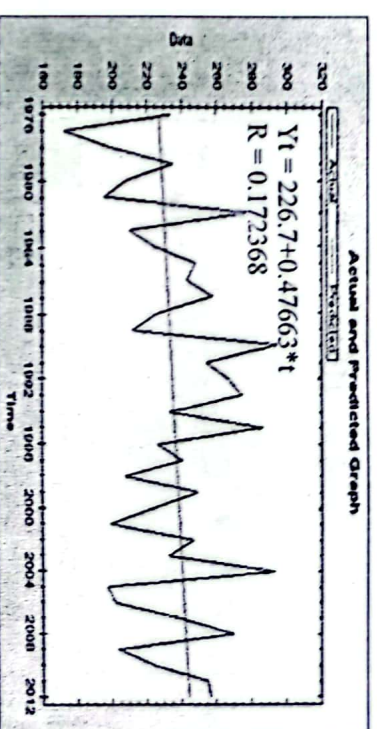


Fig 4: Trend of Actual and Predicted Mean Annual Rainfall at the Warri station.
Source: Authors' analysis (2017)

Prediction of Future Climate Change Scenario at the Kano Station (2013-2042)

YEAR	PREDICTED MEAN ANNUAL RAINFALL (MM)	PERCENTAGE INCREASE FROM BASE YEAR (%)
2013	126	-
2014	128	1.59
2015	130	3.17
2016	132	4.76
2017	135	7.14
2018	137	8.73
2019	139	10.32
2020	141	12.00
2021	143	13.50
2022	145	15.08
2023	147	16.67
2024	150	19.04
2025	152	20.63
2026	154	22.22
2027	156	23.81
2028	158	25.40
2029	160	26.99
2030	162	28.57
2031	165	30.95
2032	167	32.54
2033	169	34.12
2034	171	35.71
2035	173	37.30
2036	175	38.90
2037	177	40.48
2038	179	42.06
2039	181	43.65
2040	184	46.03
2041	186	47.62
2042	188	49.20

Source: Authors' analysis (2017)

The forecast of rainfall using trend line equation: ($Y_t = 45.052 + 2.1361 \cdot t$) of the Kano station shows a sharp but steady rise in the mean annual rainfall by (2.14mm) per annum. Using 2013 as a base year, there would be an increase of (8.7%) in the mean annual rainfall of the Kano station by 2013, (29.36%) increase by 2030 and an increase of

(49.20%) in the mean annual rainfall of the station by 2042. This however means that rainfall will continue to increase in Kano State and would have increased by a percentage of 47.61 per cent from 2013 to 2042.

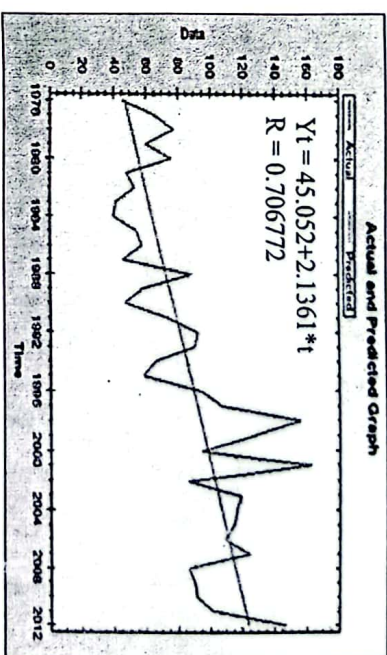


Fig 5: Trend of Actual and Predicted Mean Annual Rainfall at the Kano station.
Source: Authors' analysis (2017)

Implications of Increasing Rainfall Amounts in the Study Areas

Now that an increasing trend in rainfall amounts has been predicted for both states from 2013 to 2042, a close examination of the implications must be carried out. An increase in rainfall amounts would have both positive and negative implications. On the negative side, some of these effects are:

- Increase in the incidence of floods as can be seen in many states in Nigeria today.
 - Increase in the incidence of rainstorms in the study areas.
 - Increased occurrences of associated water-borne diseases such as cholera, typhoid, diarrhea etc.
 - Softening of the soil which leads to erosion and landslides.
- On the positive side, increased amounts of rainfall would also favor the study areas. Some of the positive implications are:
- Because both study areas are known for their agricultural produce therefore, it would lead to an increase in crop yield especially for hydrophytes such as rice.
 - Improvement of water transportation through inland water ways i.e. there would be more water in rivers so that ships can freely sail through.
 - Increased ground water and surface water supplies both for man and animal use.
 - Increased supply of water for hydro-electric power stations.

Conclusion

Rainfall was found to be negatively skewed for Kano and positively skewed for Warri. It was observed that rainfall pattern at Warri was heterogeneous, while that of Kano was homogeneous with 89.5 per cent and 10.7 per cent respectively. The mean annual rainfall in Warri was high with recorded value of 236mm, this is evident to the fact that the area lie within the coastal regions and with close proximity to the ocean. Meanwhile, Kano recorded a low mean annual rainfall of 85.64mm, this result from close proximity to Sahara desert where rainfall is little during the wet season. Thus, there is significant evidence of Climate change in the area. Long term unmitigated Climate change will likely cause more rainfall in annual totals and consequently reinforce present increasing trends exceeding the capacity of people and the natural world to adapt. Since temperature varies in this region; further study is necessary, using temperature and other climatic parameters, to assess climate change and give a more vivid, clearer picture of the climate change scenario in the regions.

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