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Trend and Variability Analysis of Rainfall and Temperature Trends in Ilorin Metropolis, Kwara State, Nigeria

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ABSTRACT Rainfall and temperature are the most important physical parameters that influence climate. This paper examines the trend and variability of rainfall and temperature of Ilorin township in Nigeria between2010-2018, using standard statistical descriptors. Rainfall had an increasing trend (positive slope value of 5.30), moderate precipitation concentration index of 12.15 percent and extremely high degree of variability with a coefficient of variation ranging between 33.54 percent and 155.73 percent. Temperature also had a slight warming or increasing trend (positive slope value of 0.012) with minimal degree of variability of coefficient of variation between 5.49 percent and 7.31 percent. The oscillating structure of both rainfall and temperature anomalies further confirm yearly fluctuations as well as change in the distribution and characteristics. It is recommended that government and non-government agencies should formulate plans and policies that will accommodate changes in rainfall and temperature patterns to successfully manage the environment.

INTRODUCTION

Climate, one of the essential components of the earth system is usually defined as the average weather. It is the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years (IPCC 2007). Variables such as rainfall, temperature, humidity and atmospheric pressure constitute the climate. Increasing variation in climate and its impact have become more threatening to human existence globally. Climate change is of critical importance globally. Climate change is currently adversely impacting the health and lives of people around the world (Simane et al. 2016) particularly in low-income countries (McMichael 2013) where there are challenges of rural-urban drift and unfriendly human activities such as grazing and pollution. The severity of climate change particularly in Africa (Ayalew et al. 2012) is more than that of terrorism (King 2004).

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Rainfall and temperature are the most important fundamental physical parameters (Cheung et al. 2008; Singh et al. 2013; Olubanjo 2019) that influence human well being (Ogunrayi et al. 2016; Simane et al. 2016) among the climate, as these parameters determine spatial and temporal distribution of runoff, soil moisture and groundwater reserves (Jain et al. 2012), the accuracy of the energy exchange process over the earth's surface (Vinnikov et al. 1990;Thapliyal and Kulshrestha 1991), socioeconomic activities (Ajewole et al. 2010), agricultural productivity (Dore 2005; Kumar and Gautam 2014) particularly in sub-Saharan Africa where over sixty percent of the population are employed (Kandlinkar and Risbey 2000) through rain fed agriculture (Akinyemi et al. 2013; Asfaw et al. 2018), amongst others.

The activities of man and natural occurrences result in global warming, which causes variations in the earth temperature (Venkataramanan and Smitha 2011; Ayanshola et al. 2018) and rainfall (Olanrewaju 2009; Ayalew et al. 2012) worldwide. Climate projections for the 21st century show a significant increase of temperature over all the ecological zones in Nigeria (Abiodun et al. 2013). Human induced changes such as bush burning, deforestation and urbanisation increase the risk of vulnerability to climate change. Mendelsohn et al. (2000) suggest that global warming might be beneficial to the agricultural sector of countries in temperate locations and be harmful to vulnerable countries in tropical region of which Nigeria is included.

The pattern and the amount of rainfall are among the most vital factors that affect agricultural production (Gajbhiye et al. 2016), industrial, domestic water supply, hydroelectric power generation (Panda and Sahu 2019) and other cultural practices. Several studies have been conducted on changing patterns of rainfall in Nigeria. For example, Olaniran and Summer (1989), Olaniran (1990), Omogbai (2010), and Akande et al. (2017) studied the changes in raindays, while Odjugo (2009) and Abiodun et al. (2013) studied the increasing damaging effects of wind and rainstorms. These changes have significant adverse effects on natural and human resources and the economy in general.

Aim of the Study

Climate varies on monthly, yearly, century or millennium time scales, andthe longer the period, the higher is the risk of outliers or extreme values that impair the outcome of the findings and this requires specialised skills to handle (Akande et al. 2017; Rustum et al. 2017). It is therefore essential to study the short-term structure (Akinyemi et al. 2013) of climatic characteristics to capture recent developments such as urbanisation and deforestation. Local and regional scale analysis of climate is more relevant to devise specific development and adaptation plans to mitigate negative effects of climate change (Babar and Ramesh 2013; Panda and Sahu 2019) than country scale, and hence the specific consideration of this research's study area.

Objectives

The objective of this study is to investigate the recent monthly and annual trend and variability of rainfall and temperature in Ilorin metropolis of Kwara State, Nigeria. Clear understanding of the uncertainties associated with rainfall and temperature patterns will provide a knowledge base for better management of the environment in the selected area

METHODOLOGY

Study Area

Ilorin doubles as a town and capital of Kwara State, located approximately on latitude $8^0$30'N of the equator and longitude $4^0$35'E of the Greenwich Meridian with an area of about 100km^{2}and estimated population of 950,000 people in the North Central geopolitical zone of Nigeria.

The climate is characterised by both wet and dry seasons with total annual rainfall between 990.3mm and 1,318mm and temperature of between 33^{O}C and 37^{O}C (Ajadi et al. 2016). The town serves as a commercial hub to other neighbouring states.

Data Collection

Secondary data from the Nigeria Meteorological Agency (NIMET), Ilorin Airport office was used to study the trend and variability of rainfall and temperature between 2010 and 2018.

Methods of Data Analysis

Trend Analysis

A trend is defined as the general movement of a series over an extended period of time. Several methods have been employed to study the trend of rainfall and temperature, the linear regression (for example, Ayoade 1974; Subbaramayya and Kumar 1987; Abaje et al. 2010; Viste et al. 2013; Asfaw et al. 2018), time series and moving average (Ayalew et al. 2012; Akinyemi et al. 2013; Ogunrayi et al. 2016), amongst others.

In this paper, charts, regression and correlation are employed. Graphical tools such as time series charts and scatter plots are used to ensure improved understanding of the pattern of climatic variables.

The regression and correlation analyses are given as:

$Y = a + bx$

Where, a and b are the intercept and the slope, x is the time period and Y is the rainfall or temperature values over a given period of time. Trend is usually derived by the value of the slope of the regression line, and a positive value of the slope indicates an increasing or upward trend while a negative value indicates a decreasing or downward trend.

$$r = \frac{s_{xy}}{S_x S_y}$$

Where, s_{xy}, s_x, s_y are covariance and standard deviations of x and y.

Variability Analysis

Several methods have also been used to study the variability of rainfall and temperature, and these include standard deviation, standardised anomaly index (SAI), skewness, kurtosis, coefficient of variation (CV), and precipitation concentration index (PCI) amongst others. In this paper, SAI, CV and PCI are employed.

Several authors have used the SAI (also called Standardised Precipitation Index (SPI)) to study variability, for example, McKee et al. (1993) used the index to define drought periods as when the index first falls below zero and continuously negative and reaches a value of -1 or less at one or more time steps and observed that the index responds more slowly to changes in precipitation as the time period is lengthened. Ayalew et al. (2012) used it for detection of inter-annual fluctuations of rainfall in Ethiopia. Akinsanola and Ogunjobi (2014) used the index to study warming and cooling phases of temperature and increase and decline amounts of rainfall (anomalies) in Nigeria. Daramola et al. (2017) also used the index to identify dry and wet years of rainfall, cold and warm years of temperature across all zones in Nigeria.

The Standardised Anomaly Index (SAI) was calculated as the difference between the annual total of a particular year and the long term average rainfall records divided by the standard deviation of the long term data. This index is used to examine the nature of the trends and enables the determination of the dry and wet years in the record. Anomalies are usually being described using standard Z score as:

$$Z = \frac{x - \bar{x}}{\sigma}$$

Where Z is the standardised anomaly, x is the annual total of a particular year, $\bar{x}$ is mean annual rainfall or temperature over a period of observation, and σ is the standard deviation of annual rainfall or temperature over the period of observation.

Coefficient of variation (CV) expressed as percentage has been used by several authors for example, Ayalew et al. (2012) and Panda and Sahu (2019) who classified degree of inter-annual variability using CV as less (CV<20), moderate (20<CV<30), high (CV> 30), very high (CV>40), and extremely high (>70).

Coefficient of variation (CV) is calculated as the ratio of Standard Deviation (σ) to the mean (ì). That is:

$$CV = \frac{\sigma}{\mu} \text{x}100$$

The precipitation concentration index (PCI) examines the variability at different scales (annual or seasonal) has been used by many authors. PCI was classified by Oliver (1980) and modified by De Luis et al. (2011) as uniform monthly distribution, that is, low precipitation concentration (<10), moderate concentration (11<PCI<15), high concentration (16<PCI<20) and very high concentration (>20), and it is calculated as:

$$PCI = \frac{\sum_{i=1}^{12} p_1^2}{(\sum_{i=1} p_i)^2} \text{x}100$$

Where, p_i = rainfall amount in the *i*th month

RESULTS

Tables 1a and 1b show the monthly and annual rainfall characteristics in Ilorin. From Table 1a, it was observed that the average monthly rainfall ranges from 2.91mm to 275.52 mm with December to February as the driest months and September as the wettest month. The monthly rainfall coefficient of variation ranging from 33.54 percent to 155.73 percent, and the highest value was found for the month of January while the lowest was for the month of September. Table 1b showed that the average annual rainfall ranges from 79.43 mm to 208.41 mm with 2018 having the highest amount of rainfall and 2014 the least. The annual rainfall coefficient of variation ranging from 82.65 percent to 102.07 percent, and all the years showed extremely high rainfall variability with 2015 having the highest and 2016

Table 1a: Descriptive characteristics of monthly rainfall in Ilorin, Kwara State, Nigeria

Parameters	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Mean (mm)	2.91	7.49	32.94	154.60	145.14	179.40	197.61	155.87	275.52	215.94	5.00	5.84
Min (mm)	0.00	0.00	4.00	21.10	42.30	89.30	93.10	51.40	185.70	122.80	0.00	0.00
Max (mm)	11.10	28.60	79.40	408.80	285.50	305.20	332.30	226.30	511.70	379.40	15.40	25.20
SD	4.53	10.80	22.05	115.94	77.85	64.68	100.69	63.58	92.40	85.08	5.70	8.76
CV (%)	155.73	144.23	66.92	74.99	53.64	36.05	50.95	40.79	33.54	39.40	114.08	149.83

Table 1b: Descriptive characteristics of annual rainfall in Ilorin, Kwara State, Nigeria

Parameters	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
Mean (mm)	108.39	109.09	122.38	111.88	79.43	93.86	93.08	107.19	208.41
Min (mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max (mm)	259.00	285.50	318.60	313.40	267.30	247.50	230.00	308.80	511.70
SD	97.36	101.82	123.69	108.30	80.26	99.06	76.93	109.42	181.87
CV (%)	89.82	93.34	101.07	96.80	101.04	105.54	82.65	102.07	87.27
Anomaly	-0.17	-0.15	0.20	-0.08	-0.95	-0.56	-0.58	-0.21	2.51

having the least. The SAI showed general decline in the volume of rainfall except for 2012 and 2018. PCI of 12.15 percent showed moderate concentration. Table 1c shows monthly rainfall pattern, which reveals that maximum amount of rainfall is between September and October in the study area. Table 1e shows the increasing trend of annual rainfall where the regression equation *Y= 88.376 + 5.296X* is showing the annual positive rate of change (slope) of 5.296 mm per year and coefficient of determination (R^2) 0.151.

Tables 2a and 2b show the monthly and annual temperature characteristics in Ilorin. From Table 2a, it was observed that the average monthly temperature ranges from 24.94 ^{o}C to 30.26^{o}C with August as the coldest month while February to April are the hottest months. The monthly temperature coefficient of variation shows that all the months have less degree of variability ranging from 0.74 percent to 3.90 percent, highest for the months of January and December while the smallest in the month of September. Table 2b showed that the average annual temperature ranges from 27.03^{o}C to 27.85^{o}C with 2015 as the hottest and 2011 as the coldest. The annual temperature coefficient of variation ranging from 5.49 percent to 7.31 percent shows that all the years showed less temperature variability with 2011 having the highest and 2013 having the least. Table 2c shows a fairly uniform monthly temperature pattern with maximum amount of temperature between February and April in the study area. Table 2e shows the increasing trend of annual temperature where the regression equation *Y= 27.237 + 0.012X* is showing the annual positive rate of change (slope) of 0.012^{o}C per year and coefficient of determination (R^2) 0.02.

Table 1e: Regression result for rainfall

	Intercept	*Slope (year)*
Coefficients	88.376	5.296
t tatistics	3.313	1.117
Standard Error	26.676	4.740
Probability	0.013	0.301

R^2=0.151, F=0.3007

Table 1c: Monthly rainfall trend in Ilorin, Kwara State, Nigeria

Month	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Mean (mm)	2.91	7.49	32.94	154.60	145.14	179.40	197.61	155.87	275.52	215.94	5.00	5.84

Table 1d: Anomaly of annual rainfall in Ilorin, Kwara State, Nigeria

Parameters	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
Anomaly	-0.17	-0.15	0.20	-0.08	-0.95	-0.56	-0.58	-0.21	2.51

Table 2a: Descriptive characteristics of monthly temperature in Ilorin, Kwara State, Nigeria

Parameters	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Mean (°C)	26.91	29.71	30.26	29.06	27.65	26.61	25.62	24.94	25.84	26.53	27.66	26.82
Min (°C)	25.55	28.40	29.90	28.20	26.70	26.20	25.30	24.50	25.60	26.30	26.00	25.15
Max (°C)	28.45	30.70	30.95	30.10	28.80	27.55	26.00	25.75	26.20	27.05	28.55	27.80
SD	1.05	0.67	0.35	0.69	0.66	0.42	0.26	0.45	0.19	0.25	0.79	0.94
CV (%)	3.90	2.24	1.17	2.36	2.38	1.58	1.03	1.79	0.74	0.94	2.85	3.50

Table 2b: Descriptive characteristics of annual temperature in Ilorin, Kwara State, Nigeria

Parameters	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
Mean (°C)	27.28	27.03	27.25	27.30	27.39	27.85	27.17	27.12	27.30
Min (°C)	24.50	24.50	25.35	25.30	24.65	25.75	25.00	24.55	24.85
Max (°C)	30.35	30.15	30.35	30.15	30.65	30.95	30.00	30.10	29.90
SD	1.93	1.98	1.60	1.50	1.65	1.90	1.79	1.72	1.57
CV (%)	7.07	7.31	5.88	5.49	6.01	6.82	6.57	6.33	5.74
Anomaly	-0.07	-1.14	-0.22	0.01	0.37	2.36	-0.56	-0.79	0.01

Table 2c: Monthly temperature trendin Ilorin, Kwara State, Nigeria

Month	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Mean (°C)	26.91	29.71	30.26	29.06	27.65	26.61	25.62	24.94	25.84	26.53	27.66	26.82

Table 2d: Anomaly of annual temperature in Ilorin, Kwara State, Nigeria

Parameters	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
Anomaly	-0.07	-1.14	-0.22	0.01	0.37	2.36	-0.56	-0.79	0.01

Table 2e: Regression result for temperature

	Intercept	*Slope (year)*
Coefficients	27.237	0.012
t statistics	151.878	0.387
Standard Error	0.179	0.032
Probability	1.42E-13	0.710

R^2=0.021, F statistic =0.710

Although the CV for temperature is found to be low as compared to rainfall, both rainfall anomalies (Table 1d) and temperature anomalies (Table 2d) show high inter annual fluctuations. There is also inverse relationship between rainfall and temperature as shown by negative correlation value of -0.127.

DISCUSSION

The monthly and annual trends have been shown using descriptive and linear regression. The findings of this study show upward trends in both rainfall and temperature of Ilorin. The rainfall study agrees with Olubanjo (2019) who reported highest rainfall in September while the singular monthly rainfall peak contradicts the bimodal monthly picks of June and September. Similar findings with singular monthly rainfall peak were reported by Akande et al. (2017) from a study over the same region and Balogun et al. (2016) from a study conducted in a nearby township of Abeokuta. Rainfall is highly concentrated between September and October. The high intensity of October rainfall and sudden drop in November depicts seasonal changes, problem of flooding and hazardous variability that negatively affect agriculture (causing shift in cropping calendar and change in types of crops planted) and the environment. The positive trend of rainfall agrees with the results found by Akinyemi et al. (2013), Gbode et al. (2015) and Akande et al. (2017). The moderate concentration of PCI agrees with the climatic classification of guinea savannah of the region. Fluctuation in rainfall as shown by monthly and inter-annual CV indicate extremely intra and inter annual variability. The result indicated that the amount of rainfall in the region is highly variable, and this reflects the diversity of climate variability in the region. This agrees with Ayinde et al. (2010), Akinsanola and Ogunjobi (2014), Ayanshola and Sule (2006), and Akinbile et al. (2019).

Similarly, there is need for deep understanding of air temperature, as this has crucial impact on the water cycle (Panda and Sahu 2019). The temperature also shows increasing pattern, though different from the estimated global warming rate of 0.9 ^{o}C in the last decade. Monthly and inter-annual temperature CV shows stability over time. The temperature study agrees with the upward trend and less variability reported in virtually all studies in the region (NIMET 2008; Olanrewaju 2009; Ogunrayi et al. 2016; Olubanjo 2019), Nigeria (Abiodun et al. 2013; Akinsanola and Ogunjobi 2014; Daramola et al. 2017; Akinbile et al. 2019), Africa (Ifejika 2010; Asfaw et al. 2018) and globally (Jain et al. 2012).

The negative correlation between rainfall and temperature agrees with several studies that drought is associated with warmer temperature and vice versa.

CONCLUSION

This study examined trend and variability of rainfall and temperature in Ilorin metropolis. Rainfall in the study area is characterised with increasing trend and high concentration in the months of September and October, which increases the risk of flooding. The high CV and anomaly indicate erratic nature and change in the distribution and characteristics of rainfall. Temperature also showed inter annual anomaly with a rising trend and minimal variability, and this further confirms the manifestation of global warming in the region. The variations in rainfall and temperature will have major implications on agriculture, socioeconomic activities and the environment, and hence the need to adopt adaptation strategies to alleviate the problems of climate change.

RECOMMENDATIONS

The findings from this research are very helpful to successfully manage the environment. Concerted efforts should be put in place by government and non-government agencies to formulate plans and policies that will accommodate changes in rainfall and temperature patterns.

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