STATISTICAL COMPARATIVE STUDY OF THE TREND AND VARIATION OF METROLOGICAL PARAMETERS IN ABEOKUTA, SOUTH-WEST NIGERIA

ABSTRACT

This study focuses on the statistical comparative study of the trend and variation of metrological parameters covering a 10 year period (2001-2010) in the capital and largest city of Ogun Sate, Abeokuta, southwest region of Nigeria. The analyzed metrological parameters were: wind speed, vapour pressure, relative humidity, temperature, sunshine and rainfall covering 10 years. The calculated coefficient of variation (CV) for sunshine (22.78%), wind speed (21.55%), and rainfall (99.12%) is a proof of exceedence of variability of threshold of 10% while the CV calculated for air temperature (5.74%), relative humidity (4.52%) and vapour pressure (5.22%) show no significance of variability. Significance test of metrological parameters' trend reveals a notable reduction in the values of vapour pressure, air temperature and relative humidity. It is, however, difficult to argue for a well-defined change in most of the meteorological parameters based on the monthly time series analyses performed in this work. Only wind speed shows statistically significant increasing trend during the period of observation at 1% significance level. The trend revealed by rainfall and sunshine are statistically not significant. ANOVA test of significant difference among meteorological parameters shows a *p*-value (Sig.) of 0.000 is an indication of significant difference in the analyzed mean monthly coefficient of variation for the metrological parameters under study. The Tukey's multiple pair comparisons test however shows that there is significant difference between the mean monthly CV of rainfall–sunshine, rainfall-vapour pressure, rainfall-wind speed, rainfall-air temperature and rainfall-relative humidity. At significance level of 5%, the calculated mean monthly CV of rainfall is significantly different from the mean monthly CV of other climatic parameters.

Keywords: Metrological parameters, Coefficient of variation, variability threshold, significance level, significance of variability.

1. INTRODUCTION

Climate study is worth investigating since human lives is strictly attached and it is important to have knowledge of our environmental changes that we would not be caught unaware by the consequences of the adverse effect offered. Climate change is associated to weather conditions and it has a great effect in environmental changes. A full knowledge on the environment will enhance proper management risks so as to avert disasters. It is of great importance to know that improper management of climate could lead to natural disasters. It is therefore imperative to introduce protective schemes through the results obtained from quality research works that related with environment. Year to year variability is caused by climate and has a link with socio-economic and environmental activities. It is of great importance toward the development and proper planning of schemes that relates to water resources such as the management of drought, the prevention and control of flood.

Importantly, natural and ecosystems coupled with the society as a whole are directly linked to the consequences of change in climatic pattern either positively or negatively. Invariably, there could be alteration in the location of the major crop production regions on the earth.

The variation of climate has a great influence on socio-economic activities. Research works conducted by [1] and [2] show that climatic parameters are closely related and have influence on crop production. Precipitation, temperature ,wind, pressure and humidity are physical conditions in the environment and atmosphere which are termed as weather because they have direct or indirect consequences upon the biosphere while the pattern of weather in a region over period of time is referred to as climate [3].Rise in number of vehicles and industries are also factors in contemporary trends in climate [3]. It was reported by [5] that it is not only soil and pests that offers draw backs in crop production but the effect of climate is of much influence.

Instability of weather could offer adverse effects in social, economic and regional competitiveness [7].The negative change in climatic pattern could be harmful to socio-economic activities thereby causing reduction in food and fibers delivery to the teeming population [8]. The study conducted by [10] revealed that metrological parameters from monthly series are of decreasing trend and not statistically significant except for rainfall and humidity that show an increasing trend which is statistically not significant.

The objectives of this study are to; examine the variations in rainfall, sunshine, air temperature, wind speed, relative humidity and water vapour patterns in the study area, examine the statistical link between sunshine, air temperature, wind speed, relative humidity rainfall and water vapour in the study area , determination of the trend of the metrological parameters and presentation of their possible effects.

2. STUDY AREA

The study area (Abeokuta) lies between longitude and latitude of 4° 19'20'' E and 7°45'20'' N respectively [4] . Abeokuta lies in the wooden savanna and the surface is characterized with masses of granite with grey color. It covers an extensive area being surrounded by mud walls which is of 18 miles in extent [9].

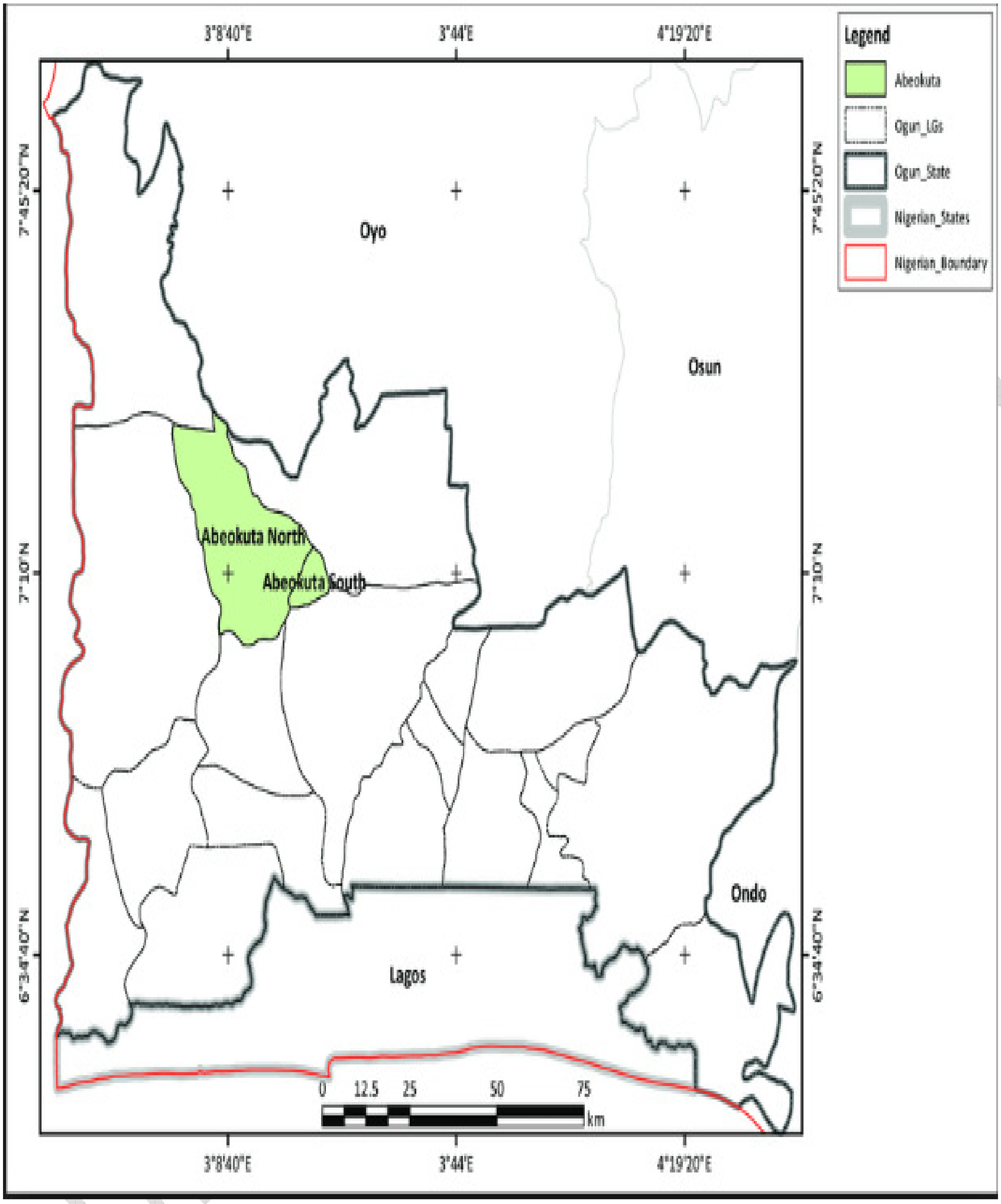


Figure 1: The map of Nigeria showing the position of Abeokuta, Ogun State [4] .

3. METHODOLOGY

Ten years metrological parameters (relative humidity, temperature, sunshine, wind speed, rainfall and vapour pressure) for Abeokuta Southwest Nigeria were collected from the Nigerian

Meteorological Agency (NIMET) archive. The coefficient of variation was calculated as described in equation (1) by [6].

$$CV = \left(\frac{\sigma}{MP}\right) \times 100\% \quad \text{\_\_(1)}$$

The calculated monthly mean of the metrological parameters is denoted as MP while σ is the standard deviation.

The statistical analysis were done using descriptive statistics, Kendall's tau_b, Spearman's rho, ANOVA and Tukey's multiple pair comparisons test. Data collected were analyzed electronically using Ms-Excel (version 2007) and SPSS (version 21.0).

The **Kendall's tau_b** for measuring order association between variables X and Y is given by the following formula :

$$\tau_b = \frac{P - Q}{\sqrt{D_r D_c}} \qquad (2)$$

Where the P and Q listed above are double the "usual" P (number of concordant pairs) and Q (number of discordant pairs). Likewise, D_r is double the "usual" $P+Q+X_0$ (the number of concordant pairs, discordant pairs, and pairs on which the row variable is tied) and D_c is double the "usual" $P+Q+Y_0$ (the number of concordant pairs, discordant pairs, and pairs on which the column variable is tied).

The **Spearman correlation coefficient** is defined as the Pearson correlation coefficient between the ranked variables.

For a sample of size *n*, the *n* raw scores X_i, Y_i are converted to ranks rg X_i, rgY_i, and r_s is computed from:

$$r_s = \rho_{rgX,rgY} = \frac{Cov(rg_X, rg_Y)}{\sigma_{rgX}\sigma_{rgY}} \qquad (3)$$

Where ρ denotes the usual Pearson correlation coefficient, but applied to the rank variables.

$Cov(rg_X, rg_Y)$ is the covariance of the rank variables.

σ_{rgX} and σ_{rgY} are the standard deviations of the rank variables.

Only if all *n* ranks are distinct integers, it can be computed using the popular formula

$$r_s = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)} \qquad (4)$$

Where $d_i = rg(X_i) - rg(Y_i)$, is the difference between the two ranks of each observation.

n is the number of observations.

ANOVA (One-way) is a technique that can be used to compare means of two or more samples (using the F distribution). The ANOVA test the null hypothesis that samples in all groups are drawn from populations with same mean values.

The normal linear model implemented in this study is means model which is given as :

$$y_{ij} = \mu_j + \epsilon_{ij} \qquad (5)$$

Tukey's multiple pair comparisons test compares the means of every treatment to the means of every other treatment; that is, it applies simultaneously to the set of all pairwise comparisons $\mu_i - \mu_j$ and identifies any difference between two means that is greater than the expected standard error.

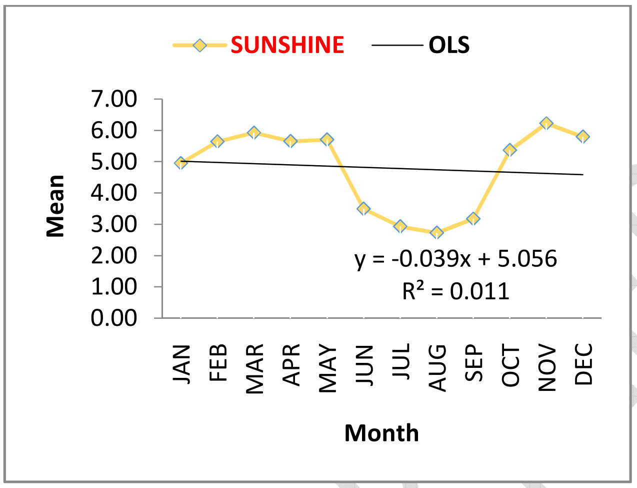
The formula for Tukey's test is:

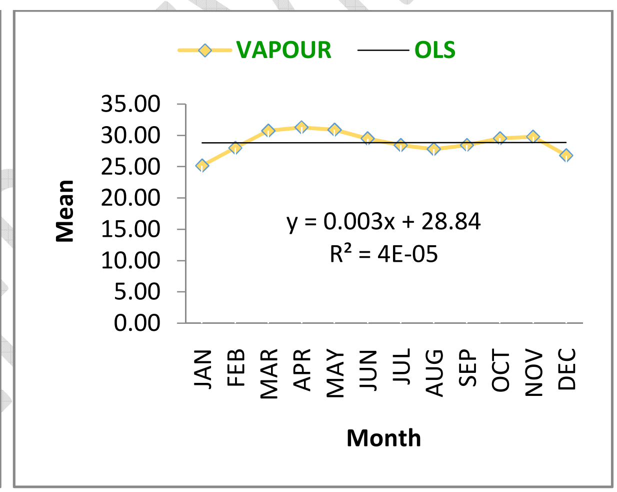
$$q_s = \frac{Y_A - Y_B}{SE} \qquad (6)$$

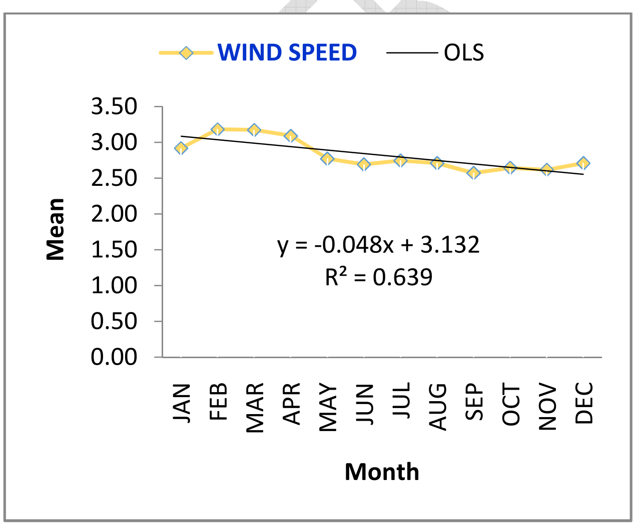
Where Y_A is the larger of the two means being compared.
Y_B is the smaller of the two means being compared.
SE is the standard error of the two sum of the means.
This q_s value can then be compared to a q value from the studentized range distribution. If the q_s value is larger than the critical value q_α obtained from the distribution, the two means are said to be significantly different at level $\alpha, 0 \leq \alpha \leq 1$.

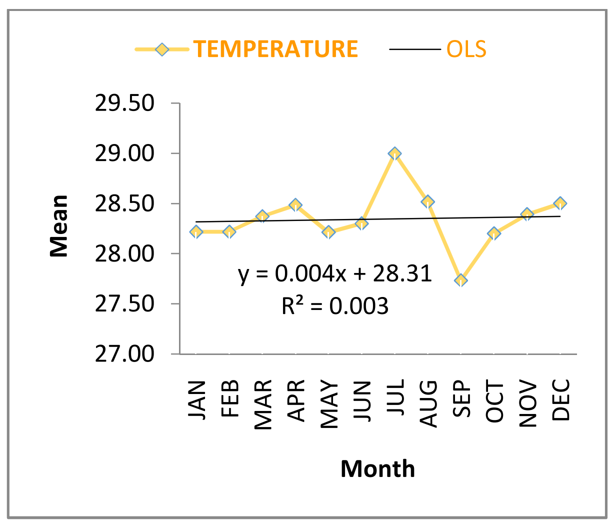
4. RESULTS

- ***Data presentation***









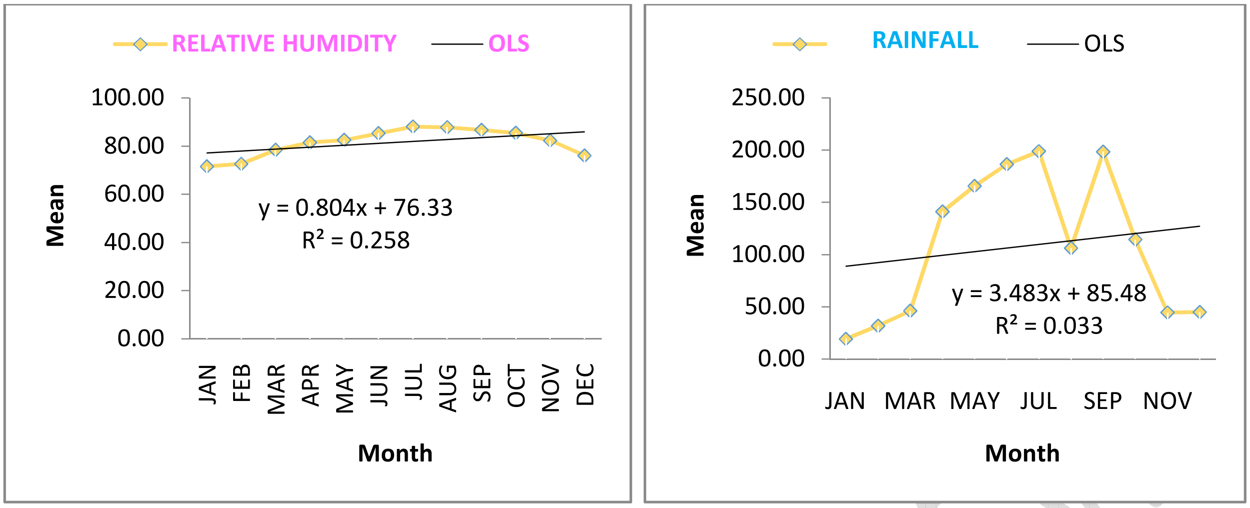
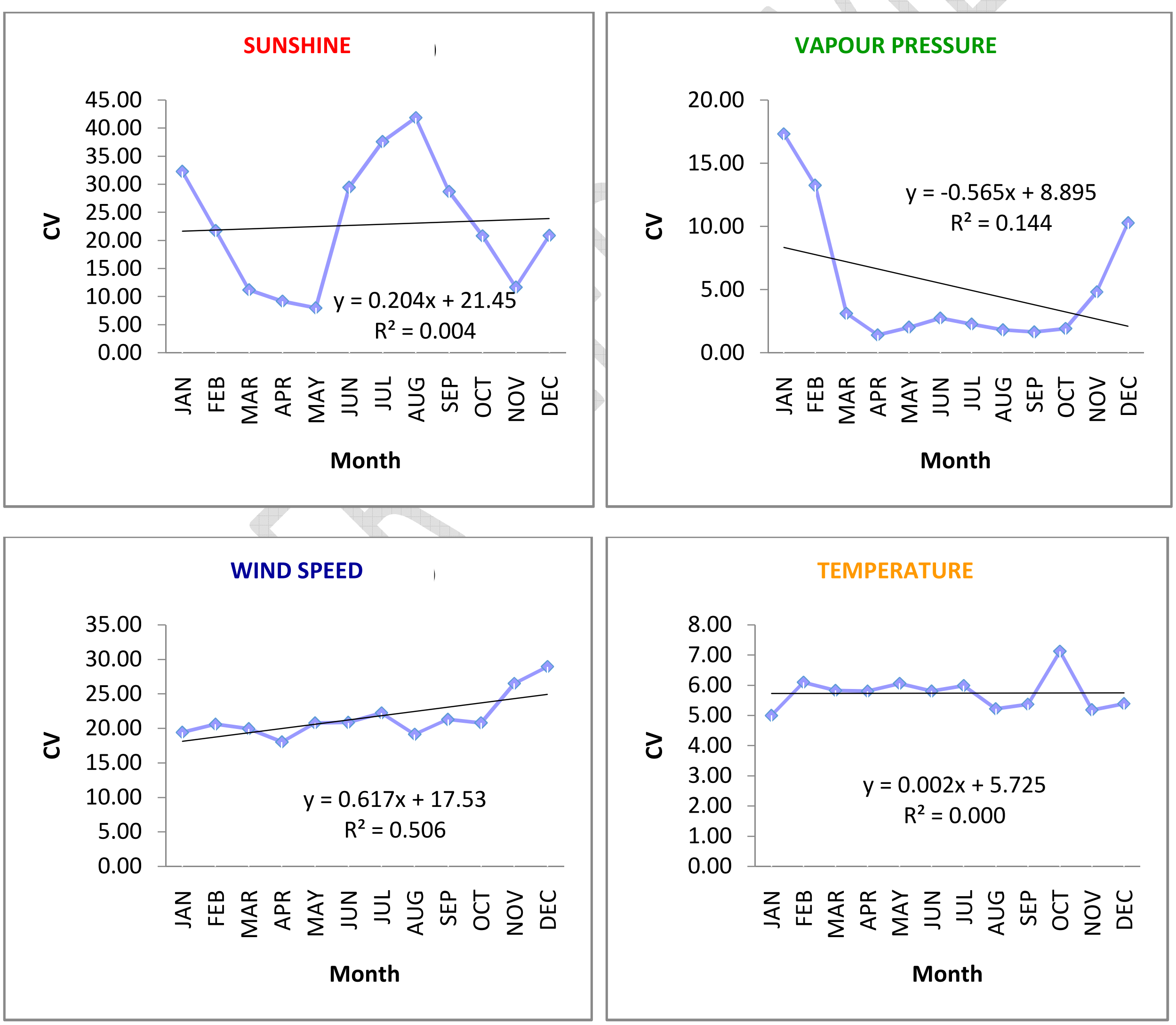


Figure 2: Monthly Mean Values and Trend of the Meteorological Parameters in Abeokuta.



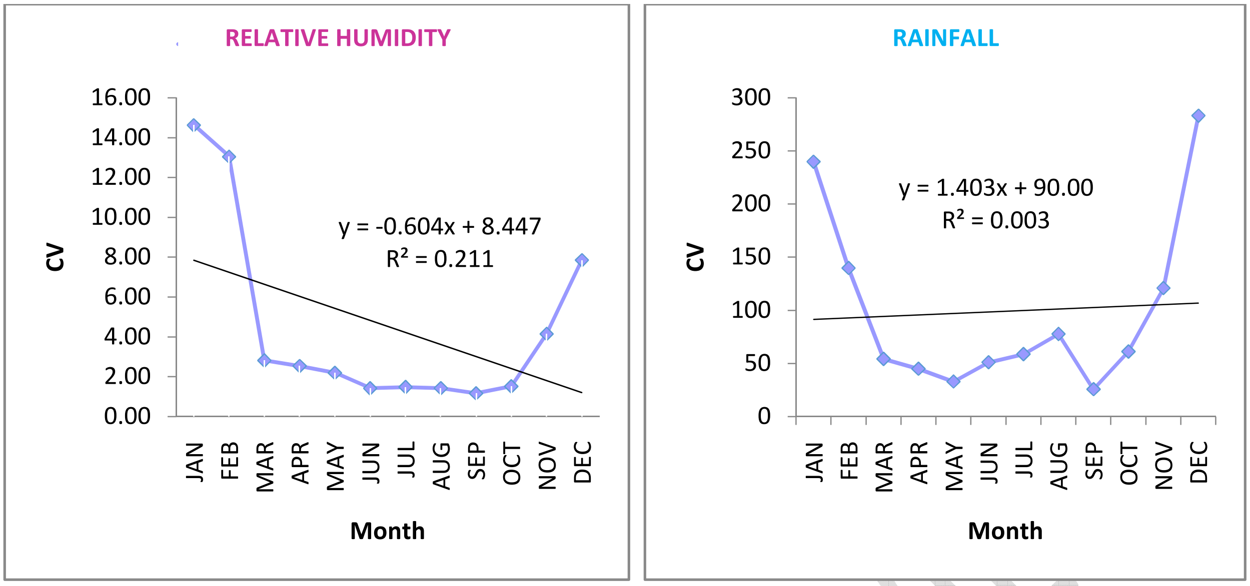


Figure 3: Monthly Coefficient of Variation (CV) and Trend of the Meteorological Parameters in Abeokuta.

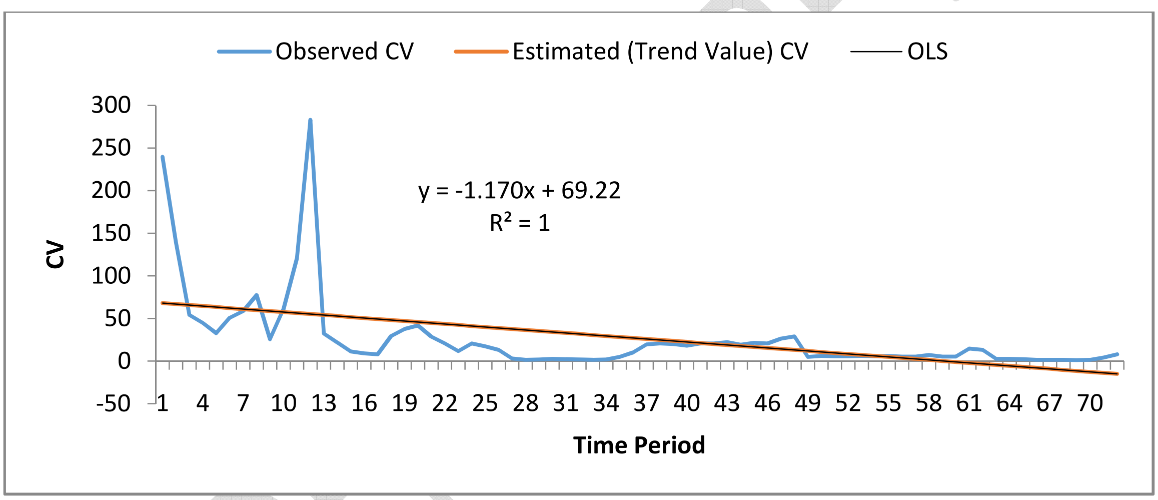


Figure 4: Time Series Plot of Observed & Estimated (Trend Value) CV.

- ***Data analysis***

Table 1: Descriptive Statistics of Monthly Coefficient of Variation (CV)

	N	Minimum	Maximum	Mean	Std. Deviation
RAINFALL	12	25.62	283.23	99.1247	83.36912
SUNSHINE	12	8.01	41.84	22.7808	11.35960
VAPOUR PRESSURE	12	1.41	17.33	5.2167	5.36420
WIND SPEED	12	18.04	28.95	21.5492	3.12828
AIR TEMPERATURE	12	5.00	7.13	5.7400	.57479
RELATIVE HUMIDITY	12	1.16	14.63	4.5150	4.74239
Valid N (listwise)	12				

Table 2: Bivariate Correlations Among Meteorological Parameters

			RAINFALL	SUNSHINE	VAPOUR PRESSURE	WIND SPEED	AIR TEMPERATURE	RELATIVE HUMIDITY
Kendall's tau_b	RAINFALL	Correlation Coefficient	1.000	.273	.545*	.091	-.121	.545*
		Sig. (2-tailed)	.	.217	.014	.681	.583	.014
		N	12	12	12	12	12	12
	SUNSHINE	Correlation Coefficient	.273	1.000	.121	.030	-.242	-.061
		Sig. (2-tailed)	.217	.	.583	.891	.273	.784
		N	12	12	12	12	12	12
	VAPOUR PRESSURE	Correlation Coefficient	.545*	.121	1.000	.182	-.152	.636**
		Sig. (2-tailed)	.014	.583	.	.411	.493	.004
		N	12	12	12	12	12	12
	WIND SPEED	Correlation Coefficient	.091	.030	.182	1.000	.000	-.121
		Sig. (2-tailed)	.681	.891	.411	.	1.000	.583
		N	12	12	12	12	12	12
	AIR TEMPERATURE	Correlation Coefficient	-.121	-.242	-.152	.000	1.000	-.091
		Sig. (2-tailed)	.583	.273	.493	1.000	.	.681
		N	12	12	12	12	12	12
	RELATIVE HUMIDITY	Correlation Coefficient	.545*	-.061	.636**	-.121	-.091	1.000
		Sig. (2-tailed)	.014	.784	.004	.583	.681	.
		N	12	12	12	12	12	12
Spearman's rho	RAINFALL	Correlation Coefficient	1.000	.315	.748**	.140	-.252	.706*
		Sig. (2-tailed)	.	.319	.005	.665	.430	.010
		N	12	12	12	12	12	12
	SUNSHINE	Correlation Coefficient	.315	1.000	.126	.049	-.322	-.273
		Sig. (2-tailed)	.319	.	.697	.880	.308	.391
		N	12	12	12	12	12	12
	VAPOUR PRESSURE	Correlation Coefficient	.748**	.126	1.000	.238	-.126	.762**
		Sig. (2-tailed)	.005	.697	.	.457	.697	.004
		N	12	12	12	12	12	12
	WIND SPEED	Correlation Coefficient	.140	.049	.238	1.000	.021	-.112
		Sig. (2-tailed)	.665	.880	.457	.	.948	.729
		N	12	12	12	12	12	12
	AIR TEMPERATURE	Correlation Coefficient	-.252	-.322	-.126	.021	1.000	-.119
		Sig. (2-tailed)	.430	.308	.697	.948	.	.713
		N	12	12	12	12	12	12
	RELATIVE HUMIDITY	Correlation Coefficient	.706*	-.273	.762**	-.112	-.119	1.000
		Sig. (2-tailed)	.010	.391	.004	.729	.713	.

N	12	12	12	12	12	12

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Table 3: Significance Test of Metrological Parameters' Trend
Significance Levels are Indicated: 95% (*), 99% (**)

Meteorological Parameter	Kendall's tau_b	Spearman's rho	Pearson
RAINFALL	0.091	0.091	0.061
SUNSHINE	-0.030	0.028	0.065
VAPOUR PRESSURE	-0.182	-0.245	-0.380
WIND SPEED	0.576** (increasing trend)	0.713** (increasing trend)	0.712** (increasing trend)
AIR TEMPERATURE	-0.121	-0.133	0.014
RELATIVE HUMIDITY	-0.303	-0.343	-0.460

Table 4: ANOVA Test of Significant Difference Among Meteorological Parameters

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	80160.369	5	16032.074	13.471	.000
Within Groups	78546.594	66	1190.100		
Total	158706.963	71			

Table 5: Tukey's Multiple Pair Comparisons test

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
RAINFALL	SUNSHINE	76.34417*	14.08368	.000	35.0072	117.6811
	VAPOUR PRESSURE	93.90833*	14.08368	.000	52.5714	135.2453
	WIND SPEED	77.57583*	14.08368	.000	36.2389	118.9128
	AIR TEMPERATURE	93.38500*	14.08368	.000	52.0481	134.7219
	RELATIVE HUMIDITY	94.61000*	14.08368	.000	53.2731	135.9469
SUNSHINE	RAINFALL	-76.34417*	14.08368	.000	-117.6811	-35.0072
	VAPOUR PRESSURE	17.56417	14.08368	.812	-23.7728	58.9011
	WIND SPEED	1.23167	14.08368	1.000	-40.1053	42.5686
	AIR TEMPERATURE	17.04083	14.08368	.830	-24.2961	58.3778
	RELATIVE HUMIDITY	18.26583	14.08368	.786	-23.0711	59.6028
VAPOUR PRESSURE	RAINFALL	-93.90833*	14.08368	.000	-135.2453	-52.5714
	SUNSHINE	-17.56417	14.08368	.812	-58.9011	23.7728
	WIND SPEED	-16.33250	14.08368	.854	-57.6694	25.0044
	AIR TEMPERATURE	-.52333	14.08368	1.000	-41.8603	40.8136
	RELATIVE HUMIDITY	.70167	14.08368	1.000	-40.6353	42.0386
WIND SPEED	RAINFALL	-77.57583*	14.08368	.000	-118.9128	-36.2389
	SUNSHINE	-1.23167	14.08368	1.000	-42.5686	40.1053
	VAPOUR PRESSURE	16.33250	14.08368	.854	-25.0044	57.6694
	AIR TEMPERATURE	15.80917	14.08368	.870	-25.5278	57.1461

	RELATIVE HUMIDITY	17.03417	14.08368	.831	-24.3028	58.3711
AIR TEMPERATURE	RAINFALL	-93.38500*	14.08368	.000	-134.7219	-52.0481
	SUNSHINE	-17.04083	14.08368	.830	-58.3778	24.2961
	VAPOUR PRESSURE	.52333	14.08368	1.000	-40.8136	41.8603
	WIND SPEED	-15.80917	14.08368	.870	-57.1461	25.5278
	RELATIVE HUMIDITY	1.22500	14.08368	1.000	-40.1119	42.5619
RELATIVE HUMIDITY	RAINFALL	-94.61000*	14.08368	.000	-135.9469	-53.2731
	SUNSHINE	-18.26583	14.08368	.786	-59.6028	23.0711
	VAPOUR PRESSURE	-.70167	14.08368	1.000	-42.0386	40.6353
	WIND SPEED	-17.03417	14.08368	.831	-58.3711	24.3028
	AIR TEMPERATURE	-1.22500	14.08368	1.000	-42.5619	40.1119

*. The mean difference is significant at the 0.05 level.

Table 6: Tukey's Homogeneous Subsets

Group	N	Subset for alpha = 0.05	
		1	2
RELATIVE HUMIDITY	12	4.5150	
VAPOUR PRESSURE	12	5.2167	
AIR TEMPERATURE	12	5.7400	
WIND SPEED	12	21.5492	
SUNSHINE	12	22.7808	
RAINFALL	12		99.1250
Sig.		.786	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

5. DISCUSSION OF RESLTS

The mean monthly values and trend of the metrological parameters in the study area are presented in Figure 2. For sunshine, months of January, February, March, April, May, October, November and December show maximum sunshine regimes. Incessant cloud formation depletes the amount of sun reaching us is accountable for the minimum sunshine experienced in August which was earlier reported by [7] for Ibadan sunshine hour in 2012. R^2 of 0.011 implies that approximately 1.1% of the variation in sunshine distribution was being explained by the monthly period of study.

A gradual pick up in vapour pressure was experienced in January which spans through the months of February, March and April but dropped in May. There was persistence in the trend of vapour pressure in July and August. October and November showed a rise in the vapour pressure while there was a sudden collapse in December. R^2 of 4E-05 implies that the monthly period of study does not explain a significant variation in vapour pressure distribution.

Unstable wind speed distribution was observed for the period under study. February and March relays peak levels of wind speed while September marked a low distribution. R^2 of 0.639 implies that approximately 63.9% of the variation in wind speed distribution is being explained by the monthly period of study.

Highest value of air temperature was recorded in July which eventually collapsed in August and spans through August and September. Least temperature is shown in September which gradually increases from the months of October to December. R^2 of 0.003 implies that approximately 0.3% of the variation in air temperature distribution is being explained by the monthly period of study.

There is an exponential rise in relative humidity in months January, February, March, April, May, June and July. August revealed upward trend movement of the relative humidity regimes which later showed a trend collapse and decreased from September to December. R^2 of 0.258 implies that approximately 25.8% of the variation in relative humidity distribution is being explained by the monthly period of study.

Mean monthly distribution of rainfall showed a low rainfall for the months of January, February, March, November and December. There was an upward increase of rainfall from April till July. A sudden collapse in the rise level of rainfall was experienced in August which later increased gradually in September and dropped down from the month of October to December. R^2 of 0.033 implies that approximately 3.3% of the variation in rainfall distribution is being explained by the monthly period of study.

Figure 3 shows the coefficients of variation (CV) for the metrological parameters under study. The highest values of the CV calculated for the climatic parameters sunshine, vapour pressure, wind speed, rainfall, air temperature and relative humidity were: 41.84%, 17.33%, 28.95%, 283.23%, 7.13% and 14.63% while lowest values were: 8.01%, 1.41%, 18.04%, 25.62%, 5.00% and 1.16% respectively. From the obtained results, rainfall exhibits the highest variation while relative humidity depicts the least variation.

The descriptive statistics result from Table 1, indicates that we expect the monthly CV for rainfall to be 99.12%, the expected monthly CV for sunshine to be 22.78%, the expected monthly CV for vapour pressure to be 5.22%, the expected monthly CV for wind speed to be 21.55%, the expected monthly CV for air temperature to be 5.74% and the expected monthly CV for relative humidity to be 4.52%.

Table 2 shows bivariate correlations among the metrological parameters using Kendall's tau_b and Spearman's rho statistics. From Kendall's tau_b analysis, it shows there is a weak positive association between rainfall-sunshine, rainfall-wind speed. Sunshine–vapour pressure, sunshine-wind speed, vapour pressure-wind speed. Weak negative association is observed between rainfall-air temperature, wind speed-relative humidity, vapour pressure-air temperature, sunshine–air temperature and sunshine–relative humidity. There is an average significant relationship between rainfall-vapour pressure, rainfall-relative humidity but a strong positive significant correlation between vapour pressure and relative humidity at 5% significance level. There is no association between air temperature–wind speed. Spearman's rho results show that there is a very strong positive significant correlation between rainfall-vapour pressure, rainfall-relative humidity, vapour pressure-relative humidity at 5% significance level. Negative correlation is experienced between rainfall-air temperature, sunshine-air temperature, sunshine-relative humidity, vapour pressure-air temperature, wind speed-relative humidity and air temperature-relative humidity.

Significance test of metrological parameters' trend from Table 3 reveals a notable deterioration in the values of vapour pressure, air temperature and relative humidity. However, it is difficult to argue for a well-defined change in most of the meteorological parameters based on the monthly time series analysis performed in this work. Only wind speed shows statistically significant increasing trend during the period of observation at 1% significance level. The trend shows by others are statistically not significant.

ANOVA Test of significant difference among meteorological parameters from Table 4 shows a *p*-value (Sig.) of 0.000 indicating a significant difference in the mean monthly coefficient of variation of the six climatic parameters (rainfall, sunshine, vapour pressure, wind speed, air

temperature and relative humidity). In other words, the mean monthly coefficient of variation of at least one of the parameters is significantly different from others.
The Tukey's multiple pair comparisons test from Table 5 shows that there is significant difference between the mean monthly CV of rainfall–sunshine, rainfall-vapour pressure, rainfall-wind speed, rainfall-air temperature and rainfall-relative humidity. It is therefore evident that the mean monthly CV of rainfall is significantly different from the mean monthly CV of the other climatic parameters at 5% significance level.
The Tukey's homogeneous subset from Table 6 shows the order of importance of the metrological parameters under study. It reveals that relative humidity is of the most important, followed by vapour pressure, air temperature, wind speed, sunshine and rainfall as the least important.

6. CONCLUSION

This study revealed the occurrence of significant difference in variation for all the investigated metrological parameters. Also, there is a notable deterioration in the values of vapour pressure, air temperature and relative humidity. Only wind speed shows statistically significant increasing trend during the period of observation while the trend shows by others are statistically not significant. Rainfall, wind speed and temperature show tolerable values which are not life threatening to the residents of Abeokuta. For vapour pressure, only months of January, August and December are safe but proper precautionary measures must be infused in other months in order to reduce problems of high blood pressure due to high vapour pressure. Since the relative humidity is higher than the tolerable limit of 60%, Abeokuta is subject to heat .Therefore, the residents should endeavor to provide themselves cooling systems for homeostasis to be engaged. Also, exposure time to sunlight should also be reduced in months of November and December respectively so as to avoid or reduce the aging of the skin due to excessive exposure to sunlight.

Include

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