A Comparative study of Time series, Empirical Orthogonal Transformation and Descriptive Statistical Analysis on Meteorological Parameters over Ogoja and Maiduguri

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ABSTRACT

In this paper, time series statistical analysis was carried out on the monthly average daily meteorological parameters of global solar radiation, sunshine hours, wind speed, mean temperature, rainfall, cloud cover and relative humidity during the period of thirty one years (1980 – 2010) using IBM SPSS Statistics version 20 with expert modeler to determine the level, trend and seasonal variations for Ogoja and Maiduguri. Seasonal Auto Regressive Integrated Moving Average models were determined for the two locations along with their respective statistical indicators of coefficient of determination, Root Mean Square Error, Mean Absolute Percentage Error and Mean Absolute Error and are found suitable for one step ahead forecast for the studied area. The factor analysis (empirical orthogonal transformation) and descriptive statistical analysis was also carried out for the study areas under investigation. The results indicated that the model type for all the meteorological parameters for Ogoja is simple seasonal while that for Maiduguri is simple seasonal except for rainfall and cloud cover with winter's additive and ARIMA models respectively. The correlation matrix obtained from the factor analysis for the studied area indicated that the global solar radiation and wind speed are more correlated with the mean temperature. The sunshine hours and mean temperature are more correlated with the global solar radiation. The rainfall is more correlated with the relative humidity; similarly, the relative humidity is more correlated with the rainfall. However, the cloud cover is more correlated to the rainfall for Ogoja while for Maiduguri the cloud cover is more correlated to the relative humidity. The component matrix analysis revealed that two seasons are identified for Ogoja; the rainy and dry seasons while for Maiduguri three seasons are identified; the rainy, cool dry (harmattan) and hot dry seasons. The skewness and kurtosis test for Ogoja indicated that the global solar radiation, sunshine hours, cloud cover and relative humidity are negatively skewed and the wind speed, mean temperature and rainfall are positively skewed while the global solar radiation, sunshine hours, wind speed, cloud cover and relative humidity indicates possibility of a leptokurtic distribution and the mean temperature and rainfall indicates possibility of a platykurtic distribution. The skewness and kurtosis for Maiduguri indicated that the solar radiation, rainfall and relative humidity are positively skewed and the sunshine hours, wind speed, mean temperature and cloud cover are negatively skewed while the global solar radiation, rainfall and cloud cover indicates possibility of a leptokurtic distribution and the sunshine hours, wind speed, mean temperature and relative humidity indicates possibility of a platykurtic distribution.

Keywords: Time series, factor analysis, descriptive statistics, meteorological parameters, Ogoja, Maiduguri.

1. INTRODUCTION

Solar radiation research is a field of rising interest due to its many applications, such as the study of evapotranspiration [1], optimization of water demand in irrigation, crop forecasting [2] and the adjustment of energy policies to promote solar energies, and research on climate change [3]. The process of converting sunlight to electricity without combustion allows creating power without direct pollution. In view of this, it is therefore necessary to propose some prediction models [4] that use this technology and to integrate solar energy photovoltaic (PV) production systems in the energetic mix [5]. Thus, solar energy forecasting is used to predict the amount of solar energy available in near terms [6]. Several methods have been developed by different researchers around the globe and the mathematical formalism of times series has often been used [7]. Time series has been defined as a set of numbers that measures the status of some activity over time. It is the historical record of some activity, with measurements taken at equally spaced intervals with a consistency in the activity and the method of measurement [8]. Autoregressive Integrated Moving Average (ARIMA) model has been studied extensively to time series analysis and forecasting. They were widespread by Box and Jenkins in the 1976s [9] making their names frequently used synonymously with general ARIMA models. Some of the best predictors found in literature are Autoregressive and moving average (ARMA) [7, 10]. The forecasting of the solar irradiance is currently done by statistical methods, among which the ARIMA model [11] is the most popular. In the research community, Autoregressive Moving Average (ARMA) methods are widely used and popular time series models compared to other models [12]. The ARMA model is able to extract many regions, useful statistical properties and can easily take on the familiar box-Jenkins method [13]. Also, these models are very flexible; thus, can be used in various types of time series with different orders. Lastly, it offers regular pervasive in individual phases (identification, estimation and diagnostic check) for a suitable model [14].

The Empirical orthogonal transformation (EOT) has become standard statistical techniques particularly in the field of climate and meteorological research and other fields such as geophysical sciences and oceanography [15]. This method of statistical analysis is used to condense any complicated data set into a finite and small number of new variables. It uses correlation between variable to determine a smaller number of new variables called components that can give vital information about the data [15].

The skewness and kurtosis are the basic components that are investigated in the descriptive statistical analysis. The skewness test (σ_k) measures the asymmetry of the independent meteorological parameters data around their mean value [16]. It tells us about the direction of variation of the dataset. If (i) the data have a Gaussian distribution (normal distribution) (ii) the data are spread out more to the left of the mean value than to its right (negatively skewed) (iii) the data are spread out more to the right than to its left (positively skewed). The Kurtosis test (k_u) describes the shape of a random variable's probability distribution, that is, it characterizes the relative peak or flatness of a distribution compared to the normal distribution. It measures the degree of normality of each of the meteorological parameters for the studied location [16].

In this present study, time series, Empirical Orthogonal Transformation (EOT) and descriptive statistical analysis on the meteorological parameters of monthly average daily global solar radiation, sunshine hours, wind speed, mean temperature, rainfall, cloud cover and relative humidity during the period of thirty one years (1980 – 2010) for two locations Ogoja and Maiduguri located in the coastal and sahelian regions of Nigeria were studied and compared.

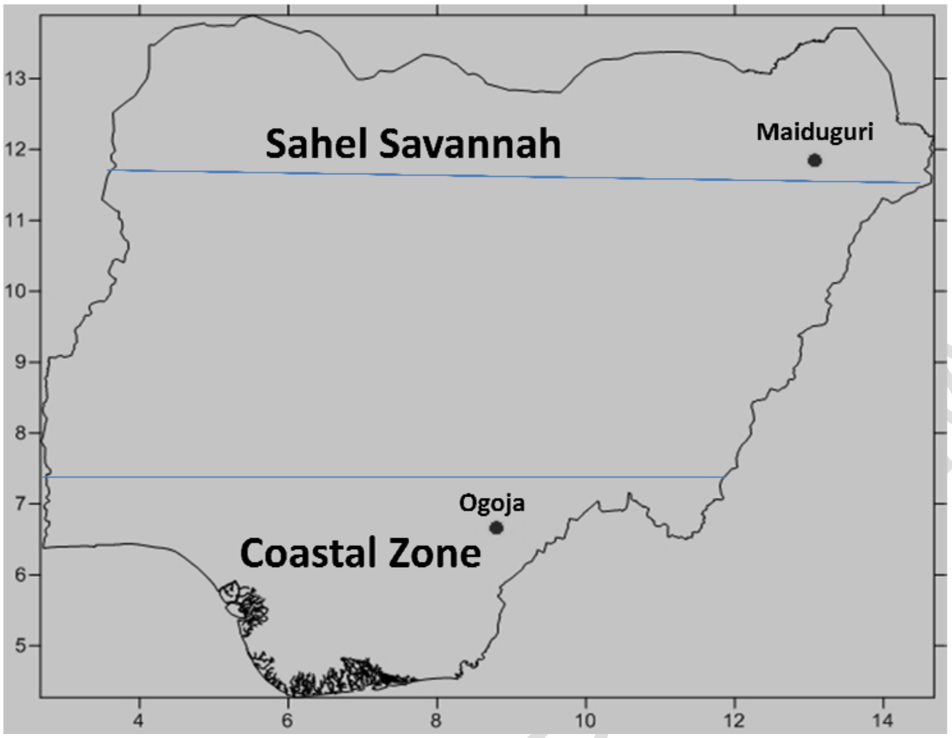

Fig. 1: Map of Nigeria showing the study areas

3. METHODOLOGY

3.1 STUDY AREA

Ogoja (Latitude 6.67.03^{0}N and Longitude 8.80^{0}E) is one of the Local Government Area in Cross River State, Nigeria. The town was one of the provinces during pre-colonial independence and is largely an agrarian area which is about 300 km north of Calabar, falls within the Coastal zone. It has many tribal units, including Ishibori (this village has different clans such as Uhmuria, Ikaptang, Ikajor, Ishinyema, Ikariku, Imerakorm) and Igoli as the central town. The key occupation of the people is subsistence agriculture, basically farming of cassava, yams, palm oil, palm wine etc. Ekajuk, is one of the major clan in Ogoja Local government area. Ogoja just like any other Coastal zone experiences two distinct seasons, the rainy and dry seasons. The rainy season lasts for about seven months, April to October while the dry season lasts from November to March.

Maiduguri (Latitude 11.85^{0}N and Longitude 13.08^{0}E) also known as Yerwa by its locals, is the capital city of Borno State in north-eastern Nigeria. The city sits along the seasonal Ngadda River which disappears into the Firki swamps in the areas around Lake Chad. The highest temperature recorded was 47 °C (117 °F) on 28 May, 1983. While the lowest temperature recorded was 5 °C (41 °F) on 26 December, 1979. Its residents are basically Muslim including Kanuri, Hausa, Shuwa, Bura, Marghi, and Fulani ethnic groups. Though, a good number of Christians from the Southern states like the Ijaw, Urhobo, Igbo, and Yoruba are also living in the city. Three seasons have been identified in Maiduguri found in the Sahelian zone: the cool dry (harmattan) season (October-March), hot dry season (April-June) and rainy season (July-September) [17]. Temperatures are usually high all the year round, with hot season temperatures under the shade. In the southern part of the state, the weather is relatively mild. In the extreme north, the rainy season lasts for less than eighty days, while in the extreme south; it can be as high as 140days. The mean annual rainfall is over 800 mm on the Biu Plateau but less than 500 mm the extreme north around Lake Chad. Changes in rainfall are over 100 %. Generally, the city experiences low relative humidity, which can be as low as 13 % in the driest months of February and March to the highest values of 70 to 80 % in the rainy season months of July and August.

3.2 STATISTICAL ANALYSIS

The measured monthly average daily global solar radiation, sunshine hours, wind speed, maximum and minimum temperature, rainfall, cloud cover and relative humidity data for Ogoja and Maiduguri were obtained from the Nigerian Meteorological Agency (NIMET). The period under focus is thirty one years (1980 – 2010). The mean temperature was obtained by taken the average of the maximum and minimum temperature.

The time series statistical analysis was carried out on the monthly averaged data using IBM SPSS Statistics version 20 with expert modeler, to determine the level, trend and seasonal variations of the meteorological parameters. The expert modeler determined whether Auto regression integration moving average (ARIMA) or exponential smoothing is the best based on which model gives the highest coefficient of determination (R^2).

An ARIMA model expresses the observation Z_t at the time t as a linear function of previous observations, a current error term and a linear combination of previous error terms. A seasonal ARIMA model is usually denoted $ARIMA\,(p,d,q) \times (P,D,Q)_s$ and contains the following terms: (1) $AR(p)$ – the non-seasonal autoregressive term of order p; (2) $I(d)$ – the non-seasonal differencing of order d; (3) $MA(q)$ – the non-seasonal moving average term of order q; (4) $AR_s(P)$ – the seasonal autoregressive term of order P; (5) $I(D)$ – the seasonal differencing of order D; (6) $MA_s(Q)$ – the seasonal moving average term of order Q.
In general the seasonal ARIMA model is expressed as [18]:

$$\phi_p(B)\Phi_P(B^s)\nabla^d\nabla_s^D Z_t = c + \theta_q(B)\Theta_Q(B^s)\varepsilon_t \qquad (1)$$

where B is the backshift operator defined by the expression:

$$BZ_t = Z_{t-1} \qquad (2)$$

where ε_t is the random error at time t usually assumed with normal distribution, zero mean and standard deviation σ_a (white noise). Sometimes an adjustment constant c is included in equation (1). The ARIMA model is developed using coefficients ϕ, Φ, θ and Θ obtained from the analysis.

$$\phi_p(B) = 1 - \phi_1 B - \phi_2 B^2 \dots\dots - \phi_p B^p \ , \ \theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 \dots\dots . -\theta_q B^q$$
$$\nabla^d = (1-B)^d \ , \ \nabla_s^D = (1-B^s)^D$$
$$\Phi_P(B^s) = 1 - \Phi_1 B^s - \Phi_2 B^{2s} \dots\dots . \Phi_P B^{ps} \ , \ \Theta_Q(B^s) = 1 - \Theta_1 B^s - \Theta_2 B^{2s} \dots\dots . \Theta_Q B^{Qs}$$

Other formulations using the concept of equation (1) and (2) are
$B^2 Z_t = Z_{t-2}$, $B^{12} Z_t = Z_{t-12}$, $\nabla Z_t = Z_t - Z_{t-1} = (Z_t - BZ_t) = (1-B)Z_t$, $\nabla^2 Z_t = \nabla(Z_t - Z_{t-1}) = \nabla Z_t - \nabla Z_{t-1}$, $\nabla_s Z_t = Z_t - Z_{t-s} = (1-B^s)Z_t$

ARIMA model ignores the independent variable completely, and uses past and present values of dependent variable to produce accurate short-term forecasting [19]. High values of stationary R^2 and R^2 are desirable also the smaller the values of Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), MaxAPE and MaxAE the better is the performance of the model.

The factor analysis using IBM SPSS Statistics version 20 was carried out to determine the correlation matrix, Kaiser-Meyer-Olkin (KMO) and Bartlett's test, scree plot and component matrix. The correlation matrix shows how each of the meteorological parameters is correlated to other parameters; the KMO and Bartlett's test measures the sampling adequacy and test of sphericity; the scree plot shows the variation of Eigenvalue with component number; the component matrix obtained for this study was to determine the prevalence of rainy/dry season in each component based on rainfall, relative humidity, solar radiation and mean temperature. High rainfall and relative humidity and low solar radiation and mean temperature indicates prevalence of rainy season while high solar radiation and mean temperature and low rainfall and relative humidity indicates prevalence of dry season.

The descriptive statistical analysis using IBM SPSS Statistics version 20 was carried out to determine the skewness, kurtosis and to compare the values of the meteorological parameters for the study areas under investigation. The skewness test (σ_k) measures the asymmetry of the six independent meteorological parameters data around their mean value; it is a measure of symmetry, or more precisely, the lack of symmetry. It tells us about the direction of variation of the dataset. If $\sigma_k = 0$, the data have a Gaussian distribution (normal distribution), while $\sigma_k < 0$ indicates that the data are spread out more to the left of the mean value than to its right (negatively skewed), when $\sigma_k > 0$ indicates that data are spread out more to the right than to its left (positively skewed) [16]. The Kurtosis test (k_u) describes the shape of a random variable's probability distribution, that is it characterizes the relative peakedness or flatness of a distribution compared to the normal distribution. It measures the degree of normality of each of the meteorological parameters under investigation [16]. For $k_u = 0$ the data have normal distribution, for $k_u > 0$ the data have positive kurtosis which implies peaked distribution, that is, leptokurtic distribution (that is, too tall), when $k_u < 0$ the data have negative kurtosis which implies flat distribution, that is, platykurtic distribution (that is, too flat, or even concave if the value is large enough).

4. RESULTS AND DISCUSSION

The time series, empirical orthogonal transformation (EOT) and descriptive statistical techniques has been employed to compare the variability for two locations, Ogoja and Maiduguri situated in the Sahelian and Coastal region of Nigeria using monthly average daily global solar radiation, sunshine hours, wind speed, mean temperature, rainfall, cloud cover and relative humidity meteorological data during the period of thirty one years (1980 – 2010).

4.1 TIME SERIES, EOT AND DESCRIPTIVE STATISTICAL ANALYSIS FOR OGOJA

Table 1 shows the model statistics for Ogoja. It was observed that the rainfall model has the highest value of stationary R^2 with 71.0% and was judged the best while wind speed and mean temperature has the least with 58.5%. Based on the coefficient of determination, R^2, the mean temperature model has the highest value with 75.4% and was judged the best while the cloud cover model has the least value with 26.4%. The RMSE, MAPE, MAE, MaxAPE and MaxAE are also given in the table. The values vary as each model is independent on others with different range of values.

Table 1: Model Statistics for Ogoja

Model	Model Fit statistics						
	Stationary R^2	R^2	RMSE	MAPE	MAE	MaxAPE	MaxAE
Global solar radiation-Model_1	0.592	0.574	1.623	8.353	1.123	547.401	11.885
Sunshine hour-Model_2	0.699	0.579	0.912	14.865	0.663	345.157	4.487
Wind speed-Model_3	0.585	0.526	0.774	15.425	0.562	139.642	6.401
T_{mean}-Model_4	0.585	0.754	0.693	1.876	0.52	9.507	2.538
Rainfall-Model_5	0.71	0.699	81.359	286.649	57.404	46163.6	363.879
Cloud cover-Model_6	0.68	0.264	0.222	1.857	0.123	32.971	1.484
Relative humidity-Model_7	0.689	0.729	7.22	8.499	4.766	113.422	30.624

The seasonal $ARIMA\ (1,0,0) \times (0,1,1)_{12}$ model with $AR = 0.474$ and $seasonal\ MA = 0.988$ developed for Ogoja with the solar radiation as dependent variable is given by the expression

$$Z_t = 0.474Z_{t-1} + Z_{t-12} - 0.474Z_{t-13} - 0.988\varepsilon_{t-12} + \varepsilon_t \qquad (3)$$

The R^2, RMSE, MAPE and MAE for Ogoja were found to be 55.3 %, 1.666 $MJm^{-2}day^{-1}$, 8.617 % and 1.153 % respectively and are significant at 95% confidence level with significant value of 0.

Table 2 shows the exponential smoothing model for the meteorological parameters for Ogoja. The results showed that all the parameters have only level and seasonal variations. It is obvious that the variation of the level is more dominant as compared to the seasonal variation since the significant level for the level is less than 0.05 while that of the seasonal variation is greater than 0.05 at 95% confidence level.

Table 2: Exponential Smoothing Model Parameters for Ogoja

Model			Estimate	Sig.
Global solar radiation-Model_1	No Transformation	Alpha (Level)	0.200	0
		Delta (Season)	5.53E-05	0.999

Sunshine hour-Model_2	No Transformation	Alpha (Level)	0.100	0
		Delta (Season)	2.76E-05	0.999
Wind speed-Model_3	No Transformation	Alpha (Level)	0.300	0
		Delta (Season)	9.65E-06	1
T_{mean}-Model_4	No Transformation	Alpha (Level)	0.400	0
		Delta (Season)	1.24E-05	1
Rainfall-Model_5	No Transformation	Alpha (Level)	0.099	0
		Delta (Season)	1.06E-05	1
Cloud cover-Model_6	No Transformation	Alpha (Level)	0.068	0
		Delta (Season)	0.186	0
Relative humidity-Model_7	No Transformation	Alpha (Level)	0.099	0
		Delta (Season)	3.57E-06	1

Table 3 shows that the model type for the model description is simple seasonal for all the meteorological parameters for Ogoja.

Table 3: Model Description for Ogoja

			Model Type
Model ID	Global solar radiation	Model_1	Simple Seasonal
	Sunshine hour	Model_2	Simple Seasonal
	Wind speed	Model_3	Simple Seasonal
	T_{mean}	Model_4	Simple Seasonal
	Rainfall	Model_5	Simple Seasonal

	Cloud cover	Model_6	Simple Seasonal
	Relative humidity	Model_7	Simple Seasonal

Table 4 presents the correlation matrix for Ogoja, it indicates how each of the meteorological parameters is correlated to other parameters. It was observed that the global solar radiation and wind speed are more correlated to the mean temperature with 53.4% and 28.6% respectively. The sunshine hours and mean temperature are more correlated to the global solar radiation with 45.2 % and 53.4% respectively. The rainfall is more correlated to the relative humidity with 68.0%. The cloud cover and relative humidity are more correlated to the rainfall with 22.3% and 68.0% respectively. The results showed that a negative correlation (inverse relationship) exists between the global solar radiation and the meteorological parameters of rainfall, cloud cover and relative humidity. Negative correlations (inverse relationship) exist between the sunshine hours and the meteorological parameters of rainfall, cloud cover and relative humidity. Negative correlations (inverse relationship) exist between the wind speed and the meteorological parameters of rainfall and relative humidity. Negative correlations (inverse relationship) exist between the mean temperature and the meteorological parameters of rainfall, cloud cover and relative humidity. Negative correlations (inverse relationship) exist between the rainfall and the meteorological parameters of global solar radiation, sunshine hours, wind speed and mean temperature. Negative correlations (inverse relationship) exist between the cloud cover and the meteorological parameters of global solar radiation, sunshine hours and mean temperature. Negative correlations (inverse relationship) exist between the relative humidity and the meteorological parameters of global solar radiation, sunshine hours, wind speed and mean temperature.

Table 4: Correlation matrix for Ogoja

		GSR	SSH	WS	T_{mean}	RF	CC	RH
Correlation	GSR	1	0.452	0.171	0.534	-0.374	-0.095	-0.353
	SSH	0.452	1	0.095	0.314	-0.402	-0.182	-0.367
	WS	0.171	0.095	1	0.286	-0.008	0.12	-0.163
	T_{mean}	0.534	0.314	0.286	1	-0.425	-0.003	-0.35
	RF	-0.374	-0.402	-0.008	-0.425	1	0.223	0.680
	CC	-0.095	-0.182	0.12	-0.003	0.223	1	0.207
	RH	-0.353	-0.367	-0.163	-0.35	0.680	0.207	1

In Table 5, the Kaiser-Meyer-Olkin (KMO) shows that the sampling adequacy of 71.2% was obtained. $\geq (0.05)$ or $\geq 50\%$ is the acceptable value and is in agreement with the study report by Aliyu et al. [15]. The Bartlett's test of sphericity gives degree of freedom of 21 and it's significant at 95% confidence level.

Table 5: KMO and Bartlett's Test for Ogoja

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.712
	Approx. Chi-Square	652.89
	df	21
Bartlett's Test of Sphericity	Sig.	0

Fig. 2 shows the scree plot for Ogoja. The scree plots which indicates the relationship between the eigenvalues and component numbers; to extract initial factors, the most common approach is to use a statistics called the eigenvalues. Eigenvalue is a measure that reflects the amount of variance in the original variables is set to be a decisive factor. The eigenvalue decreases from 2.80 to 0.30. According to SalahShour et al. [20], general agent are selected such that their eigenvalues are greater than one. It can be observed that the Eigenvalue greater than one for Ogoja is component 1 and 2.

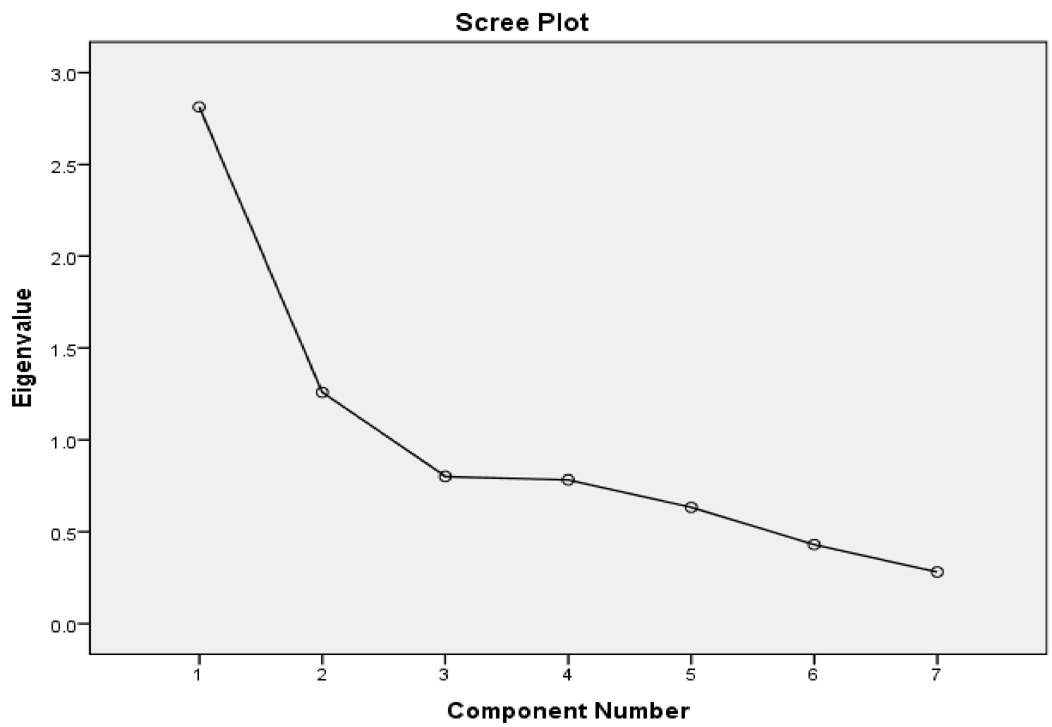

Fig.2: Scree Plot for Ogoja

The component matrix for Ogoja is given in Table 6. For component 1 the rainfall and relative humidity has negative correlation of 78.4% and 76.2% while global solar radiation and mean temperature has correlation of 72.4% and 70.4% this is an indication that the rainy season is prevalence. Component 2 shows that rainfall and relative humidity has correlation of 27.1% and 17.5% while solar radiation and mean temperature has correlation of 19.6% and 37.6% this is an indication that the dry season is prevalence. The overall results indicated that two seasons are identified in Ogoja; the rainy and dry seasons respectively.

Table 6: Component Matrix for Ogoja

	Component	
	1	2
Rainfall	-0.784	0.271
Relative humidity	-0.762	0.175

Global solar radiation	0.724	0.196
T_{mean}	0.704	0.376
Sunshine hour	0.672	-0.094
Wind speed	0.269	0.705
Cloud cover	-0.272	0.686

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 7 shows the descriptive statistics for Ogoja. It was observed that the global solar radiation, sunshine hours, cloud cover and relative humidity data spread out more to the left of their mean value (negatively skewed) and the wind speed, mean temperature and rainfall data spread out more to the right of their mean value (positively skewed). The global solar radiation, sunshine hours, wind speed, cloud cover and relative humidity data have positive kurtosis which indicates a relatively peaked distribution and possibility of a leptokurtic distribution and the mean temperature and rainfall data have negative kurtosis which indicates a relatively flat distribution and possibility of a platykurtic distribution. In the study carried out by Hejase and Assi [16] at Al Ain city – UAE, they found that the temperature, sunshine hours and global solar radiation spread out more to the left of their mean value (negatively skewed) and the wind speed and relative humidity spread out more to the right of their mean value (positively skewed). The wind speed and sunshine hours have positive kurtosis while the temperature, relative humidity and global solar radiation have negative kurtosis; comparing with the results for Ogoja in this study, it was observed that for the skewness test, there are differences in the temperature and relative humidity data and similarity in the wind speed, sunshine hours and global solar radiation data, while for the kurtosis test, there are differences in the relative humidity and global solar radiation data and similarity in the mean temperature, wind speed and sunshine hours data; the differences is due to atmospheric and climatic conditions associated with the locations
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The sum of global solar radiation, mean temperature, rainfall and relative humidity during the period under investigation for Ogoja are 5984.510 $MJm^{-2}day^{-1}$, 10270.100 ^{0}C, 58466.400 mm and 27115.000 % respectively.

Table 7: Descriptive Statistics for Ogoja

	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Skewness	Kurtosis
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
GSR	22.255	2.171	24.426	5984.510	16.087	2.482	-0.643	2.856
SSH	7.100	1.300	8.400	2149.900	5.779	1.403	-0.695	0.164
WS	8.700	1.100	9.800	1459.100	3.922	1.122	0.677	1.645
T_{mean}	7.800	24.000	31.800	10270.100	27.608	1.396	0.645	-0.112
RF	625.500	0.000	625.500	58466.400	157.168	147.977	0.637	-0.514

CC	2.800	4.500	7.300	2572.600	6.916	0.258	-4.699	30.589
RH	65.000	25.000	90.000	27115.000	72.890	13.845	-1.313	1.096

4.2 TIME SERIES, EOT AND DESCRIPTIVE STATISTICAL ANALYSIS FOR MAIDUGURI

Table 8 shows the model statistics for Maiduguri. It was observed that the rainfall model has the highest value of stationary R^2 with 71.1% and was judged the best while the cloud cover has the least with 52.6%. Based on the coefficient of determination, R^2, the relative humidity model has the highest value with 91.2% and was judged the best while the sunshine hour model has the least value with 49.3%. The RMSE, MAPE, MAE, MaxAPE and MaxAE are also given in the table. The values vary as each model is independent on others with different range of values.

Table 8: Model Statistics for Maiduguri

Model	Model Fit statistics						
	Stationary R^2	R^2	RMSE	MAPE	MAE	MaxAPE	MaxAE
Global solar radiation-Model_1	0.572	0.71	2.528	7.274	1.615	166.047	20.072
Sunshine hour-Model_2	0.647	0.493	0.939	9.671	0.737	55.483	3.273
Wind speed-Model_3	0.583	0.533	1.009	15.182	0.764	106.854	3.838
T_{mean}-Model_4	0.656	0.893	1.155	3.307	0.881	19.726	4.092
Rainfall-Model_5	0.711	0.755	37.557	306.443	23.113	30796.7	286.317
Cloud cover-Model_6	0.526	0.526	0.548	5.41	0.264	216.917	4.555
Relative humidity-Model_7	0.606	0.912	6.299	14.158	4.315	115.928	28.994

The seasonal $ARIMA\,(1,0,1)\times(0,1,1)_{12}$ model with $AR = 0.934$, $MA = 0.412$ and $seasonal\; MA = 0.967$ developed for Maiduguri with the solar radiation as dependent is given by the expression

$$Z_t = 0.934Z_{t-1} + Z_{t-12} - 0.934Z_{t-13} - 0.967\varepsilon_{t-1} - 0.967\varepsilon_{t-12} + 0.398\varepsilon_{t-13} + \varepsilon_t \quad (4)$$

The R^2, RMSE, MAPE and MAE for Maiduguri were found to be 69.7 %, 2.637 $MJm^{-2}day^{-1}$, 7.929 % and 1.760 % respectively.

Table 9 shows the exponential smoothing model for the meteorological parameters for Maiduguri. The results showed that all the parameters have only level and seasonal variations, except for rainfall with level, trend and seasonal variations and cloud cover with ARIMA model. It is obvious that the variation of the level is more dominant as compared to the trend and seasonal variations since the significant level for the level is less than 0.05 while that of the trend and seasonal variations are greater than 0.05 at 95% confidence level. The estimates of the ARIMA model for cloud cover are $constant = 6.655$; $AR = 0.619$; $MA = -0.47$ and $Seasonal$ $MA = -0.378$.

Table 9: Exponential Smoothing Model Parameters for Maiduguri

Model			Estimate	Sig.
Global solar radiation-Model_1	No Transformation	Alpha (Level)	0.500	0
		Delta (Season)	2.79E-06	1
Sunshine hour-Model_2	No Transformation	Alpha (Level)	0.100	0
		Delta (Season)	3.18E-05	0.999
Wind speed-Model_3	No Transformation	Alpha (Level)	0.400	0
		Delta (Season)	6.19E-05	0.998
T_{mean}-Model_4	No Transformation	Alpha (Level)	0.300	0
		Delta (Season)	2.96E-06	1
Rainfall-Model_5	No Transformation	Alpha (Level)	0.008	0.033
		Gamma (Trend)	4.53E-05	0.919
		Delta (Season)	0	0.981
Relative humidity-Model_7	No Transformation	Alpha (Level)	0.100	0
		Delta (Season)	8.87E-05	0.996

Table 10 shows that the model type for the model description is simple seasonal for all the meteorological parameters for Maiduguri, except for rainfall and cloud cover with winter's additive and ARIMA models respectively.

Table 10: Model Description for Maiduguri

Model ID			Model Type
	Global solar radiation	Model_1	Simple Seasonal
	Sunshine hour	Model_2	Simple Seasonal
	Wind speed	Model_3	Simple Seasonal
	T_{mean}	Model_4	Simple Seasonal
	Rainfall	Model_5	Winters' Additive
	Cloud cover	Model_6	ARIMA(1,0,9)(0,0,1)
	Relative humidity	Model_7	Simple Seasonal

Table 11 presents the correlation matrix for Maiduguri, it indicates how each of the meteorological parameters is correlated to other parameters. It was observed that the global solar radiation and wind speed are more correlated to the mean temperature with 28.1% and 23.7% respectively. The sunshine hours and mean temperature are more correlated to the solar radiation with 5.7 % and 28.1% respectively. The rainfall is more correlated to the relative humidity with 80.8%. The cloud cover is more correlated to the relative humidity with 27.2%. The relative humidity is more correlated to the rainfall with 80.8%. The results showed that a negative correlation (inverse relationship) exists between the global solar radiation and the meteorological parameters of rainfall, cloud cover and relative humidity. Negative correlations (inverse relationship) exist between the sunshine hours and the meteorological parameters of wind speed, mean temperature, rainfall, cloud cover and relative humidity. Negative correlations (inverse relationship) exist between the wind speed and the meteorological parameters of sunshine hours, rainfall, cloud cover and relative humidity. Negative correlations (inverse relationship) exist between the mean temperature and the meteorological parameter of sunshine hours. Negative correlations (inverse relationship) exist between the rainfall and the meteorological parameters of global solar radiation, sunshine hours and wind speed. Negative correlations (inverse relationship) exist between the cloud cover and the meteorological parameters of global solar radiation, sunshine hours and wind speed. Negative correlations (inverse relationship) exist between the relative humidity and the meteorological parameters of global solar radiation, sunshine hours and wind speed.

Table 11: Correlation Matrix for Maiduguri

		GSR	SSH	WS	T_{mean}	RF	CC	RH
Correlation	GSR	1	0.057	0.031	0.281	-0.251	-0.100	-0.273
	SSH	0.057	1	-0.036	-0.24	-0.502	-0.082	-0.495
	WS	0.031	-0.036	1	0.237	-0.001	-0.092	-0.120
	T_{mean}	0.281	-0.240	0.237	1	0.131	0.137	0.235
	RF	-0.251	-0.502	-0.001	0.131	1	0.205	0.808
	CC	-0.100	-0.082	-0.092	0.137	0.205	1	0.272
	RH	-0.273	-0.495	-0.120	0.235	0.808	0.272	1

In Table 12, the Kaiser-Meyer-Olkin (KMO) shows that the sampling adequacy of 59.0% was obtained. $\geq (0.05)$ or $\geq 50\%$ is the acceptable value and is in agreement with the study report by Aliyu et al. [15].The Bartlett's test of sphericity gives degree of freedom of 21 and it's significant at 95% confidence level.

Table 12: KMO and Bartlett's Test for Maiduguri

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.59
	Approx. Chi-Square	717.528
	df	21
Bartlett's Test of Sphericity	Sig.	0

Fig. 3 shows the Scree plot for Maiduguri. The scree plots which indicates the relationship between the eigenvalues and component numbers; to extract initial factors, the most common approach is to use a statistic called the eigenvalues. Eigenvalue is a measure that reflects the amount of variance in the original variables is set to be a decisive factor. The eigenvalue decreases from 2.40 to 0.20. According to SalahShour et al. [20], general agent are selected such that their eigenvalues are greater than one. It can be observed that the Eigenvalue greater than one for Maiduguri is component 1, 2 and 3.

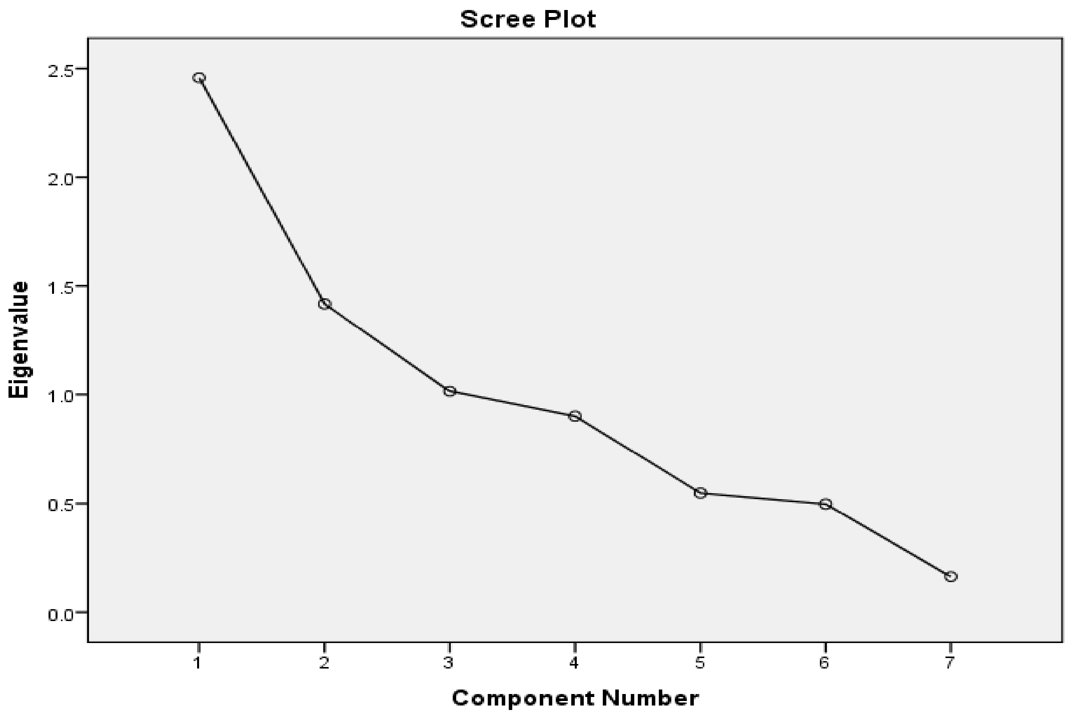

Fig. 3: Scree Plot for Maiduguri

The component matrix for Maiduguri is given in Table 13. For component 1 the relative humidity and rainfall has correlation of 91.3% and 88.5% while the mean temperature and global solar radiation has positive and negative correlation of 31.1% and 31.8% this is an indication that the rainy season is prevalence. Component 2 shows that the relative humidity and rainfall has negative correlation of 7.9% and 7.6% while the mean temperature and global solar radiation has correlation of 78.8% and 65.5% this is an indication that the hot dry season is prevalence. Component 3 shows that the relative humidity and rainfall has positive and negative correlation of 2.3% and 13.2% while the mean temperature and global solar radiation has correlation of 18.9% and 39.5% this is an indication that the cool dry (harmattan) season is prevalence. The overall results indicated that three seasons are identified in Maiduguri; the cool dry (harmattan) season, hot dry and rainy seasons respectively.

Table 13: Component Matrix for Maiduguri

	Component		
	1	2	3
Relative humidity	0.913	-0.079	0.023
Rainfall	0.885	-0.076	-0.132
Sunshine hour	-0.7	-0.213	0.154
T_{mean}	0.311	0.788	0.189

Global solar radiation	-0.318	0.655	0.395
Cloud cover	0.388	-0.066	0.634
Wind speed	-0.039	0.553	-0.617

Extraction Method: Principal Component Analysis.
a. 3 components extracted.

Table 14 shows the descriptive statistics for Maiduguri. It was observed that the solar radiation, rainfall and relative humidity data spread out more to the right of their mean value (positively skewed) and the sunshine hours, wind speed, mean temperature and cloud cover data spread out more to the left of their mean value (negatively skewed). The solar radiation, rainfall and cloud cover data have positive kurtosis which indicates a relatively peaked distribution and possibility of a leptokurtic distribution and the sunshine hours, wind speed, mean temperature and relative humidity data have negative kurtosis which indicates a relatively flat distribution and possibility of a platykurtic distribution. In the study carried out by Hejase and Assi [16] at Al Ain city – UAE, they found that the temperature, sunshine hours and global solar radiation spread out more to the left of their mean value (negatively skewed) and the wind speed and relative humidity spread out more to the right of their mean value (positively skewed). The wind speed and sunshine hours have positive kurtosis while the temperature, relative humidity and global solar radiation have negative kurtosis; comparing with the results for Maiduguri in this study, it was observed that for the skewness test, there are differences in the wind speed and global solar radiation data and similarity in the mean temperature, sunshine hours and relative humidity data, while for the kurtosis test, there are differences in the relative humidity and global solar radiation data and similarity in the mean temperature, wind speed and sunshine hours data; the differences is due to atmospheric and climatic conditions associated with the locations.

The sum of global solar radiation, mean temperature, rainfall and relative humidity during the period under investigation for Ogoja are 8579.549 $MJm^{-2}day^{-1}$, 10327.550 ^{0}C, 17847.700 mm and 14589.000 % respectively.

Table 14: Descriptive Statistics for Maiduguri

	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Skewness	Kurtosis
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
GSR	28.163	11.188	39.352	8579.549	23.063	4.686	0.141	0.454
SSH	6.400	4.400	10.800	3041.700	8.177	1.317	-0.303	-0.586
WS	7.000	2.100	9.100	2086.900	5.610	1.474	-0.107	-0.419
T_{mean}	16.500	18.400	34.900	10327.550	27.762	3.524	-0.340	-0.516
RF	371.600	0.000	371.600	17847.700	47.978	75.595	1.746	2.389
CC	5.300	1.900	7.200	2481.800	6.672	0.793	-3.419	13.128
RH	86.000	10.000	96.000	14589.000	39.218	21.228	0.447	-1.238

5. CONCLUSION

In this paper, the time series, factor and descriptive statistical analysis for Ogoja and Maiduguri using meteorological parameters of monthly average daily global solar radiation, sunshine hours, wind speed, maximum and minimum temperature, rainfall, cloud cover and relative humidity during the period of thirty one years (1980 – 2010) has been addressed. ARIMA model for Ogoja and Maiduguri were developed along with their respective statistical indicators of R^2, RMSE, MAPE and MAE. The result indicated that the models are suitable for one step ahead forecast for the locations. Furthermore, the time series analysis for Ogoja shows that the patterns of variation for the meteorological parameters are level and seasonal with the level variation been dominant. For Maiduguri, the pattern of variation is also level and seasonal except for rainfall where level, trend and seasonal variations were observed and ARIMA model for cloud cover. The correlation matrix obtained from the factor analysis for the locations indicated that the global solar radiation and wind speed are more correlated to the mean temperature. The sunshine hours and mean temperature are more correlated to the global solar radiation. The rainfall is more correlated to the relative humidity and the relative humidity is more correlated to the rainfall. However, the cloud cover is more correlated to the rainfall for Ogoja while for Maiduguri the cloud cover is more correlated to the relative humidity. The scree plots revealed that eigenvalues greater than one are found from component numbers 1 and 2 for Ogoja and 1, 2 and 3 for Maiduguri. It was observed that the component matrix analysis for Ogoja has two components indicating prevalence of rainy and dry seasons respectively while for Maiduguri has three components indicating prevalence of rainy, cool dry (harmattan) and hot dry seasons respectively. Based on skewness and kurtosis test, the result indicated that for Ogoja, the global solar radiation is negatively skewed and the wind speed and mean temperature are positively skewed while the sunshine hours, wind speed and relative humidity indicates possibility of a leptokurtic distribution. For Maiduguri, the global solar radiation is positively skewed and the wind speed and mean temperature are negatively skewed and the sunshine hours, wind speed and relative humidity indicates possibility of a platykurtic distribution. The rainfall and relative humidity for Ogoja is greater than that of Maiduguri while the global solar radiation and mean temperature for Maiduguri is greater than that of Ogoja, this is expected as Ogoja is a Coastal zone while Maiduguri is a Sahelian zone.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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