ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2521-0831 (Print)
ISSN: 2521-084X(Online)
CODEN: MSMAD

Matrix Science Mathematic (MSMK)

DOI: http://doi.org/10.26480/msmk.01.2022.05.12

CrossMark

RESEARCH ARTICLE

MULTIVARIATE MODELS FOR PREDICTING GLOBAL SOLAR RADIATION IN JOS, NIGERIA

D.O. Akpootu[a]*, M. I. Iliyasu[b], B.M. Olomiyesan[c], S.A. Fagbemi[d], S.B. Sharafa[a], M. Idris[e], Z. Abdullahi[f], N.O. Meseke[g]

[a] Department of Physics, Usmanu Danfodiyo University, Sokoto, Nigeria
[b] Physics Unit, Umaru Ali Shinkafi Polytechnic, Sokoto, Nigeria
[c] Examination Development Department, National Examinations Council (NECO)
[d] Department of Physics, Federal University Dutsin-Ma, Katsina, Nigeria
[e] Department of Physics, Bayero University, Kano, Nigeria
[f] Department of Physics, Adamu Augie College of Education, Kebbi State, Nigeria
[g] Department of Physics, University of Ilorin, Nigeria
**Corresponding Author E-mail: davidson.odafe@udusok.edu.ng*

ARTICLE DETAILS

Article History:

Received 28 May 2022
Accepted 30 June 2022
Available online 06 July 2022

ABSTRACT

This study developed two to six multivariate regression equations that reliably predict global radiation in Jos (Latitude 9.87 °N and Longitude 8.75 °E). Thirty-one years (1980 – 2010) observed monthly mean daily global solar radiation, sunshine hours, maximum and minimum temperatures, cloud cover, rainfall, relative humidity and wind speed data were used in this study with the clearness index as the response variable and other variables as predictors. The seven validation indices employed are the coefficient of determination (R^2), Mean Bias Error (MBE), Root Mean Square Error (RMSE), Mean Percentage Error (MPE), t – test, Nash – Sutcliffe Equation (NSE) and Index of Agreement (IA) to determine the reliability, suitability and applicability of the developed models. The results in this study revealed that all the developed multivariate models were found reliable for global solar radiation estimation in Jos depending on the obtainable meteorological data measured in the location. The correlation between the measured and predicted (developed) global solar radiation shows a perfect correlation as depicted from the figures.

KEYWORDS

multivariate regression models, global solar radiation, meteorological parameters, validation indices, Jos

1. INTRODUCTION

The energy emanated from the sun in radiant form to the earth's surface is referred to as solar radiation (Akpootu et al., 2019a). The solar radiation has been considered as the main significant input parameter used for the design and in evaluating solar energy devices. Also, solar energy is top most among the various alternative sources of energy due to the fact that it is the energy from the sun (Gana and Akpootu, 2013a). The ultimate sources of renewable energy in nature are the solar radiation arriving on the surface of the earth (Akpootu and Sulu, 2015). The world most cleanest abundant renewable energy is the solar energy (Olomiyesan et al., 2015). With the decrease in cost and rapid improvement in technology of solar energy as a renewable energy with potential to mitigate some of the negative environmental problems; it still have a significant position in the energy structure (Despotovic et al., 2015; Freitas et al., 2015). Technology for measuring solar radiation is expensive and has high risk in the use of the instruments (Alam et al., 2005). Thus, there is the need to come up with other methods for estimating this important parameter.

One of the methods employed is the use of empirical models. Accurate modeling strongly relies on the quality and quantity of the measured data and this is an excellent method for the determination of solar radiation at regions where measured data are lacking (Al-Salihi et al., 2010). Several studies have been done on global solar radiation prediction. Few studies carried in Nigeria include: Gana and Akpootu compares the predictability of four sunshine based models in Kebbi (Gana and Akpootu, 2013b). The result in their study revealed that model 2 (quadratic equation) which is the empirical regression equation based on performed better the best (Ogelman et al., 1984). Akpootu and Iliyasu developed one to six variable correlation models to investigate the impact of some meteorological variables on the estimation of global solar radiation in Kano, Northwestern, Nigeria (Akpootu and Iliyasu, 2015a). According to them, the developed models were found suitable based on the six validation indices employed. Akpootu and Sanusi developed new temperature-based model for estimating global solar radiation in Portharcourt (Akpootu and Sanusi, 2015).

The empirical model developed is a multivariate temperature-based model that contains the differences in temperature and temperature ratio terms. Other studies include (Falayi, 2013; Ajayi et al., 2014; Akpootu and Iliyasu, 2015b). The few distinct studies that have been carried out for the estimation of global solar radiation at various locations across the different climatic zones in Nigeria which developed new sunshine and temperature dependent models through the modification of the existing models and the validation indices improved greatly and performed better than the existing are found in the studies done (Akpootu et al., 2019b; Akpootu et al., 2019c; Akpootu et al., 2019d). The aim of this investigation is to develop two to six multivariate equations that reliably predict global solar radiation for Jos using measured monthly average daily global solar radiation, sunshine hours, maximum and minimum temperatures, cloud cover, rainfall, relative humidity, and wind speed data. The developed models were tested statistically using seven validation indices.

Quick Response Code	Access this article online	
	Website: www.matrixsmathematic.com	**DOI:** 10.26480/msmk.01.2022.05.12

Cite The Article: D.O. Akpootu, M. I. Iliyasu, B.M. Olomiyesan, S.A. Fagbemi, S.B. Sharafa, M. Idris, Z. Abdullahi, N.O. Meseke (2022). Multivariate Models for Predicting Global Solar Radiation in Jos, Nigeria. *Matrix Science Mathematic, 6(1): 05-12.*

2. METHODOLOGY

2.1 Acquisition of Data

Optimal climate modelling is guaranteed, if the data used are extended for at least thirty years (WMO, 1967; Ojo and Adeyemi 2014). Based on this fact, the measured monthly average daily global solar radiation, sunshine hours, wind speed, maximum and minimum temperatures, rainfall, cloud cover and relative humidity meteorological data for the period of thirty-one years (1980-2010) was utilized in this study. The meteorological data were obtained from the Nigerian Meteorological Agency (NIMET), Oshodi, Lagos, Nigeria. The multivariate empirical were developed using twenty-five (25) (1980- 2004) years data while the models were validated using six (6) years (2005-2010) data. The location under investigation is Jos (Latitude 9.87 $°N$ and Longitude 8.75 $°E$).

2.2 Regression Analysis

The monthly average daily extraterrestrial radiation on a horizontal surface (H_o) can be calculated for days giving average of each month was computed through the equation (Iqbal, 1983):

$$H_o = \left(\frac{24}{\pi}\right) I_{sc}\left[1 + 0.033cos\left(\frac{360n}{365}\right)\right]\left[cos\varphi cos\delta sin\omega_s + \left(\frac{2\pi\omega_s}{360}\right)\sin\varphi\sin\rho\right] \quad (1)$$

The solar constant, $I_{sc} = 1367\ Wm^{-2}$, φ is the latitude of the region, ρ is the solar declination and ω_s is the mean sunrise hour angle for the given month and n is the number of days of the year starting from 1^{st} of January to 31^{st} of December. The solar declination (ρ) and the mean sunrise hour angle (ω_s) are estimated using equations (2) and (3) (Iqbal, 1983):

$$\rho = 23.45\sin\left\{360\left(\frac{284+n}{365}\right)\right\} \quad (2)$$

$$\omega_s = cos^{-1}(-\tan\varphi\tan\rho) \quad (3)$$

The maximum possible sunshine duration, monthly average day length (S_o) in hours for a given month was calculated using the equation (Iqbal, 1983).

$$S_o = \frac{2}{15}\omega_s \quad (4)$$

The clearness index (K_T) has been defined using equation (5) (Falayi et al., 2011)

$$K_T = \frac{H}{H_o} \quad (5)$$

Multivariate equation for estimating the global solar radiation with the clearness index as the dependent variable and the six independent meteorological variables is given as (Akpootu et al., 2019a).

$$\frac{H}{H_0} = a + bx_1 + cx_2 + dx_3 + ex_4 + fx_5 + gx_6 \quad (6)$$

where $a \dots\dots..g$ are the regression coefficients and $x_1 \dots\dots.x_6$ are the parameters that are correlated. In this study, the number of ways by which the meteorological variables are combined was obtained using the expression (Akpootu et al., 2019a). The K_T is the response variable while other variables are the predictors.

$$n_{C_r} = \frac{n!}{(n-r)!r!} \quad (7)$$

where n is the total number of meteorological variables under study and r is the number of meteorological variables that will be combined. High R^2 has been selected for further statistical analysis based on the method described (Akpootu et al., 2019a).

2.3 Validation of the Developed Models

The predicted values of the multivariate regression models were statistically validated by calculating the Mean Bias Error (MBE), Root Mean Square Error (RMSE), Mean Percentage Error (MPE), t-test, Nash-Sutcliffe equation (NSE) and the Index of Agreement (IA). Also, the R^2 was determined. The validation indices are obtained through the equations (El-Sebaii and Trabea, 2005).

$$MBE = \frac{1}{n}\sum_{i=1}^{n}\left(H_{i,cal} - H_{i,mea}\right) \quad (8)$$

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}\left(H_{i,cal} - H_{i,mea}\right)^2\right]^{\frac{1}{2}} \quad (9)$$

$$MPE = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{H_{i,mea}-H_{i,cal}}{H_{i,mea}}\right) * 100 \quad (10)$$

The t-test with $(n-1)$ degrees of freedom according to a study is: (Bevington, 1969)

$$t = \left[\frac{(n-1)(MBE)^2}{(RMSE)^2-(MBE)^2}\right]^{\frac{1}{2}} \quad (11)$$

The detailed descriptions of the t – test validation is found in (Akpootu et al., 2019b; Akpootu et al., 2019d).

The Nash-Sutcliffe equation (NSE) was calculated using the equation (Jiandong et al., 2012)

$$NSE = 1 - \frac{\sum_1^n\left(H_{i,mea}-H_{i,cal}\right)^2}{\sum_1^n\left(H_{i,mea}-\bar{H}_{i,meas}\right)^2} \quad (12)$$

Willmott defined the Index of Agreement (IA) using the equation (Willmott, 1981).

$$IA = 1 - \frac{\sum_{i=1}^{n}\left(H_{i,cal}-H_{i,mea}\right)^2}{\sum_{i=1}^{n}\left(\left|H_{i,cal}-\bar{H}_{i,mea}\right|+\left|H_{i,mea}-\bar{H}_{i,meal}\right|\right)^2} \quad (13)$$

From equations (8) – (13), $H_{i,mea}$, $H_{i,cal}$ and n are the i^{th} measured and i^{th} calculated values of daily global solar radiation and the total number of observations respectively, similarly, $\bar{H}_{i,mea}$ is the mean measured global radiation. Zero value for MBE have been reported to be ideal by (Halouani et al., 1993; Almorox et al., 2005; Chen et al., 2004). Positive and negative values of MPE and MBE imply overestimation and underestimation respectively in their calculated values. The acceptable range of percentage error is $\pm 10\%$ (Merges et al., 2006). The lower the value of MBE, RMSE, MPE and t – test, the better is the performance of the model. Similarly, the higher the value of the R^2, NSE and IA the better is the performance of the model as well. The MBE and RMSE are measured in $MJm^{-2}day^{-1}$, while R^2, MPE, NSE and IA are in percentage (%), t – test is non dimensional.

3. RESULTS AND DISCUSSION

3.1 Multivariate Regression Models for Jos

The multivariate regression models for two variable correlations for Jos are

$$\frac{H}{H_0} = 0.562 + 0.291\frac{S}{S_0} - 0.00254\ RH \quad (14a)$$

$$\frac{H}{H_0} = 0.984 - 0.00779\ T_{mean} - 0.00406\ RH \quad (14b)$$

$$\frac{H}{H_0} = 1.40 - 0.000526\ RF - 0.113\ CC \quad (14c)$$

$$\frac{H}{H_0} = 1.17 - 0.0635\ CC - 0.00295\ RH \quad (14d)$$

$$\frac{H}{H_0} = 0.881 - 0.00588\ WS - 0.00424\ RH \quad (14e)$$

Table 1: Statistical validation indices for two variable correlation models

Models	R^2	MBE	RMSE	MPE	t	NSE	IA
Eqn.14a	99.0	-0.0082	0.3832	0.0450	0.0706	99.6097	99.9025
Eqn.14b	98.6	-0.0176	0.4375	0.0564	0.1335	99.4913	99.8725
Eqn.14c	98.5	0.1067	0.4547	-0.5243	0.8004	99.4504	99.8645
Eqn.14d	98.2	-0.0352	0.4938	0.1541	0.2368	99.3520	99.8374
Eqn.14e	97.6	-0.0057	0.5656	0.0686	0.0337	99.1497	99.7890

Table 1 shows the validation indices for the two variable correlations for Jos. The model (Eqn. 14a) has the highest value of R^2 with 99.0 %. The model (Eqn. 14e) has the lowest MBE value with underestimation of 0.0057 $MJm^{-2}day^{-1}$ in its predicted value. The model (Eqn. 14a) has the lowest RMSE value of 0.3832 $MJm^{-2}day^{-1}$. The model (Eqn. 14a) has the lowest MPE value with overestimation of 0.0450 % in its predicted value. The model (Eqn. 14e) has the lowest $t-$ test value of 0.0337. The model (Eqn. 14a) has the highest NSE and IA value with 99.6097 % and 99.9025 % respectively.

Table 2: Rank obtained for the two variable correlation models for Jos

Models	R^2	MBE	RMSE	MPE	t	NSE	IA	Rank
Eqn.14a	1	2	1	1	2	1	1	9
Eqn.14b	2	4	2	2	3	2	2	17
Eqn.14c	3	5	3	5	5	3	3	27
Eqn.14d	4	3	4	4	4	4	4	27
Eqn.14e	5	1	5	3	1	5	5	25

The various ranks obtained by for the two multivariate regression models (Table 2) are within the range of 9 to 27. In general, the results revealed that the model equation (Eqn. 14a) that relates the response variable with the predictor variables of sunshine duration and relative humidity was found more suitable for global solar radiation prediction in Jos as compared to other multivariate models.

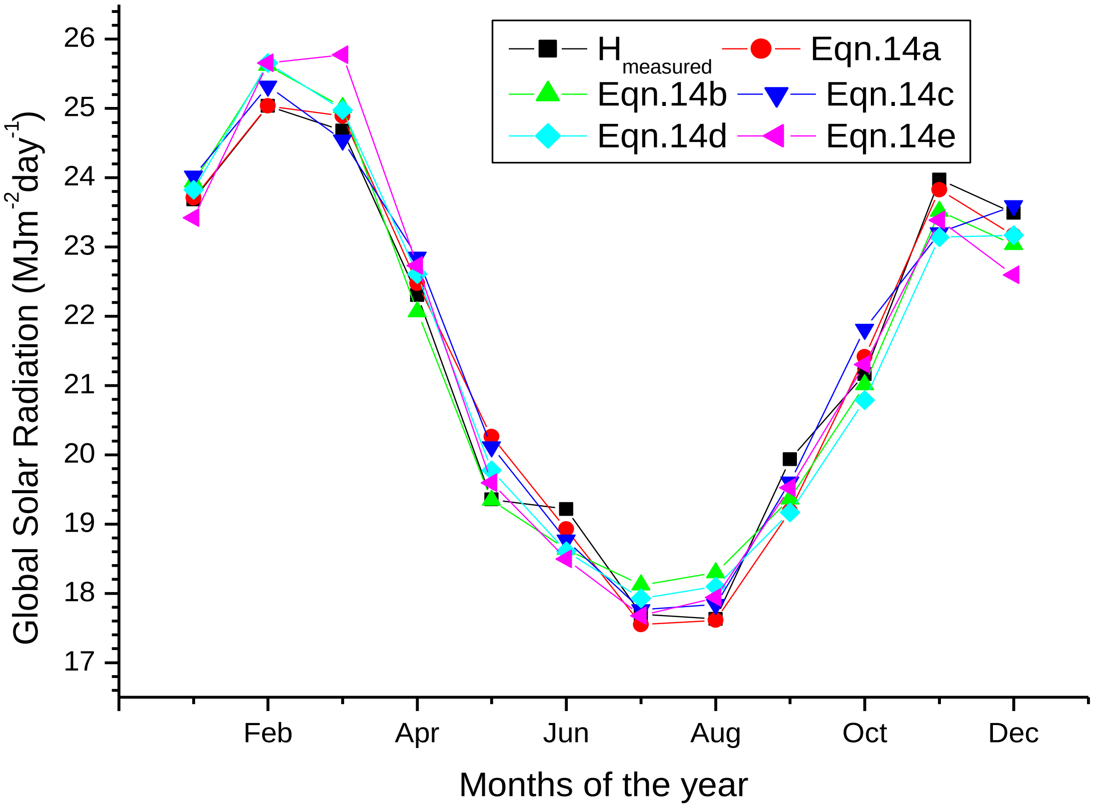

Figure 1: Correlation between the measured and estimated global solar radiation for two variable correlations in Jos

Figure 1 displayed the correlation between the measured and the predicted global solar radiation for two variable correlations in Jos. The figure shows that all the predicted models underestimated the measured global solar radiation in the months of June, September and November. It is apparent that the model (Eqn. 14c) overestimated the measured and other estimated models in the months of April, October and December; similarly, are the model (Eqn. 14e) in March and the model (Eqn. 14a) in the month of May.

The multivariate regression models for three variable correlations for Jos are:

$$\frac{H}{H_0} = 0.722 + 0.224\frac{S}{S_0} - 0.00470\, T_{mean} - 0.00287\, RH \quad (15a)$$

$$\frac{H}{H_0} = 0.629 + 0.293\frac{S}{S_0} - 0.00646\, WS - 0.00267\, RH \quad (15b)$$

$$\frac{H}{H_0} = 0.737 + 0.252\frac{S}{S_0} - 0.0254\, CC - 0.00229\, RH \quad (15c)$$

$$\frac{H}{H_0} = 0.995 - 0.00970\, T_{mean} - 0.000335\, RF - 0.00276\, RH \quad (15d)$$

$$\frac{H}{H_0} = 0.556 + 0.306\,\frac{S}{S_0} + 0.000086\, RF - 0.00279\, RH \quad (15e)$$

Table 3: Statistical validation indices for three variable correlation models

Models	R^2	MBE	RMSE	MPE	t	NSE	IA
Eqn.15a	99.3	0.0231	0.3115	-0.1345	0.2468	99.7422	99.9357
Eqn.15b	99.1	-0.0106	0.3502	0.0630	0.1004	99.6740	99.9185
Eqn.15c	99.1	-0.0276	0.3670	0.1241	0.2506	99.6421	99.9102
Eqn.15d	99.1	0.0037	0.3519	-0.0327	0.0353	99.6710	99.9178
Eqn.15e	99.0	-0.0293	0.3795	0.1370	0.2570	99.6172	99.9040

Table 3 shows the validation indices for the three variable correlations for Jos. The model (Eqn. 15a) has the highest value of R^2 with 99.3 %. The model (Eqn. 15d) has the lowest MBE and is overestimated by 0.0037 $MJm^{-2}day^{-1}$ in its predicted value. The model (Eqn. 15a) has the lowest value of RMSE with 0.3115 $MJm^{-2}day^{-1}$. The model (Eqn. 15d) has the lowest value of MPE with 0.0327 % underestimated predicted value. The model (Eqn. 15d) has the lowest $t-$ test value of 0.0353. The model (Eqn. 15a) was found to be having the highest value of NSE and IA with 99.7422 % and 99.9357 % respectively.

Table 4: Rank obtained for the three variable correlation models for Jos

Models	R^2	MBE	RMSE	MPE	t	NSE	IA	Rank
Eqn.15a	1	3	1	4	3	1	1	14
Eqn.15b	2	2	2	2	2	2	2	14
Eqn.15c	2	4	4	3	4	4	4	25
Eqn.15d	2	1	3	1	1	3	3	14
Eqn.15e	3	5	5	5	5	5	5	33

The various ranks obtained for the three multivariate regression models (Table 4) are within the range of 14 to 33. In general, the results revealed that the model equations (Eqn. 15a, 15b and 15d) that relate the response variable with the predictor variables found in the equations were found more suitable for global solar radiation prediction in Jos as compared to other multivariate models.

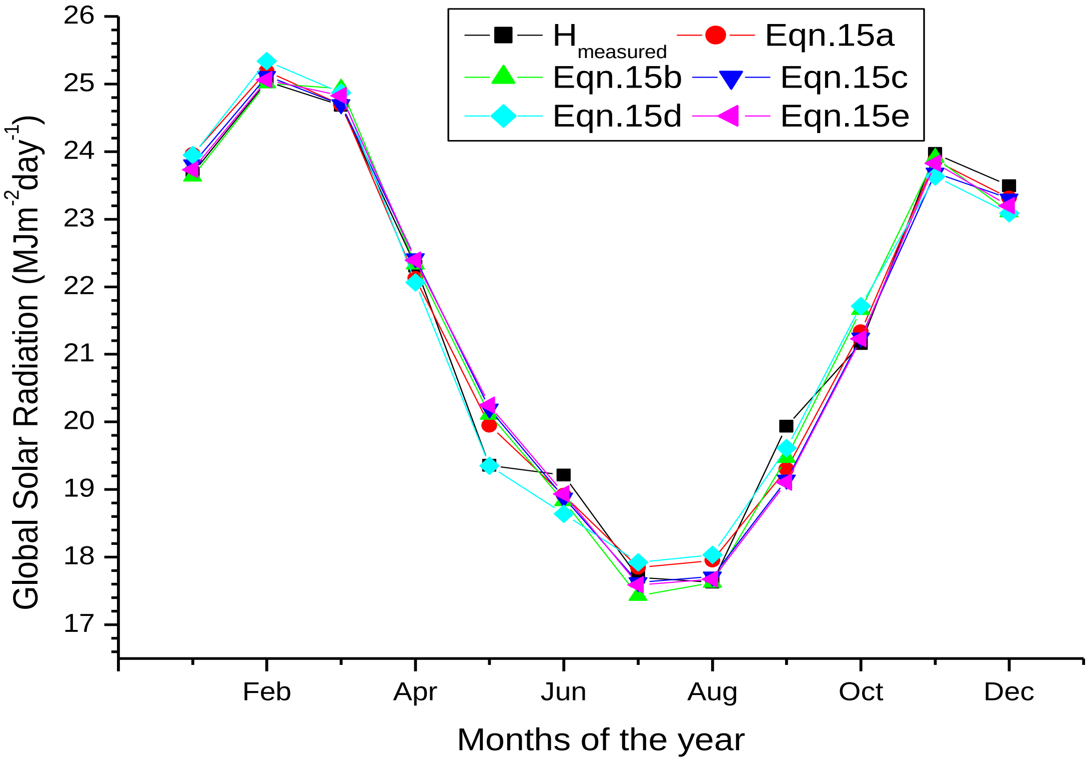

Figure 2: Correlation between the measured and estimated global solar radiation for three variable correlations in Jos

Figure 2 displayed the correlation between the measured and the predicted global solar radiation for three variable correlations in Jos. The figure shows that all the predicted models were found to have underestimated the measured global solar radiation in the months of June, September, November and December.

The multivariate regression models for four variable correlations for Jos are

$$\frac{H}{H_0} = 0.772 + 0.229\frac{S}{S_0} - 0.00563\ WS - 0.00448\ T_{mean} - 0.00297\ RH \quad (16a)$$

$$\frac{H}{H_0} = 1.02 + 0.218\ \frac{S}{S_0} - 0.0112\ WS - 0.0499\ CC - 0.00227\ RH \quad (16b)$$

$$\frac{H}{H_0} = 0.678 + 0.350\frac{S}{S_0} - 0.0132\ WS\ - 0.000308\ RF - 0.00369\ RH \quad (16c)$$

$$\frac{H}{H_0} = 0.776 + 0.181\frac{S}{S_0} - 0.00605\ T_{mean} - 0.000133\ RF - 0.00258\ RH \quad (16d)$$

$$\frac{H}{H_0} = 0.641 + 0.234\frac{S}{S_0} - 0.00589\ T_{mean} + 0.0174\ CC\ - 0.00313\ RH \quad (16e)$$

Table 5: Statistical validation indices for four variable correlation models

Models	R^2	MBE	RMSE	MPE	t	NSE	IA
Eqn.16a	99.4	-0.0139	0.2835	0.0492	0.1623	99.7864	99.9464
Eqn.16b	99.4	-0.1093	0.3093	0.5077	1.2521	99.7457	99.9354
Eqn.16c	99.4	-0.0226	0.2981	0.0948	0.2524	99.7639	99.9408
Eqn.16d	99.4	0.0057	0.2958	-0.0485	0.0635	99.7675	99.9418
Eqn.16e	99.4	-0.0176	0.3048	0.0631	0.1922	99.7532	99.9381

Table 5 shows the validation indices for the four variable correlations for Jos. All the models have the same R^2 (99.4%). The model (Eqn. 16d) has the lowest MBE value with overestimation of 0.0057 $MJm^{-2}day^{-1}$ in its predicted value. The model (Eqn. 16a) has the lowest value of RMSE with 0.2835 $MJm^{-2}day^{-1}$. The model (Eqn. 16d) has the lowest MPE which underestimated 0.0485 % in its predicted value. The model (Eqn. 16d) has the lowest value of $t-$ test with 0.0635. The model (Eqn. 16a) has the best (highest) value of NSE and IA with 99.7864 % and 99.9464 % respectively.

Table 6: Rank obtained for the four variable correlation models for Jos								
Models	**R^2**	**MBE**	**RMSE**	**MPE**	**t**	**NSE**	**IA**	**Rank**
Eqn.16a	1	2	1	2	2	1	1	10
Eqn.16b	1	5	5	5	5	5	5	31
Eqn.16c	1	4	3	4	4	3	3	22
Eqn.16d	1	1	2	1	1	2	2	10
Eqn.16e	1	3	4	3	3	4	4	22

The various ranks obtained for the four variable multivariate regression models (Table 6) are within the range of 10 to 31. In general, the results revealed that the model equations (Eqn. 16a and 16d) that relates the response variable with the other predictor variables were found more suitable for global solar radiation prediction in Jos as compared to other multivariate models.

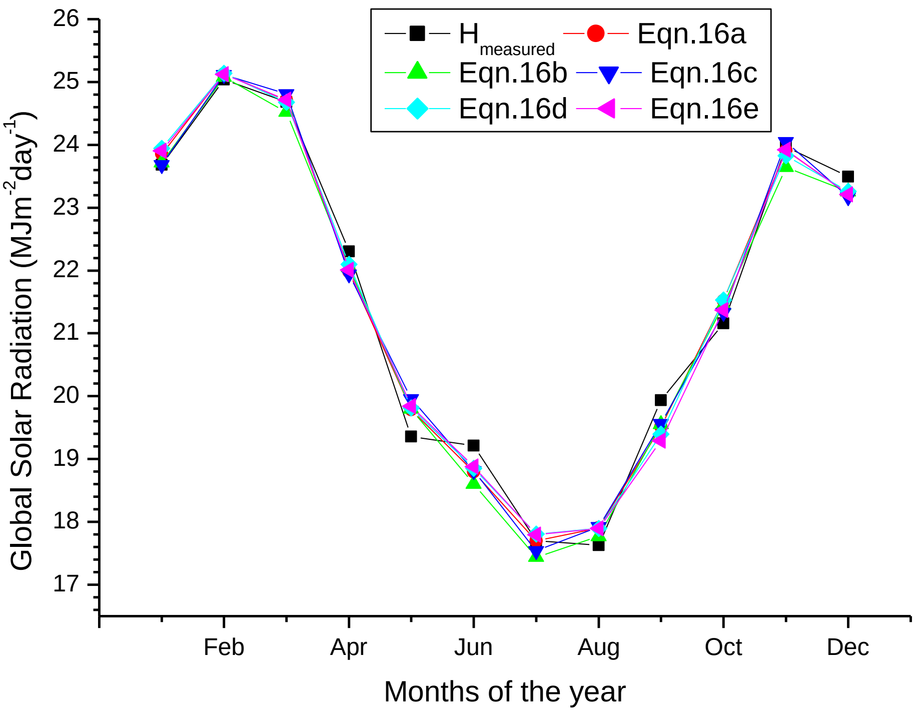

Figure 3: Correlation between the measured and estimated global solar radiation for four variable correlations in Jos

Figure 3 displayed the correlation between the measured and the predicted global solar radiation for four variable correlations in Jos. The figure clearly shows that all the predicted models overestimated the measured global solar radiation in the months of May, August and October and underestimated the measured in the months of June, September and December. It is clear that the model (Eqn. 16b) underestimated the measured and other estimated models in the months from March, June, July and November.

The multivariate regression models for five variable correlations for Jos are

$$\frac{H}{H_0} = 0.915 + 0.276\frac{S}{S_0} - 0.0133\, WS + 0.000173\, RF - 0.0328\, CC - 0.00298\, RH \quad (17a)$$

$$\frac{H}{H_0} = 0.894 + 0.219\frac{S}{S_0} - 0.00799\, WS - 0.00290\, T_{mean} - 0.0218\, CC - 0.00268\, RH \quad (17b)$$

$$\frac{H}{H_0} = 0.753 + 0.263\frac{S}{S_0} - 0.00797\, WS - 0.00339\, T_{mean} + 0.000098\, RF - 0.00322\, RH \quad (17c)$$

Table 7: Statistical validation indices for five variable correlation models							
Models	**R^2**	**MBE**	**RMSE**	**MPE**	**t**	**NSE**	**IA**
Eqn.17a	99.5	-0.0033	0.2808	0.0006	0.0392	99.7904	99.9475
Eqn.17b	99.5	0.0242	0.2810	-0.1349	0.2862	99.7902	99.9476
Eqn.17c	99.4	0.0015	0.2827	-0.0247	0.0181	99.7876	99.9469

Table 7 shows the validation indices for the five variable multivariate regression models for Jos. The models (Eqn. 17a and Eqn. 17b) have the highest value of R^2 with 99.5 %. The model (Eqn. 17c) has the lowest MBE and 0.0015 $MJm^{-2}day^{-1}$ overestimated predicted value. The model (Eqn. 17a) has the lowest RMSE with 0.2808 $MJm^{-2}day^{-1}$ value. The model (Eqn. 17a) having the lowest value of MPE with 0.0006% overestimation in its predicted value. The model (Eqn. 17c) has the lowest $t-$ test value of 0.0181. (Eqn. 17a) has the best (highest) NSE value with 99.7904 % and (Eqn. 17b) has the best (highest) IA value with 99.9476 %.

Table 8: Rank obtained for the five variable correlation models for Jos								
Models	**R^2**	**MBE**	**RMSE**	**MPE**	**t**	**NSE**	**IA**	**Rank**
Eqn.17a	1	2	1	1	2	1	2	10
Eqn.17b	1	3	2	3	3	2	1	15
Eqn.17c	2	1	3	2	1	3	3	15

The various ranks obtained for the five variable correlation models (Table 8) are within the range of 10 to 15. In general, the results revealed that the model equations (Eqn. 17a) that relates the response variable with predictor variables was found more suitable for global solar radiation prediction in Jos as compared to other multivariate models.

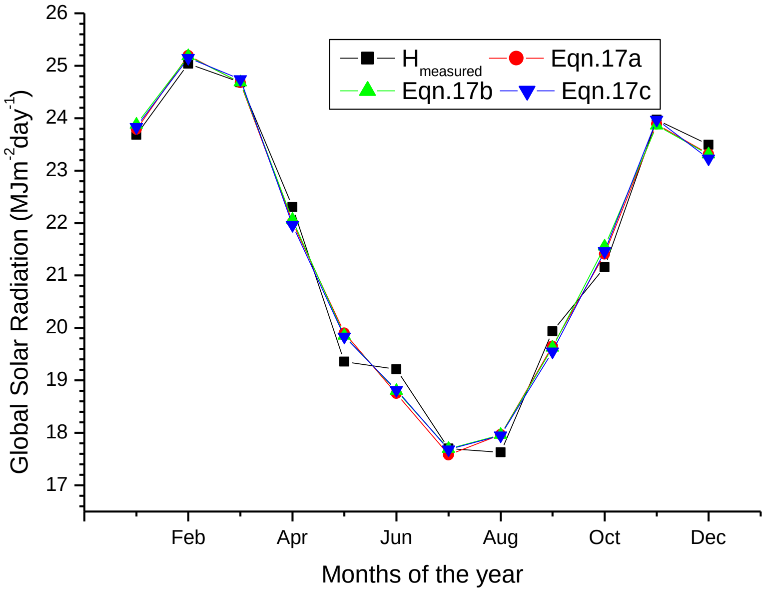

Figure 4: Correlation between the measured and estimated global solar radiation for five variable correlations in Jos

Figure 4 displayed the correlation between the measured and the predicted global solar radiation for five variable correlations in Jos. The figure shows that all the various predicted models overestimated the measured global solar radiation in the months of January, February, May, August and October and underestimated the measured in the months of April, June, September and December.

The multivariate regression models for six variable correlations for Jos are:

$$\frac{H}{H_0} = 0.890 + 0.261\frac{S}{S_0} - 0.0114\, WS - 0.00121\, T_{mean} + 0.000128\, RF - 0.0256\, CC - 0.00297\, RH \qquad (18)$$

Table 9: Statistical validation indices for six variable correlation models

Models	**R²**	**MBE**	**RMSE**	**MPE**	**t**	**NSE**	**IA**
Eqn.18	99.5	0.0076	0.2792	-0.0524	0.0901	99.7929	99.9482

The statistical test indices for the six variable correlations as shown on Table 9 revealed high significant relationship between the predicted and the observed global solar radiation based on the six meteorological parameters used in Jos.

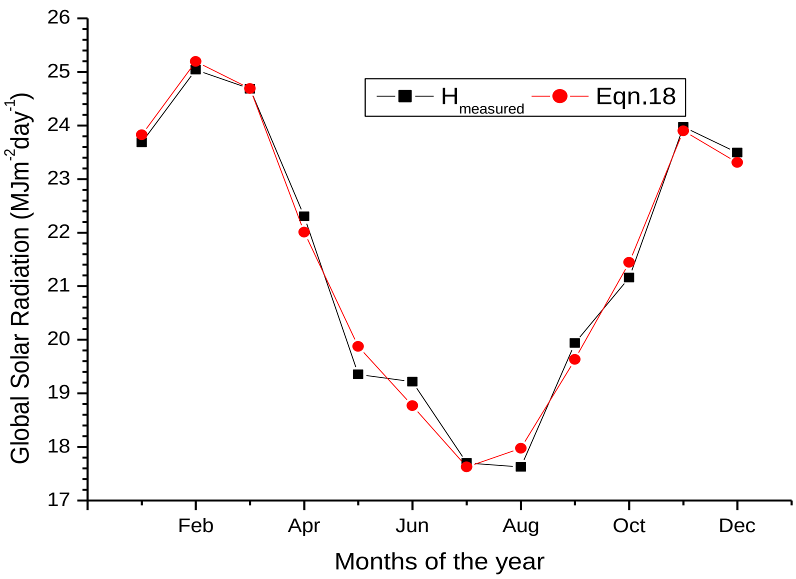

Figure 5: Correlation between the measured and estimated global solar radiation for six variable correlations in Jos

Figure 5 displayed the correlation between the measured and the predicted global solar radiation for six variable correlations in Jos. The figure revealed that the estimated model overestimated the measured global solar radiation in the months of January, February, May, August, and October and underestimated the measured in the months of April, June, September, November and December. There is no noticeable difference in the month of March.

4. Conclusion

In this present investigation, multivariate regression models were developed. The developed models were statistically tested using seven different validation test indices. The results revealed that the developed multivariate regression models were found appropriate for the prediction of global solar radiation in Jos with high accuracy. The two variable multivariate regression model (Eqn. 14a) that correlated the response variable with the predictor variables of sunshine duration and relative humidity was reported more accurate. The three variable multivariate regression model (Eqn. 15a, 15b and 15d) that correlates the response variable with the predictor variables of sunshine duration, mean temperature and relative humidity; response variable with the predictor variables of sunshine duration, wind speed and relative humidity; response variable with the mean temperature, rainfall and relative humidity was reported more accurate. The four variable multivariate regression model (Eqn. 16a and 16d) that correlates the response variable with the predictor variables of sunshine duration, wind speed, mean temperature and relative humidity; response variable with the predictor variables of sunshine duration, mean temperature, rainfall and relative humidity was reported more accurate. The five variable multivariate regression model (Eqn. 17a) that correlates the response variable with the predictor variables of sunshine duration, wind speed, rainfall, cloud cover and relative humidity was reported more accurate. The six variable multivariate regression model (Eqn. 18) that correlates the response variable with the meteorological parameters shows a high significant relationship for the location and is suitable for Jos. This unique study is important because the developed multivariate regression models are simple and the meteorological parameters used are readily available in the location under investigation.

Acknowledgements

The authors are thankful to the management and staff of the Nigerian Meteorological Agency (NIMET), Oshodi, Lagos, for making available all the data used in this study. The suggestions offered by the anonymous reviewers are highly appreciated.

References

Ajayi, O.O., Ohijeagbon, O.D., Nwadialo, C.E., and Olasope, O., 2014. New Model to Estimate Daily Global Solar Radiation over Nigeria. Sustainable Energy Technologies and Assessments., 5, Pp. 28 – 36.

Akpootu, D.O., and Iliyasu, M.I., 2015a. The Impact of some Meteorological Variables on the Estimation of Global Solar Radiation in Kano, Northwestern, Nigeria. Journal of Natural Sciences Research., 5 (22), Pp. 1 – 13.

Akpootu, D.O., and Iliyasu, M.I., 2015b. A Comparative Study of some Meteorological Parameters for Predicting Global Solar Radiation in Kano, Nigeria Based on Three Variable Correlations. Advances in Physics Theories and Applications., 49, Pp. 1 – 9.

Akpootu, D.O., and Sanusi, Y.A., 2015. A New Temperature-Based Model for Estimating Global Solar Radiation in Port-Harcourt, South-South Nigeria. The International Journal of Engineering and Science., 4 (1), Pp. 63-73.

Akpootu, D.O., and Sulu, H.T., 2015. A Comparative Study of Various Sunshine Based Models for Estimating Global Solar Radiation in Zaria, North-Western, Nigeria. International Journal of Technology Enhancements and Emerging Engineering Research., 3 (12), Pp. 1 – 5.

Akpootu, D.O., Tijjani, B.I., and Gana, U.M., 2019a. Empirical models for predicting global solar radiation using meteorological parameters for Sokoto, Nigeria. International Journal of Physical Research., 7 (2), Pp. 48 – 60. DOI: 10.14419/ijpr.v7i2.29160

Akpootu, D.O., Tijjani, B.I., and Gana, U.M., 2019b. New temperature dependent models for estimating global solar radiation across the midland climatic zone of Nigeria. International Journal of Physical Research., 7 (2), Pp. 70 – 80. DOI: 10.14419/ijpr.v7i2.29214

Akpootu, D.O., Tijjani, B.I., and Gana, U.M., 2019c. New temperature dependent models for estimating global solar radiation across the coastal climatic zone of Nigeria. International Journal of Advances in Scientific Research and Engineering (ijasre)., 5 (9), Pp. 126 – 141. DOI: 10.31695/IJASRE.2019.33523

Akpootu, D.O., Tijjani, B.I., and Gana, U.M., 2019d. Sunshine and Temperature Dependent Models for Estimating Global Solar Radiation Across the Guinea Savannah Climatic Zone of Nigeria. American Journal of Physics and Applications., 7 (5), Pp. 125-135. doi: 10.11648/j.ajpa.20190705.15

Alam, M., Saha, S., Chowdhury, M., and Rahman, M., 2005. Simulation of Solar Radiation System, Am. J. Appl. Sci., 2 (4), Pp. 751-758.

Almorox, J., Benito, M., and Hontoria, C., 2005. Estimation of monthly Ångström-Prescott Equation coefficients from measured daily data in Toledo, Spain. Renewable Energy., 30, Pp. 931-936.

Al-Salihi, A., Kadum, M., and Mohammed, A., 2010. Estimation of Global Solar Radiation on Horizontal Surface Using Meteorological Measurement for different Cities in Iraq, Asian J. Sci. Res., 3 (4), Pp. 240–248.

Bevington, P.R., 1969. Data reduction and error analysis for the physical sciences, first ed. McGraw Hill Book Co., New York.

Chen, R., Ersi, K., Yang, J., Lu, S., and Zhao, W., 2004. Validation of five global radiation Models with measured daily data in China. Energy Conversion and Management., 45, Pp. 1759-1769.

Despotovic, M., Nedic, V., Despotovic, D., and Cvetanovic, S., 2015. Review and statistical analysis of different global solar radiation sunshine models. Renewable and Sustainable Energy Reviews., 52, Pp. 1869–1880.

El-Sebaii, A., and Trabea, A., 2005. Estimation of Global Solar Radiation on Horizontal Surfaces Over Egypt, Egypt. J. Solids, 28 (1), Pp. 163-175.

Falayi, E.O., 2013. The Impact of Cloud Cover, Relative Humidity, Temperature and Rainfall on Solar Radiation in Nigeria, Energy and Power., 3 (6), Pp. 119 – 127.

Falayi, E.O., Rabiu, A.B., and Teliat, R.O., 2011. Correlations to estimate monthly mean of daily diffuse solar radiation in some selected cities in Nigeria, Pelagia Research Library., 2 (4), Pp. 480-490.

Freitas, S., Catita, C., Redweik, P., and Brito, M., 2015. Modelling solar potential in the urban environment: State-of-the-art review. Renewable and Sustainable Energy Reviews., 41, Pp. 915–931.

Gana, N.N., and Akpootu, D.O., 2013a. Angstrom Type Empirical Correlation for Estimating Global Solar Radiation in North-Eastern Nigeria. The International Journal of Engineering and Science (IJES)., 2 (11), Pp. 58 – 78.

Gana, N.N., and Akpootu, D.O., 2013b. Estimation of global solar radiation using four sunshine based models in Kebbi, North-Western, Nigeria. Pelagia Research Library., 4 (5), Pp. 409-421.

Halouani, N., Nguyen, C.T., and Vo-Ngoc, D., 1993. Calculation of monthly average Solar radiation on horizontal surfaces using daily hours of bright sunshine. Solar Energy., 50, Pp. 247-248.

Iqbal, M., 1983. An introduction to solar radiation, first ed. Academic Press, New York.

Jiandong, L., Jingmiao, L., Hans, W. L., Deliang, C., Qiang, Y., Dingrong, W., and Shigenori, H., 2012. Observation and calculation of the solar radiation on the Tibetan Plateau. Energy conversion and Management., 57, Pp. 23 – 32.

Merges, H.O., Ertekin, C., and Sonmete, M.H., 2006. Evaluation of global solar radiation Models for Konya, Turkey. Energy Conversion and Management., 47, Pp. 3149-3173.

Ogelman, H., Ecevit, A., and Tasdemiroglu, E., 1984. A new method for estimating solar radiation from bright sunshine data, Solar Energy., 33, Pp. 619 – 625.

Ojo, O.S., and Adeyemi, B., 2014. Estimation of Solar Radiation using Air Temperature and Geographical Coordinate over Nigeria. The Pacific Journal of Science and Technology., 15 (2), Pp. 78–88.

Olomiyesan, B.M., Oyedum, O.D., Ugwuoke, P.E., Ezenwora, J.A., and Ibrahim, A.G., 2015. Solar Energy for Power Generation: A Review of Solar Radiation Measurement Processes and Global Solar Radiation Modelling Techniques. Nigerian Journal of Solar Energy., 26 Pp. 1 – 8. https://doi.org/10.1155/2016/8197389.

Willmott, C., 1981. On the validation of models. Phys. Geography., 2, Pp. 211-228.

WMO. 1967. A Note on Climatological Normal. Technical Note. World Meteorological Organization, Geneva, Switzerland.