# PREDICTION OF GLOBAL SOLAR RADIATION USING SUNSHINE HOURS: A CASE STUDY OF OWO, SOUTH-WEST, NIGERIA

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**ABSTRACT**

*Solar energy has been identified as a desirable alternative energy resource, which has a crucial and important role to play in meeting the nations (most especially, Nigeria's) future energy demands. The best solar radiation information is often obtained from experimental measurements of the global and diffuse components of the solar insolation at specific location. However, due to very few locations conducting such measurements and the high cost of solar radiation measuring devices, various models are being developed for the prediction of solar radiation at all sites of interest. In this study, an empirical correlation equations of the Angstrom type were developed to predict the monthly mean daily global solar radiation incident on a horizontal surface in Owo (latitude $7^0 10^{'}$N), South-West Nigeria. Data on monthly mean daily sunshine hours and the global solar radiation covering a period of twenty years for Owo were collected from Nigeria Metrological Agency Oshodi, Lagos, Nigeria. The required correlation was obtained through regression analysis. The regression coefficient a and b were found to be 0.1723 and 0.5313 respectively. The results obtained were validated using statistical indicators and compared with measured and previous findings. The correlation Coefficient, Mean Bias Error (MBE) and Root Mean Square Error (RMSE) obtained for the developed equation are 0.7541, 0.0084 and 1.59701 respectively, indicating existence of statistically significant relationship between the clearness index and relative sunshine duration for the location. Good agreement was recorded between measured values and predicted global solar radiation values using the developed correlation model. Results from the study will increase baseline data required for design of solar energy applications for use.*

***Key points:*** *Electrical energy, solar energy, Solar radiation, Sunshine hour and Regression equation*

## INTRODUCTION

Electrical energy plays the most vital role in the growth, progress and development, as well as poverty eradication and security of any nation. Uninterrupted electrical energy supply is a vital issue for all countries today. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, and environmentally friendly (Oyedepo, 2012).

It is a known fact that fossil fuel from which developing countries energy usage is derived majorly is limited in supply and environmentally inimical to health. There is a clear need to invest into alternative energy source. This has a very important role to play in meeting the future energy needs most especially in the sparsely distributed and poor non- urban communities. Solar energy from the sun is not only infinite, but also abundant; enough to take care of mankind's energy requirements. The sun radiates a hundred billion megawatts. Out of this, the earth receives about two hundred million megawatts. It was earlier estimated that by the year 2000, the energy requirement for the total population of the earth would be 15 million megawatts (McGown and Bockris, 1980).

Studies relevant to the availability of solar energy resources in Nigeria (Adeyemo, 1995; Sambo, 1988; Ojosu, 1990; FMST, 1987) indicate the viability of solar energy for domestic and industrial applications. Solar energy presents great development opportunities in developing countries like Nigeria because most of them receive substantial sunlight throughout the year. In rural areas un-served by electric grids, solar photovoltaic energy can provide basic services such as refrigeration, irrigation, communications, and lighting. Another equally important reason that favours solar energy utilization is that it is pollution – free. Unlike the other energy resources, the use of solar energy would not lead to any serious negative environmental impact(s). Solar radiation, according to Sanusi and Abioye, (2011) at the earth's surface is essential for the development and utilization of solar energy. It is needed for designing collectors for solar appliances. The solar radiation received at a particular location on the Earth's surface must be known in order to evaluate the performance of any solar system at a given location. This energy depends on two main factors, namely the extraterrestrial solar irradiance and the state of the atmosphere (Augustine and Nnabuchi, 2009a).

The extraterrestrial solar irradiance varies according to the latitude of the location, the distance of the Earth from the Sun, and the time of the year. On any particular day, it varies from zero at sunrise to a maximum at noon and back zero at sunset (Liou, 1980). When solar radiation enters the atmosphere, a part of the incident energy is removed through the processes of scattering, absorption, and reflection. The scattering of solar radiation is mainly by atmospheric molecules and aerosols. The absorption of solar radiation is mainly by ozone, water vapor, oxygen, carbon (IV) oxide, as well as clouds; while the reflection of solar radiation is mainly by clouds and this plays an overriding part in reducing the energy density of the solar radiation reaching the surface of the Earth (Exell, 2000). The encounters of solar radiation with clouds lead to the variation in intensity of sunshine and the number of sunshine hours at the ground surface. The variation, however, is not due only to the clouds but also to the angle of incidence of the Sun's rays with the ground surface and its azimuth (Babatunde, 1988). These in turn, are due to the rotation of the Earth around the Sun and the inclination of its axis with the plane of its orbit round the Sun. The result is the variation in the number of hours of sunshine and its intensity on the Earth's surface (Augustine and Nnabuchi. 2009a).

Many studies have estimated solar radiation in Nigeria (Adeyemo, 1995;Akpabio et al.,2004; Bamiro, 1983; Sanusietal, 2011; Ogolo, 2010;). A simple linear relationship to estimate global solar radiation was first developed by Angstrom (1924) and later modified by Prescott in1940.

An accurate knowledge of solar radiation distribution at a particular geographical location is of vital importance for the development of many solar energy devices and for determining their efficiency. This accurate measurement modeling depends on the quality and quantity of the measured data used and a better tool for estimating the global solar radiation of a location where such measurements are not available (Sanusi and Abisoye, 2011). Therefore, for a time-saving climatic data capture, it becomes imperative to develop an expression from which global solar radiation can be determined and from available literature such models have not been found for Owo, hence the objective of the present study. This study seeks to develop a regression equation model using climatic data obtained from Nigerian Meteorological Agency, Oshodi Lagos, Nigeria. This is imperative for the development, evaluation and the application of solar energy technology.

## METHODOLOGY

The steps involved in carrying out the work are as follows:

Sourcing for data such as mean daily sunshine hours and Average monthly daily solar radiation (global) for Owo were obtained from the Nigerian Meteorological Agency, Oshodi Lagos, Nigeria. The data covered a period of Twenty years (1989 - 2009). The monthly average data were processed in preparation for the model.

**Modeling Equation**

To develop the required model equation for the prediction, the regression constants were first determined through the equation 1. The values of the clearness index $\frac{\bar{H}_M}{H_o}$ and relative sunshine hour $\frac{\bar{n}}{N}$

(as a climatic factor) were calculated to give model equation in the form of equation 1:

$$\frac{\bar{H}_m}{\bar{H}_o} = a + b\frac{\bar{n}}{N} \text{-----------------} \quad eqn.\ 1$$

Where, $\frac{H_m}{H_o}$ Clearness Index, $\frac{\bar{n}}{N}$ = Relative Sunshine Hour,

### Determination of Clearness Index $\frac{H_m}{H_o}$

In order to find the values of clearness index, monthly average daily global solar radiation data collected from Nigerian Meteorological Agency using Gun Bellani distillate for twenty years were processed using equation 2 below;

$$\overline{H_{GB}} = \frac{1}{N}\sum_{i=1}^{N} H_i ----------------- eqn.2$$

The values obtained were converted and standardized after Folayan (1988), using the conversion factor equation (3) (Falayi et al, 2008) to cater for any error during measurement and recording.

$$\bar{H}_m = (1.35 \pm 0.176) H_{GB} ---------- eqn.3$$

Where, $H_{GB}$ = the raw data obtained using Gun-Bellani distillate

$H_m$ = Monthly average daily (global) solar radiation $MJm^{-2}$

N = Total number of year of data. i = number of data point, (20)

The equations 2 and 3 were incorporated into computer program (EXCEL) to determine the values of $H_m$ the result is shown in table 1 for Owo. Also, the monthly average daily extraterrestrial radiation $H_o$ model was calculated through the following relations (Duffie and Beckman, 1980; Adeyemo, 1997):

$$\bar{H}_o = I_{sc} I_0 COS\theta_Z ---------- eqn\ 4$$

Where

$$I_0 = \left[1 + 0.033COS\left(\frac{360\bar{D}}{365}\right)\right]$$

= Extraterrestrial radiation

D = the characteristic day number, $I_{sc}$

= 1367 $Wm^{-2}$ = Solar constant

$COS\theta_Z$ = Zenith angle of the Sun

For a horizontal surface at any time between sunrise and sunset, according to Adeyemo, (1997), Duffie and Beckman, (1980) and Liu (1996), Zenith angle is determined using;

$$COS\theta_Z = Sin\delta Sin\phi + Cos\phi Cos\, w_s\, Cos\delta$$

Substitute for $I_0$ and $COS\theta_Z$ in equation 4,It become:

$$H_0 = \frac{24 \times 3.6 \times 10^{-3} \times I_{sc}}{\pi}\left[1 + 0.33Cos\left(360\frac{\bar{D}}{365}\right)\right]\cos\phi\cos\delta\sin\omega + \sin\phi\sin\delta - eqn.\ 5$$

Where,

$\delta$ = the solar angle of declination and is approximately give and calculated using equation (6)

$$\delta = 23.45\sin\left(\frac{360\left(\bar{D} + 284\right)}{365}\right) ------------- eqn.6$$

$\bar{D}$ = the characteristic day number

$\phi$ = the latitude angle and $\omega_s$ is the sunset hour angle of typical day of each month given as:

$$w = \omega_s = \cos^{-1}(-\tan\phi\tan\delta) ----- eqn.7$$

In order to determine the monthly average daily extraterrestrial radiation, $\bar{H}_o$ equations 6 and 7were used first to determine declination angle and sunset angle respectively; latitude angle is the latitude of the location which in this case were latitude 7°10'N for Owo. These were incorporated into equation 5 to find the values of $H_o$ .The values of the monthly average daily global solar radiation $\bar{H}_m$ from equation 3, the monthly average daily extraterrestrial radiation $\bar{H}_o$ values calculated from equation 5 through EXCEL package were presented in table 1 and the values of their ratio to give clearness index $\frac{\bar{H}_m}{\bar{H}_o}$ were also calculated using EXCEL package and presented in table 1.

**Determination of Relative Sunshine Hour, $\frac{\bar{n}}{\bar{N}}$**

In developing the model, the sunshine hour values were also calculated through the equation 8 below using climatic raw data collected from Meteorological agency, Oshodi, Lagos for Owo. The data obtained for twelve (12) months of each year and for twenty (20) years were summed up per month and the average was determined for each month.

Where, $\bar{n} = \frac{1}{N}\sum_{i=1}^{N} n_i -------------- eqn8$

$\bar{n}$ = the monthly average of daily sunshine duration

i = current number of data point being summed. N = Total number of data points = 20

While, the value of monthly average daily maximum number of hour of possible sunshine (day length is calculated using equation 10 below and the results were presented in table 1;

$$\square = \frac{2}{15}\square ------------ .9$$

Substituting equation 9 into 10,

$$\bar{\bar{N}} = \frac{2}{15}(\cos(-tan\emptyset tan\partial)) ------- eqn.10$$

**Determination of Regression Constants (a and b)**

The regression constants a and b were determined in order to complete the model regression equation. They depend on the location and relationship between the clearness index and relative sunshine hour. The physical significance of the regression constants is that 'a' represents the case of overall atmospheric transmission for an overcast sky condition ( i.e. $\frac{\bar{n}}{\bar{N}}$ while 'b' is the rate of increase of $\frac{H_m}{H_o}$ with $\frac{\bar{n}}{\bar{N}}$. In this study, the constants were determined by the interaction between clearness index values (dependent variables) and relative sunshine hour values (independent variables) using computer package (EXCEL) through least square methods as shown in figure 1 using equations 11 and 12 below;

$$\hat{b} = \frac{M\sum\frac{\overline{H_m}}{H_o}\sum\left(\frac{\bar{n}}{\bar{N}}\right)^2 - \sum\frac{\bar{n}}{\bar{N}}\sum\frac{\overline{H_m}}{\overline{H_0}}}{M\sum\left(\frac{\bar{n}}{\bar{N}}\right)^2 - \left(\sum\frac{\bar{n}}{\bar{N}}\right)^2} \text{-----------} eqn.\ 11$$

$$\hat{a} = \frac{\overline{H_M}}{\overline{H_0}} - \hat{b} \text{---------------} eqn.\ 12$$

Where M = the number of data points = 20

Furthermore, using the regression constants values to replace a and b, linear regression model was generated. This model was used to calculate the monthly average daily (global) solar radiation as a function of relative sunshine hours and compared the values with the measured values (raw data) collected from meteorological agency for twenty years and their percentage error is calculated using EXCEL package. The result is presented in table 2. The model is of the form express as:

$$\bar{H} = \bar{H}_0\left(a + b\frac{\bar{n}}{\bar{N}}\right)$$

### Model Validation and Assessment

In validating the models developed, the estimation accuracy was evaluated by calculating Mean Bias Error (MBE) and Root Mean Square Error (RMSE). Mean Bias Error is one of the statistical indicators commonly adopted in comparing the models of solar radiation predictions values from the measured values. Low values of MBE are desirable, Root Mean Square Error measures the variation of predicted values around the measured values. The expressions are as follows-

$$MBE(\%) = 100\left(\frac{1}{\bar{R}_m}\right)\left(\sum\frac{E_i}{M}\right) \text{---------} eqn.\ 13$$

$$RMSE(\%) = 100\left(\frac{1}{\bar{R}_m}\right)\left(\sum\frac{E_i}{M}\right)^{0.5} \text{-----------} eqn.\ 14$$

Where, $E_i = H_{cal} - H_{meas}$ 1,2……..M,

M = the total no of observation $\bar{R}_m$ the arithmetic mean value of the M measured values of the global solar radiation.

## RESULT AND DISCUSSION

Table 1 shows the dependent variable (i.e. Clearness Index) and Independent Variable (i.e. Sunshine Hour) for Owo within the given period of time, 1989 – 2008. From the table, the maximum values of the monthly mean daily sunshine hours and monthly mean daily (global) solar radiation on a horizontal surface are 6.98 hours in the month of April and 17.799MJm$^{-2}$day$^{-1}$in the month of February respectively. According to the literature available, it has been established that insolation instrument records hour of bright sunshine when solar radiation flux density is above threshold value of 210Wm$^{-2}$, and during the month of April and February highest values are recorded. These values are characteristic of a tropical location. Hence, during the month of April, a very high mean daily sunshine hour is obtained because it has a high clearness index.

**TABLE 1: Processed Monthly Average Daily (Global) Solar Radiation and Sunshine Hour Data for Owo (1989-2008)**

| S/N | MONTH | n (hr) | N (hr) | $\hat{H}_m$(MJm$^{-2}$day$^{-}$ | $\hat{H}$o (MJ$^{-2}$day$^{-}$) | $\frac{?}{?}$ | $\frac{?_?}{?_0}$ |
|---|---|---|---|---|---|---|---|
| 1 | JAN | 5.735 | 11.6305 | 14.78925 | 34.12459 | 0.493101 | 0.43338983 |
| 2 | FEB | 6.63 | 11.777 | 17.79975 | 35.42087 | 0.5629601 | 0.50252147 |
| 3 | MAR | 4.51 | 11.9578 | 15.61275 | 37.35693 | 0.3771594 | 0.41793446 |
| 4 | APR | 6.985 | 12.158 | 17.79300 | 35.5798 | 0.5745173 | 0.50008706 |
| 5 | MAY | 4.315 | 12.326 | 14.06700 | 35.68502 | 0.3500726 | 0.39419898 |
| 6 | JUN | 4.68 | 12.4089 | 14.06025 | 33.12483 | 0.37715 | 0.42446252 |
| 7 | JUL | 3.97 | 12.3716 | 11.31300 | 35.82449 | 0.3208972 | 0.31578953 |
| 8 | AUG | 3.775 | 12.2287 | 9.20700 | 36.65147 | 0.3086994 | 0.25120414 |
| 9 | SEP | 4.34 | 12.0357 | 12.52800 | 36.13718 | 0.3605939 | 0.34667897 |
| 10 | OCT | 4.045 | 11.8357 | 14.74875 | 37.0977 | 0.3417635 | 0.39756512 |
| 11 | NOV | 5.835 | 11.6686 | 14.87700 | 36.25314 | 0.5000591 | 0.41036448 |
| 12 | DEC | 6.265 | 11.5888 | 13.74300 | 35.50778 | 0.5406103 | 0.38704199 |

It was also observed from the table that minimum values of the monthly mean daily sunshine hours and the monthly daily global solar radiation on a horizontal surface for Owo are 3.775 hours and 9.2070 $MJm^{-2}day^{-1}$ respectively. These minimum values occur in the month of August. Similarly, these values are characteristic of a tropical location. In Nigeria tropical climate, August is a month characterized by heavy rain. Two types of global solar radiation were observed from the result. There were high irradiation values in the dry season associated with long duration of sunshine hours (usually above 4 hours/day) and less cloudy skies. On the other hand, there were low irradiation values in the rainy season. This is the time when the rain bearing clouds normally pervade the sky. Such periods are associated with less sunshine hour. Therefore, it is evident that the monthly variations of average daily sunshine duration for Owo have relationship with solar radiation.

Using the values of Clearness index $\bar{n}/\bar{N}$ and relative sunshine hour $\bar{H}_m/\bar{H}_0$ from the table 1 a graph was generated (figure 1)and the regression equation was obtained-

$$\bar{H}_m = \bar{H}_o\left(0.1723 + 0.5313\frac{\bar{n}}{\bar{N}}\right) - - - - - - - - 15$$

From the equation 15, the regression constants (i.e. 'a' and 'b') were seen to be: a = 0.1723 , this is the intercept on $\bar{H}_m/\bar{H}_0$ while b = 0.5313, this is the slope of the equation that links monthly average daily (Global) Solar Radiation and Sunshine Hour together. The transmissivity of the atmosphere for global solar radiation under perfectly clear sky condition has also been interpreted through the sum of the regression constants (i.e. a+ b ) and is a function of type of thickness of the cloud (Isikwue et al, 2012) . This implies that, the transmissivity of the solar radiation for Owo is the addition of regression constants which is 0.7036 ( i. e 0.1723 + 0.5313) under perfect clear sky conditions. This value shows reasonable agreement as reported for most tropical regions (Godffrey and Anthony, 2014) and when compared with other study areas like Iseyin (0.9451), (Falayi, et al, 2008); Enugu (0.583); (Augustine and Nnabuchi, (2010); Warri (0.79), (Augustine and Nnabuchi, (2010); Lokoja (0.757); (Ogolo, 2010).

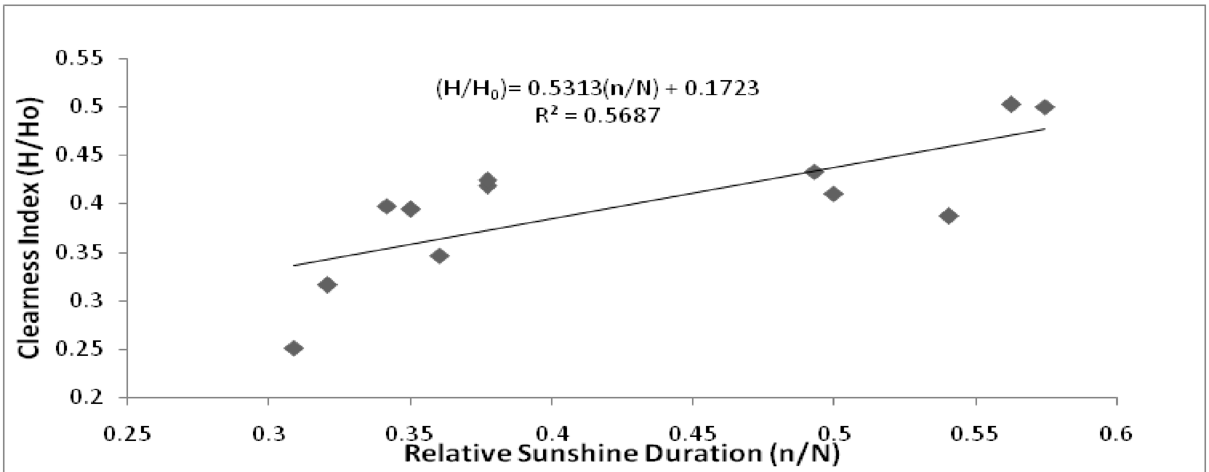


***Fig.1: Relationship between Clearness Index and Relative Sunshine Duration for Owo (1989 - 2008)***

From the Fig.1 above, it is clearly shown that there is good positive relationship between Clearness Index and Sunshine Hour. This is depicted by the value of Coefficient of Determination $R^2$ which is 0.5687; for which R = 0.754 which measures the degree of relationship between Dependent Variable (Global Solar Radiation) and Independent Variable (Sunshine Hour).

From equation 15, $H_{cal}$ can be calculated as; $H_m = H_0(0.1723 + 0.5313 = \frac{\bar{n}}{\bar{N}}$ $H_{cal}$ Calculated Monthly Global Solar Radiation. Thus, Table 2 gives the values of calculated monthly average daily solar radiation (global) for Owo, South-West Nigeria.

Note that Percentage Error, Error(%)

$$\frac{H_{meas} - H_{Cal}}{H_{meas}} X\ 100$$

**Table 2: Comparison between Calculated and Measured Monthly Average daily (Global) Solar Radiation for Owo**

| MONTH | $\hat{H}_{meas}$ | $\hat{H}o$ ($MJ^{m-2}day$) | □/□ | □□/□$_0$ | □ cal | Error (%) |
|---|---|---|---|---|---|---|
| JAN | 14.78925 | 34.12459 | 0.493101 | 0.43338983 | 14.819783 | -0.2064519 |
| FEB | 17.79975 | 35.42087 | 0.5629601 | 0.50252147 | 16.697425 | 6.19295907 |
| MAR | 15.61275 | 37.35693 | 0.3771594 | 0.41793446 | 13.922446 | 10.826983 |
| APR | 17.79300 | 35.5798 | 0.5745173 | 0.50008706 | 16.990817 | 4.50842716 |
| MAY | 14.06700 | 35.68502 | 0.3500726 | 0.39419898 | 12.785715 | 9.10844696 |
| JUN | 14.06025 | 33.12483 | 0.37715 | 0.42446252 | 12.344957 | 12.19959223 |
| JUL | 11.31300 | 35.82449 | 0.3208972 | 0.31578953 | 12.280375 | -8.55100575 |
| AUG | 9.20700 | 36.65147 | 0.3086994 | 0.25120414 | 12.326327 | -33.8799534 |
| SEP | 12.52800 | 36.13718 | 0.3605939 | 0.34667897 | 13.149725 | -4.96268323 |
| OCT | 14.74875 | 37.0977 | 0.3417635 | 0.39756512 | 13.128094 | 10.98842852 |
| NOV | 14.87700 | 36.25314 | 0.5000591 | 0.41036448 | 15.877782 | -6.7298505 |
| DEC | 13.74300 | 35.50778 | 0.5406103 | 0.38704199 | 16.316754 | -18.7277476 |

From the Table 2, one can see that both measured and calculated values are close. This shows that the predicted value through the use of the Measured and Calculated Monthly Global Solar Radiation would be reliable. The percentage error, as shown in the table ranges between -33.9 and 12.2. This is generally low and it is in accordance with the estimated level of relationship between the clearness index and the sunshine hours as shown in the correlation coefficient (R =0.7541 ) or coefficient of determination ($R^2$ = 0.5687). Observation from Fig. 2 shows that both the calculated and measured vary correspondingly except in August, November and December where they exhibit over estimation.

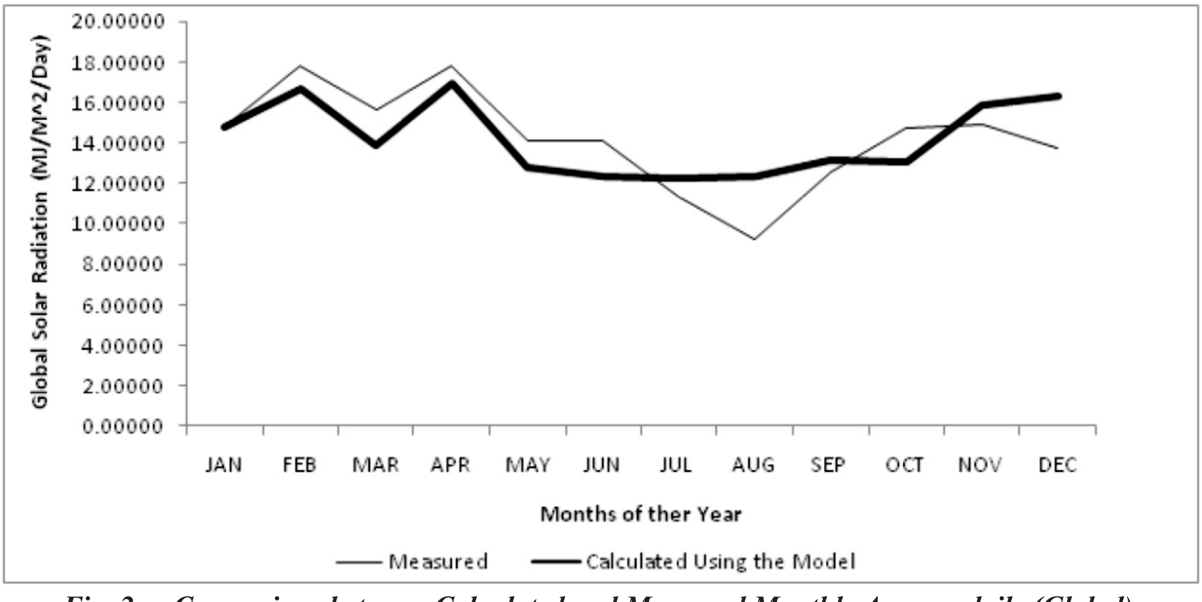


***Fig. 2: Comparison between Calculated and Measured Monthly Average daily (Global) Solar Radiation for Owo (1989 - 2008)***

Validation of results of the regression analysis was ascertained through mean bias errors (MBE) and the root mean square errors (RMSE) through the application of EXCEL and SPSS and the results are presented in Table 3 below. Several authors have recommended that a Zero value for MBE is ideal and low RMSE is desirable. From the table, the MBE values obtained for Owo from the models were positive and if approximated to zero, it showed that this models appear to be accurate and this is supported by low RMSE value (1.59704).The results show that the proposed model which equation is accurate and can be used for estimating solar radiation for the location.

**Table 3: Validation of Model Developed Results**

| Variables | Regression Equation | a | b | R | $R^2$ | MBE | RMSE |
|---|---|---|---|---|---|---|---|
| sunshine Hour | $\overline{H}_m = \overline{H}_o (0.1723 + 0.5313 \frac{\overline{n}}{\overline{N}})$ | 0.1723 | 0.5313 | 0.754122 | 0.5687 | 0.0084 | 1.59701 |

**Comparison of Models on Global Solar Radiation**

A comparison of results obtained for the regression analysis on the correlation between global solar radiation and sunshine hours for Owo (latitude 7.18$^0$N longitude 5.5$^0$E) with other results for major cities in Nigeria such as Enugu (latitude 7.55$^0$N longitude 6.47$^0$E) , Calabar (latitude 4.970N longitude 88.35$^0$E), Port Harcouurt (latitude 4.85$^0$N longitude 7.02$^0$E), Onne (latitude4.46$^0$N longitude 7.10$^0$N) and Iseyin (latitude 7.98$^0$N longitude 3.6$^0$E) indicates that the closest agreement exists between the regression coefficient and coefficient of determination of Owo (latitude 7.18$^0$N longitude 5.5$^0$E) and Enugu (latitude 7.55$^0$N longitude 6.47$^0$E), Ikeja and Akure. This is as a result of the closeness of their latitude and geographical area (Coastal area). This implies that the model is adequate for predicting the solar radiation for Owo.

**CONCLUSIONS AND RECOMMENDATION**

The main conclusion of the present research is that a linear regression analysis of the global solar radiation and sunshine duration data carried out by means of the least-squares technique gave an Angstrom-type radiation model suitable for estimating monthly average daily global irradiation incident on horizontal surfaces in Owo (latitude 7.18$^0$N, longitude 5.58$^0$E at altitude of 348m above sea level) The empirical correlation equation obtained is:

$$\overline{H}_m = \overline{H}_0(0.1723 + 0.5313) \frac{\overline{n}}{\overline{N}}$$

The maximum and minimum values of the global solar radiation were found to be 17.79975MJm$^{-2}$ day$^{-1}$ and 9.20700 MJm$^{-2}$ day$^{-1}$, occurring in February and August respectively. There were high irradiation values in the dry season associated with long duration of sunshine hours and less cloudy skies, while there were low irradiation values in the rainy season. The correlation coefficient and coefficient of determination for the developed equation were also found to be 0.754 and 0.5687, respectively.

Good agreement was recorded between measured values and values calculated by the developed correlation equation, the percentage error between the measured and predicted values ranged between -33.9 and 12.2%, which makes the equation useful in estimating global solar radiation (where there is no data) especially in the coastal climatic zone of South Western Nigeria, and in places on the same latitude as Owo.

A comparison of results obtained for the regression analysis for Owo with other results for selected major cities in Nigeria showed that the closest agreement exists between Owo (latitude 7.18$^0$N, longitude 5.58$^0$E) and Enugu (latitude 7.55$^0$N longitude 6.47$^0$E), Ikeja (latitude 6.58$^0$N longitude 3.33$^0$E) and Akure (latitude 7.23$^0$N, longitude 5.22$^0$E).

Validation of the developed models through statistical indicators showed that there are statistically significant relationships between the clearness index and relative sunshine hour. The global solar radiation intensity value produced by this approach can be used in the design and performance analysis of solar technologies, which are currently gaining attention in developing countries most especially Nigeria. Therefore, the model is recommended for use in predicting the global solar radiation for Owo.

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