Estimation of global solar radiation using four sunshine based models in Kebbi, North-Western, Nigeria

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ABSTRACT

An accurate knowledge of the solar radiation distribution at a particular geographical location is of vital importance for the development of many solar energy devices and for estimates of their performance. In this paper, the measured data of global solar radiation on a horizontal surface and number of bright sunshine hours for Kebbi (Latitude 12.47ºN, Longitude 4.3ºE, Altitude 205m above the sea level) were analyzed. Regression constants for the first order Angstrom-type correlations for Kebbi was calculated and developed using the method of regression analysis. The monthly calculated clearness index and monthly sunshine duration were correlated and modeled using four sunshine-based models i.e. linear, quadratic, exponential and power equations. Comparing these models, it was observed that the quadratic equation model performed better in terms of coefficient of determination(R^2) and correlation coefficient (r) than the other three models, given $R^2 = 100\%$ and $r = 1.00$

Keywords: Measured global solar radiation, calculated global solar radiation, Clearness index, Sunshine duration, Kebbi, regression analysis.

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INTRODUCTION

Solar radiation has been identified as the largest renewable resource on earth. The energy source is more evenly distributed in the Sunbelt of the World than wind or biomass, allowing for more site locations [1]. The maximum intensity of solar radiation at the earth's surface is about 1.2 kW/m^2 but it is encountered only near the equator on clear days at noon. Under these ideal conditions the total energy received is from 6-8 kWh/m^2 per day [2-4]. Solar energy is not available continuously because of the day/night cycle and cloud cover. Its intensity varies according to season, geographical location, and position of the collector [5].

Studies on solar radiation have become an important issue for renewable energy issues stemming from oil crises, global warming and other environmental problems, thus increasing the need of reliable measurements of surface solar radiation [6].

Solar radiation was historically monitored by measuring the sunshine duration with Campbell-Stokes recorders. An estimate of the global solar radiation was then obtained through the well-known Angstrom–Prescott equation [7-8]. Although pyranometers are nowadays available to directly measure the global solar radiation, the sunshine duration is still an essential climatological parameter that is still monitored in many meteorological stations in order to extend the historical time series [9].

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[7] proposed first theoretical model for estimating global solar radiation based on sunshine duration. [10] and [8] reconsidered this model in other to make it possible to calculate monthly average of the daily global solar radiation on a horizontal surface from monthly average daily total insolation on an extraterrestrial horizontal surface. [11], for Turkey [12], for Bahrain [13], for Greece [14], for Spain [15], for Sri Lanka [16] and others have developed the modified versions of fundamental Angstroms empirical relations based on sunshine duration. [17] and [18], [19], [20] and others have proposed the estimate model based on temperature multi parameter models (MPM) were given by [21], for Egypt, [22], for Nigeria, [23], for India, [24], for Zimbabwe, [25], for Egypt and [26], [27], Elazing for Turkey and for Krygyztan, etc; for estimating the global solar radiation based on longitude, latitude, altitude and routinely available meteorological parameter such as minimum maximum temperature, relative humidity, rainfall, cloudiness and wind speed data. [28], [29], [30-32], have explored the estimation model for India, Africa, World and observed usefulness of these meteorological parameters for global solar radiation (GSR) estimation review of some literature reviews reveals that mostly the efforts are to develop an estimation model for a single location or a group of locations for a small region. Therefore, there exists a clear scope for the development of a global estimation model describing the wider area of the World. Iranna-Bapat's models help partially in deriving solar radiation data for large area on the earth surface [32].

A lot of researchers have developed a correlation involving global solar radiation and sunshine hours of different locations in Nigeria. For example [33] developed a linear and quadratic equations for Benin, Ibadan and Samaru, [34] also developed a linear relation for Northern Nigeria., [35] developed the linear relation for Bauchi, [36] developed a quadratic relation for Calabar, Port Harcout and Enugu, [37] developed a model for Ilorin, [38] and [39] developed models for Onne. It is observed that the regression coefficients are not universal but depend on climatic conditions and the nature of the pollutants of the environments [40].

Hence, the essence of this study is aimed at developing an Angstrom-type of empirical correlation model for the estimation of global solar radiation and as well as using four sunshine-based models for Kebbi and other surrounding towns of similar meteorological conditions.

MATERIALS AND METHODS

In this present study, data of the monthly mean of daily global solar radiation and sunshine duration from Nigeria Meteorological Agency (NIMET) Abuja, Nigeria for Kebbi location were collected and utilized. The data obtained cover a period of fifteen years (1990-2005) for Kebbi (Latitude 12.47ºN, Longitude 4.3ºE and altitude 205 meters)

The first correlation proposed for estimating the monthly average daily global radiation is based on the method of [7]. The original Angstrom-Prescott type regression equation-related monthly average daily radiation to clear day radiation in a given location and average fraction of possible sunshine hours is given by

$$\frac{H}{H_o} = a + b\left(\frac{S}{S_o}\right) \tag{1}$$

where H is the monthly average daily global radiation on a horizontal surface (MJ/m² /day), H_O the monthly average daily extraterrestrial radiation on a horizontal surface (MJ/m² /day), S the monthly average daily hours of bright sunshine, S_O the monthly average day length, and "a" and "b" values are known as Angstrom constants and they are empirical. The monthly average daily extraterrestrial radiation on a horizontal surface (H_O) can be computed from the following equation (2) [41]:

$$H_O = \left(\frac{24}{\pi}\right)I_{SC}\left[1 + 0.033\cos\left(\frac{360n}{365}\right)\right] \times \left[\cos\phi\cos\delta\sin w_s + \left(\frac{2\pi W_s}{360}\right)\sin\phi\sin\delta\right] \tag{2}$$

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Where I_{sc} is the solar constant (=1367 W m^{-2}), ϕ the latitude of the site, δ the solar declination, W_s the mean sunrise hour angle for the given month, and n the number of days of the year starting from the first of January. The solar declination (δ) and the mean sunrise hour angle (W_s) can be calculated by the following equations [41]: equations (3) and (4) respectively in equation (2):

$$\delta = 23.45 \sin\left(360\frac{284+n}{365}\right) \tag{3}$$

$$W_S = Cos^{-1}\left(-\tan\phi\tan\delta\right) \tag{4}$$

For a given month, the maximum possible sunshine duration (monthly average day length (S_o) can be computed by using the following equation [41]:

$$S_o = \frac{2}{15}W_S \tag{5}$$

Then, the monthly mean of daily global radiation H was normalized by dividing with monthly mean of daily extraterrestrial radiation H_O. We can define clearness index (K_T) as the ratio of the observed/measured horizontal terrestrial solar radiation (H), to the calculated/predicted horizontal/extraterrestrial solar radiation (H_O) or clearness index (K_T) gives the percentage deflection by the sky of the incoming global solar radiation and therefore indicates both level of availability of solar radiation and changes in atmospheric conditions in a given locality [42], [40]

$$K_T = \frac{H}{H_o} \tag{6}$$

In this study, H_O and S_O were computed for each month by using Equations (2) and (5), respectively. The regression coefficients *a* and *b* in Equation (1) have been obtained from the graph of $\frac{H}{H_o}$ *against* $\frac{S}{S_o}$. The values of the monthly average daily global radiation H and the average number of hours of sunshine were obtained from monthly measurements covering a period of 15 years. The regression coefficient *a* and *b* from the calculated monthly average global solar radiation has been obtained from the relationship given as [43]:

$$a = -0.110 + 0.235\cos\phi + 0.323\left(\frac{S}{S_O}\right) \tag{7}$$

$$b = 1.449 - 0.553\cos\phi - 0.694\left(\frac{S}{S_O}\right) \tag{8}$$

To compute estimated values of the monthly average daily global radiation H_{Cal} , the values of computed *a* and *b* from equations (7) and (8) were used in Equation (1) [44].

Four models were selected for this study. They are [8], [45], [46] and [47] models of estimation of monthly mean of daily horizontal global solar radiation as summarized in the Table below:

Table 1: Sunshine-based models

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Model no	Regression	Source
1	$\dfrac{H}{H_o} = a + b\left(\dfrac{S}{S_o}\right)$	Angstrom- Prescott (1940)
2	$\dfrac{H}{H_O} = a + b\left(\dfrac{S}{S_o}\right) + c\left(\dfrac{S}{S_o}\right)^2$	Ogelman *et al.*, (1984)
3	$\dfrac{H}{H_o} = a^{\left(\frac{1}{\left(\frac{S}{s_o}\right)}\right)}$	El- Metwally (2005)
4	$\dfrac{H}{H_o} = a\left(\dfrac{S}{S_o}\right)^b$	Bakirci (Exponential)(2009)

Sunshine-based models

The most commonly used parameter for estimating global solar radiation is sunshine duration. Sunshine duration can be easily and reliably measured, and data are widely available at the weather stations. Most of the models for estimating solar radiation that appear in the literature only use sunshine ratio ($\dfrac{S}{S_o}$) for prediction of monthly average daily global radiation [48].

1). Angstrom – Prescott model.

[8] model is the most commonly used model as given by:

$$\frac{H}{H_o} = a + b\left(\frac{S}{S_o}\right)$$

(9)

Where H is the global solar radiation, H_O the extraterrestrial solar radiation, S the actual sunshine hour, S_O maximum possible duration, **a** and **b** are empirical coefficients. H_O and S_O were calculated using equation (2) and (5).

2). Ogelman *et al* model.

Following the presented equation has been presented by Ogelman for estimating global solar radiation [45]

$$\frac{H}{H_O} = a + b\left(\frac{S}{S_o}\right) + c\left(\frac{S}{S_o}\right)^2$$

(10)

Where a,**b** and **c** are empirical coefficients.

3). El-Metwally model.
El-Metwally developed following model for estimating global solar radiation[46].

$$\frac{H}{H_o} = a^{\left(\left[\frac{1}{\left(\frac{S}{s_o}\right)}\right]\right)}$$

(11)

Where a is empirical coefficient.

4). Bakirci (exponential) (2009) model.

Bakirci developed the following model for global solar radiation prediction [47]:

$$\frac{H}{H_o} = a\left(\frac{S}{S_o}\right)^b$$

(12)

Where **a** and **b** are empirical coefficients.

Table 2: The input Meteorological parameters for Kebbi for the period of fifteen years   (1990 - 2005)

Months	Hcal	H_o	S	S_o	$Hcal/H_o$	S/S_o
Jan	18.80	29.49	7.71	11.28	0.6373	0.6834
Feb	20.13	31.83	7.63	11.46	0.6322	0.6660
Marc	20.62	34.30	6.82	11.74	0.6010	0.5809
Apri	23.81	38.31	7.67	12.10	0.6215	0.6336
May	24.54	39.47	7.89	12.44	0.6217	0.6344
Jun	23.98	38.60	8.03	12.68	0.6214	0.6333
Jul	21.53	37.84	6.53	12.73	0.5689	0.5132
Aug	20.10	38.74	5.36	12.56	0.5189	0.4269
Sept	23.19	38.96	6.95	12.24	0.5952	0.5676
Oct	23.21	36.55	8.03	11.89	0.6350	0.6753
Nov	20.88	32.05	8.56	11.55	0.6514	0.7412
Dec	18.36	28.57	7.96	11.32	0.6427	0.7032

Table 3: Summary of monthly mean average of regression constants, extraterrestrial solar radiation, measured and calculated values, measured and calculated clearness index for Kebbi   (1990 - 2005)

Months	a	b	H_o	Hm	Hcal	Hm/Ho	Hcal/Ho
Jan	0.34	0.43	29.49	34.55	18.80	1.1715	0.6373
Feb	0.33	0.45	31.83	36.54	20.13	1.1478	0.6322
Marc	0.31	0.51	34.30	38.92	20.62	1.1346	0.6010
Apri	0.32	0.47	38.31	38.71	23.81	1.0105	0.6215
May	0.32	0.47	39.47	36.04	24.54	0.9130	0.6217
Jun	0.32	0.47	38.60	33.36	23.98	0.8644	0.6214
Jul	0.29	0.55	37.84	31.51	21.53	0.8328	0.5689
Aug	0.26	0.61	38.74	30.84	20.10	0.7962	0.5189
Sept	0.30	0.52	38.96	31.74	23.19	0.8146	0.5952
Oct	0.34	0.44	36.55	33.65	23.21	0.9207	0.6350
Nov	0.36	0.39	32.05	35.38	20.88	1.1038	0.6514
Dec	0.35	0.42	28.57	35.03	18.36	1.2263	0.6427

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Table 4: Calculated monthly mean global solar radiation, input parameters and modeled values (1-4) for Kebbi for the period of fifteen years (1990-2005)

| Months	Hcal	H_o	S	S_o	Hcal/H_o	S/S_o	model 1	model 2	model 3	model 4
Jan	18.80	29.49	7.71	11.28	0.6373	0.6834	0.6382	0.6373	0.6530	0.2988
Feb	20.13	31.83	7.63	11.46	0.6322	0.6660	0.6309	0.6322	0.6457	0.2933
Marc	20.62	34.30	6.82	11.74	0.6010	0.5809	0.5952	0.6010	0.6057	0.2661
Apri	23.81	38.31	7.67	12.10	0.6215	0.6336	0.6173	0.6215	0.6315	0.2831
May	24.54	39.47	7.89	12.44	0.6217	0.6344	0.6176	0.6218	0.6318	0.2833
Jun	23.98	38.60	8.03	12.68	0.6214	0.6333	0.6172	0.6214	0.6313	0.2830
Jul	21.53	37.84	6.53	12.73	0.5689	0.5132	0.5667	0.5690	0.5669	0.2435
Aug	20.10	38.74	5.36	12.56	0.5189	0.4269	0.5305	0.5189	0.5054	0.2135
Sept	23.19	38.96	6.95	12.24	0.5952	0.5676	0.5896	0.5952	0.5986	0.2617
Oct	23.21	36.55	8.03	11.89	0.6350	0.6753	0.6348	0.6350	0.6496	0.2963
Nov	20.88	32.05	8.56	11.55	0.6514	0.7412	0.6625	0.6514	0.6750	0.3166
Dec	18.36	28.57	7.96	11.32	0.6427	0.7032	0.6465	0.6427	0.6609	0.3049
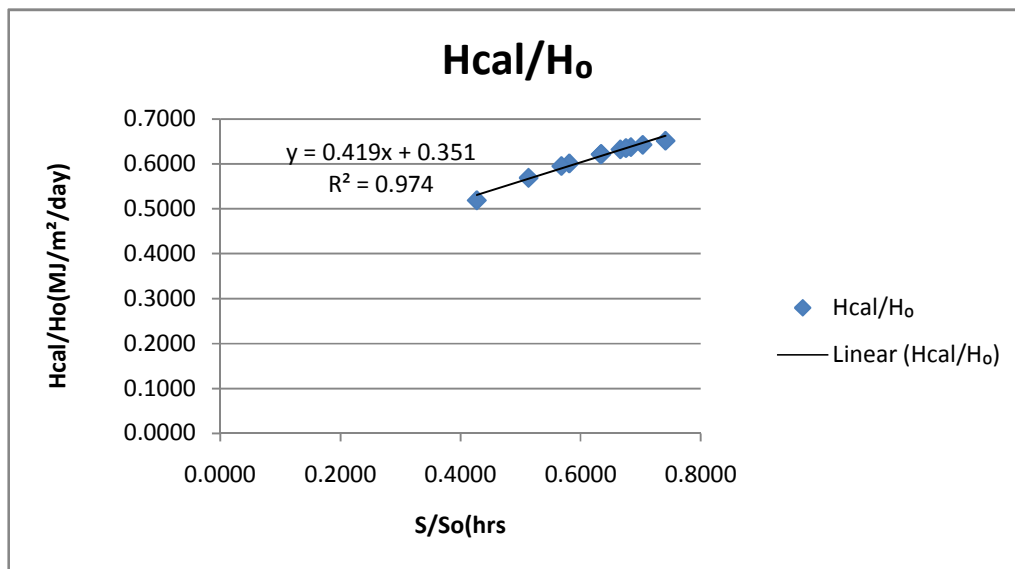
Figure 1: Variation of clearness index with respect to sunshine hours for Kebbi(1990 - 2005)
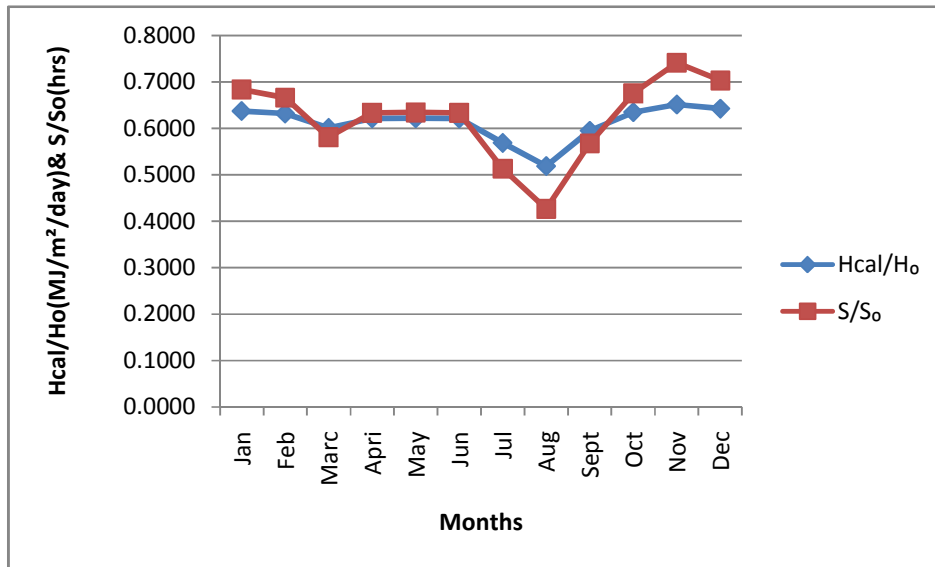
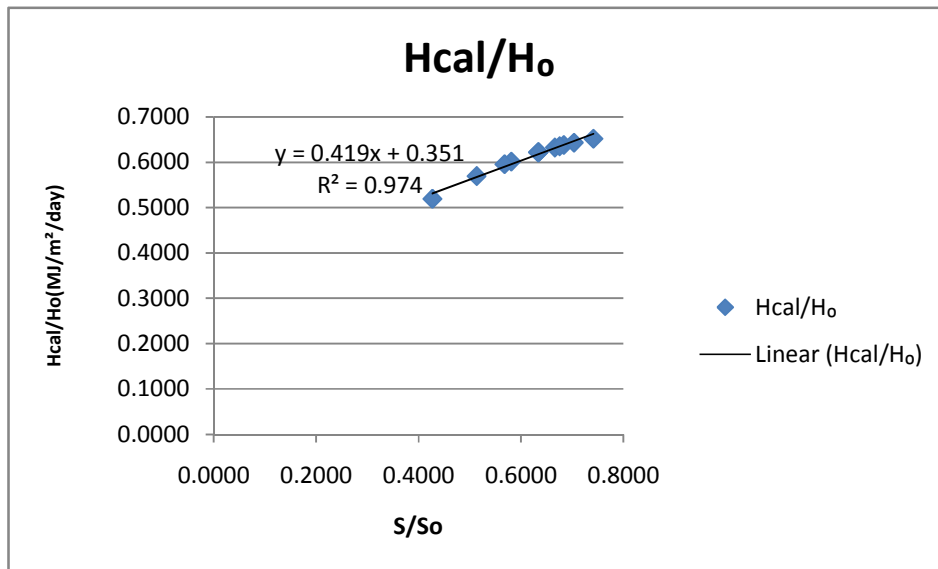**Figure 2: Correlation of monthly variation of Hcal/Ho and S/So for Kebbi (1990 - 2005)**

**Figure 3: Angstrom - Prescott (1940) model fitting for variation of clearness index (Hcal/Ho)
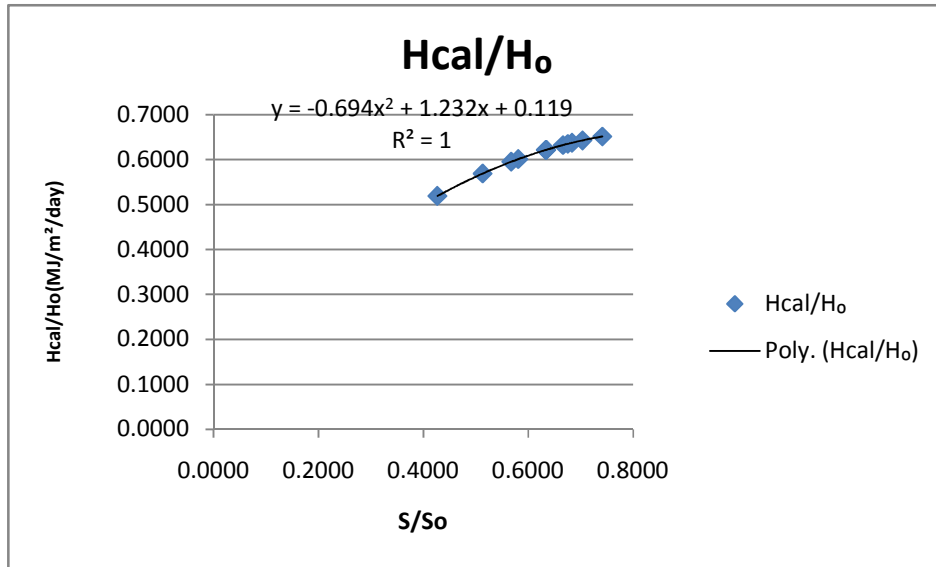versus relative sunshine duration(S/So) for Kebbi(1990 - 2005)**

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**Figure 4: Ogelman etal (1984) model fitting for variation of clearness index (Hcal/Ho)
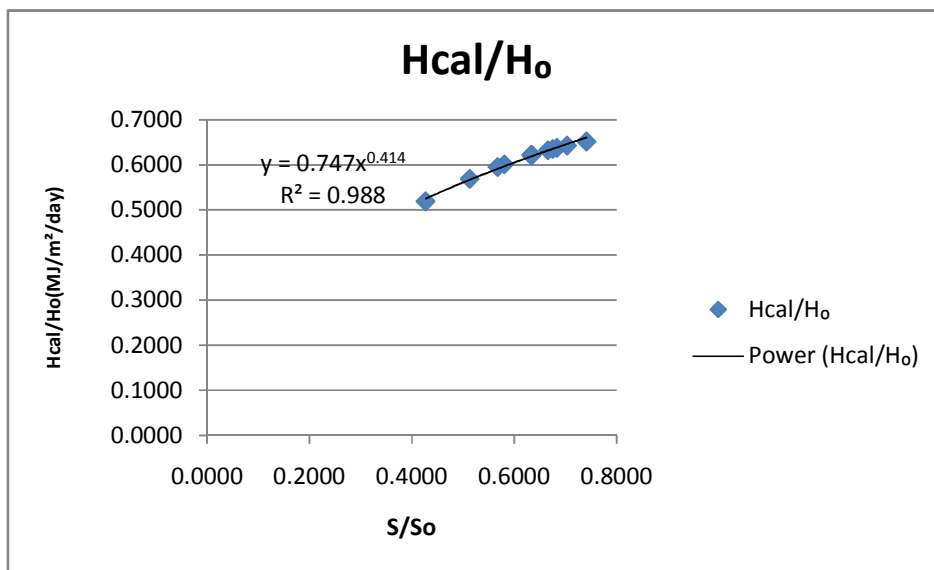versus relative sunshine duration(S/So) for Kebbi(1990 - 2005)**

**Figure 5: El-Metwally(2005) model fitting for variation of clearness index (Hcal/Ho)
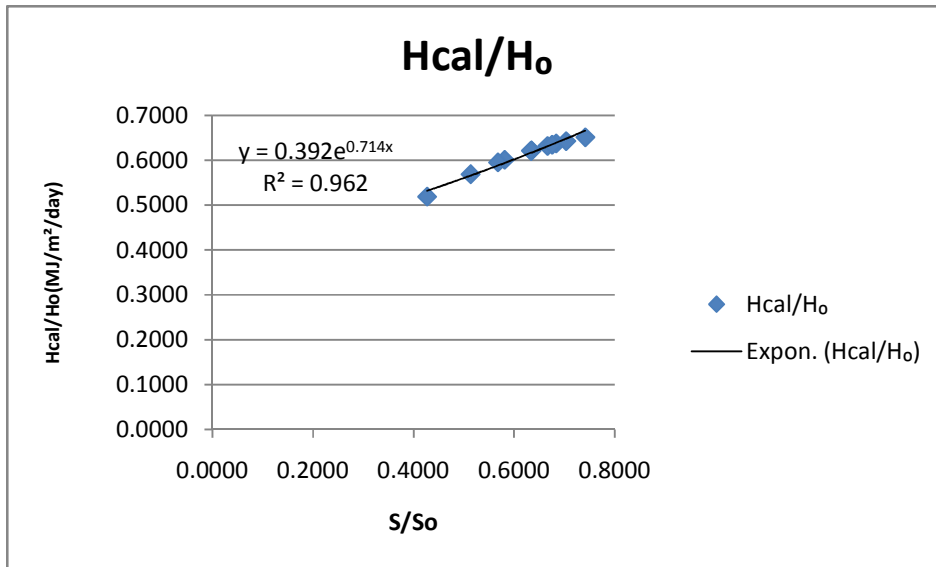versus relative sunshine duration(S/So) for Kebbi(1990 - 2005)**

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Figure 6: Bakirci(exponential)(2009) model fitting for variation of clearness index (Hcal/Ho) versus relative sunshine duration(S/So) for Kebbi(1990 - 2005)
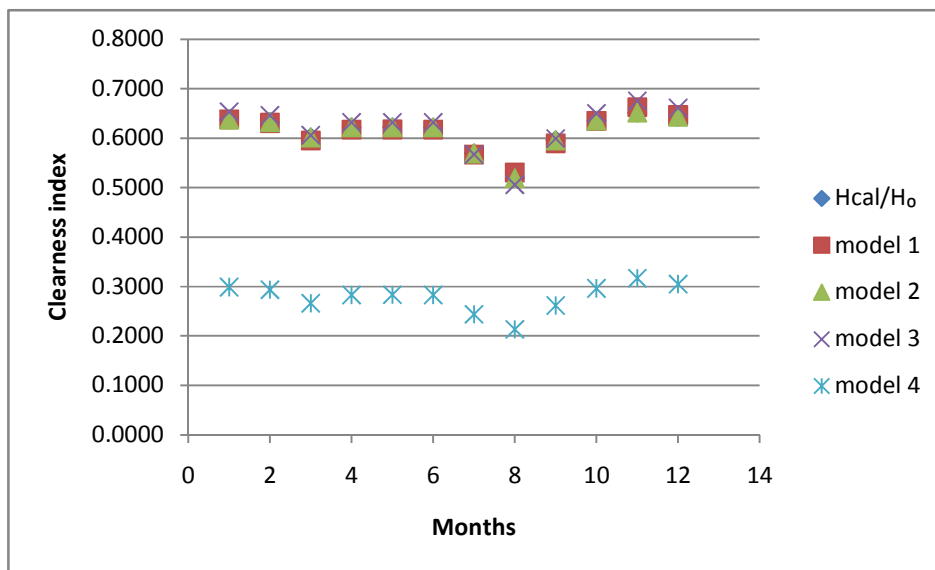

Figure 7: The comparison between calculated clearness index and four modeled values for Kebbi (1990-2005)

RESULTS AND DISCUSSION

The extraterrestrial solar radiation H_O (MJ/M^2/day) and the monthly day length S_O (hr) were computed for each month using equations (2) – (5), the input parameters for the calculation of the mean monthly global solar radiation for Kebbi (1990- 2005) are shown in the Table 2. It is observed that sunshine duration is above 55 per cent throughout the year with exception of the months of July- August (cf.table 2). Using these parameters, the regression constants 'a' and 'b' evaluated as 0.351 and 0.420 respectively. Substituting these values into equation (1), we now established the empirical correlation for the estimation developed for Kebbi as

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$$\frac{H_{cal}}{H_o} = 0.351 + 0.420 \left(\frac{S}{S_o} \right) \tag{13}$$

The coefficient of determination, R^2, (97.40%) obtained for this analysis shown in Figure 1, i.e., the model best fits the data. The value of $\frac{H_{cal}}{H_o}$ (= 0.5189) corresponding to the lowest value of $\frac{S}{S_o}$ (= 0.4269) and Hcal (20.10MJ/m^2/day) in the month of August is an indication of poor sky condition. These conditions correspond to the general wet or rainy season (June – September) observed in Nigeria, during which there is much cloud cover.

The regression constants (Table 3), **a** and **b** of different months were evaluated from equations (7) – (8). To compute the calculated values of the mean monthly average of global solar radiation H_{cal} , the values of **a** and **b** were inserted into equation (1) and the correlation may be used to compute Hcal at other locations having the same altitude. Looking at these values of measured and calculated clearness indexes; it is observed that both of them had the lowest values in the month of August. (Throughout the year) $\frac{H_{meas}}{H_o}$ (= 0.7962), $\frac{H_{cal}}{H_o}$ (= 0.5189) with H_{meas} (30.84 MJ/m^2/day) and H_{cal} (= 20.10 MJ/m^2/day) which can be traced to the meteorological conditions for Kebbi.

The correlation of monthly variation of calculated clearness index and sunshine fraction for Kebbi for the period of fifteen years is shown in Figure 2. Though there is similarity in both patterns, however, there is significance difference in the values of both parameters. It is observed clearly that there is a defined trough in the curves in the months of July – August. This is an indication that the atmospheric condition of Kebbi and its environs was at a poor state in which the sky was not clear. The value of the clearness index and the relative sunshine duration in Table 2 were observed to be 0.5189 and 0.4269 respectively. The results suggest that the rainfall in Kebbi is at peak during the month of July – August when the sky is cloudy and the solar radiation is fairly low. However, just immediately after the August minimum, the clearness index and the relative sunshine duration increased remarkably with the cloud cover crossing over the clearness index. Both the values of the clearness index and relative sunshine duration in November reached peaks at 0.6514 and 0.7412 respectively. This implies that a clear sky will obviously fell within the dry season and hence a high solar radiation is experienced. Obviously, this is generally the dry season period in Nigeria.

The calculated monthly mean global solar radiation, input parameters and four modeled values for kebbi for the period of fifteen years (1990 - 2005) are shown in table 4 and the comparisons between calculated clearness index and the four modeled values for Kebbi was also observed in Figure 7 above. It was clearly shown that from January – April, model 1 under estimated the calculated clearness index but model 2 gave 100% of the calculated clearness index while model 3 overestimated more than the model 2 at the months of January – June. At the month of May, models 1 and 2 gave almost the same results and models 1, 2 and 3 also gave almost the results in the month of July. From the of months of August – October, it was observed that model 3 gave 100% of the clearness index while model 1 overestimated at the month of August and gave almost 100% in the month of September. However, in model 4, we observed that it was underestimated for all the months of the year. At the month of November, model 1 and 3 was overestimated; model 2 gave 100% while model 4 was too low. Lastly, model 2 gave 100% of the calculated clearness index at the month of December.

Therefore, it can be concluded that model 2 is the best out of the four models of the sunshine-based models for Kebbi because it gave 100% of the calculated clearness index for all the months of the year. Both model 1 and 2 performed correctly in the month of May while model 4 underestimated for all the months of the year.

In the sunshine-based models proposed for this study, four models were used to show the validation of relative sunshine duration and clearness index for Kebbi for the period of fifteen years (1990 - 2005). Figure 3-6 show the results of the performance of each model in terms of regression of coefficient (R²), correlation coefficient (r). The empirical correlation models were also developed for the four sunshine-based models for Kebbi (1990 - 2005). The results for the four sunshine-based models were summarized below:

1. The empirical correlation for [8] model in equation (9) was

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$$\frac{H_{cal}}{H_o} = 0.3513 + 0.4198\left(\frac{S}{S_o}\right) \tag{14}$$

The coefficient of determination, R^2 (97.40%) obtained for this analysis shows that the model is excellently fits for the data (Figure3).

2. The empirical correlation model for [45] model in equation (10) was

$$\frac{H_{cal}}{H_o} = 0.1195 + 1.232\left(\frac{S}{S_o}\right) - 0.694\left(\frac{S}{S_o}\right)^2 \tag{15}$$

The coefficient of determination, R^2 (100%) obtained for this analysis shows that the model is excellently fits for the data (Figure 4).

3. The empirical correlation model for [46] model in equation (11) was

$$\frac{H_{cal}}{H_o} = 0.747^{\left(\frac{1}{\left(\frac{S}{S_o}\right)}\right)} \tag{16}$$

The coefficient of determination, R^2 (98.80%) obtained for this analysis shows that the model is excellently fits for the data (Figure 5).

4. The empirical correlation for Bakirci [47] model in equation (12) was

$$\frac{H_{cal}}{H_o} = 0.392\left(\frac{S}{S_o}\right)^{0.714} \tag{17}$$

The coefficient of determination, R^2 (96.20%) obtained for this analysis shows that the model is excellently fits for the data (Figure 6).

In summary, model 2 performed excellently in term of both coefficient of regression (R²) and correlation coefficient (r) than model 1, 3 and 4 while model 3 performed better than model 1 and model 4 having 98.80% coefficient of determination.

CONCLUSION

Kebbi is endowed appreciable with solar radiation and large rural dwellers lived in villages without proper infrastructure to develop an electricity grid, the use of PV is seen as attractive alternative because of its modular features, namely, its ability to generate electricity at the point of use, its low maintenance requirements and its non-polluting characteristics. Solar radiation models are desirable for designing solar- energy systems and good evaluations of thermal environments in buildings. This study employed a Angstrom model for predicting global solar radiation in Kebbi. The global solar radiation data set for Kebbi for the period of fifteen years (1990 - 2005) was analyzed using a regression technique in order to correlate the calculated clearness index and normalized relative sunshine duration with four sunshine-based models. Hence, the study resulted in the development of empirical correlation model for Kebbi and as well as the four sunshine-based models. Since no research regarding the potential of solar energy has been done prior to this work, this study will be very helpful to use these resources at Kebbi. It was observed that model 2(quadratic equation) performed better for estimating global solar radiation for

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Kebbi than model 1(linear), 3(power), and 4(exponential) equations because it has both higher regression of coefficient and correlation coefficient.

REFERENCES

[1]Muller- Steinhagen H, *A Vision for Sustainable Electricity Generation*, **2003**

[2]Halacy D S, Engineering Fundamentals, New York, **1980**

[3]Androsky A, *Aerospace Corporation El Segundo, CA, Report No: ATR –74 –(9470)* **1973**

[4]Spillman CK, Robbins FV, Hines RH, *Kansas State University, Manhattan, KS.* **1979**

[5]Abdulrahim, AT, Diso IS, El-Jummah AM, *Continental Journal of Engineering Sciences*, **2011,** 6(3), 30-37.

[6]Gairaa K, Bakelli Y, *International Journal Of Energy And Environment* , **2011**, **2(2),** 255-260.

[7]Angstrom A *Q. J. Roy. Meteor. Soc*, **1924,** 50, 121–125.

[8]Prescott JA *Trans. R. Soc of Australia* , **1940,** 64, 114–125.

[9]Journee M Demain C Bertrand C, *Advances in Sciences and Research open Access proceedings*. **2013** 10, 15-19.

[10] Page JK, Proceedings of UN Conference on New Sources of Energy, Rome (Agriculture and Food Organization, AFO United Nations), **1961** 4, 378

[11]Tiris M Tiris C, Erdalli Y, Marmara Research Centre, Institute of Energy Systems and Environmental Research, NATO-TU-COATING, Gebze, Turkey. **1997**

[12]Bahel V, Baksh H, Shrinivasan R, *Energy*, **1987**, 12, 131.

[13]Zabara K, Sol. Wind Technology, **1986**, 3, 267.

[14]Almorox J Hontoria C, *Energy Conversion and Management* **2004**, 45 1529-1535.

[15]Samuel TDMA, *Solar Energy*, **1991**, 47, 333

[16]Newland FJ, *Solar Energy* , **1988**, 43(4), 227.

[17]Allen RG, *J. Hydraul. Eng. ASCE* **1997**, 2, 56.

[18] Hargreaves GH, Samani ZA, *Trans. ASAE* **1985,** 1(2), 96.

[19]Bristow KL, Campbell GS, *Agric. Forest Meteorol* **1984**, 31, 150.

[20] Chen R, Ersi K, Yang J, Lu S, Zhao W, *Energy Convers Manage*, **2004**, 45, 1759.

[21]Trabea AA, Mosalam Shaltout MA, *Renewable Energy*, **2000** 21, 297.

[22]Ojosu J O, Komolafe LK, Nigerian Journal Solar Energy **1987**, 16, 69.

[23]Garg HP, Garg ST, Proceedings of the National Solar Energy Convention (Allied Publishers, New Delhi, 1982), **1982**, pp. 1,004.

[24] Lewis G, *Sol. Energy* **1983**, 31, 609.

[25]El-Metwally M, *Atmos. Res*. **2004**, 69, 217.

[26]Turk Togrul I, Togrul H Evin D, *Renewable Energy* **2000**, 19, 587.

[27]Turk Togrul I, *J. Therm. Sci. Technol*. **2009**, 29(2), 99.

[28]Korachagaon Bapat VN, Anjum Magami I, *Int. J. Mech. Mater. Eng*. **2008**, 3(2), 139.

[29] Korachagaon I, Ph.D. dissertation, Shivaji University, Kolhapur, India. **2011**

[30]Korachagaon I Bapat VN, *Int. J. Emerging Technol. Appl. Eng. Technol. Sci*. **2009** 2(2), 250.

[31]Korachagaon I Bapat VN, *Int. J. Appl. Eng. Res*. **2011**, 6(7), 1425.

[32]Korachagaon I Bapat VN, *Journal of Renewable and Sustainable Energy* **2012**, 4, 043101.

[33]Fagbenle RL *Nig. J. Renewable Energy* **1993**, 3: 813.

[34]Sambo AS. *Solar Wind Technology*, **1986**, 3, 89.

[35]Burari FW, Sambo AS, Mshelia E.D, *Nigerian Journal of Renewable Energy*, **2001** 9, 34 – 36.

[36]Augustine C, Nnabuchi MN, *International Journal of Physical Sciences*, **2009** 4(4), 182-188.

[37]Udo SO, *Turks J. Phys*, **2002** 26, 229 – 236.

[38]Akpabio LE, Udo SO Etuk SE, *Turkish J. Phys*. **2005**, 29, 63.

[39]Akpabio LE, Etuk SE, *Turkish J. Phys***. 2002**, 27: 161-167.

[40]Tijjani BI, *Bayero Journal of Pure and Applied Sciences*, **2011**, 4(2), 24 – 27

[41]Duffie JA Beckman WA Solar Engineering Of Thermal Processing, 2nd Ed. Madison: John Wiley &Sons, Inc. **1991**

[42]Falayi EO, Rabiu AB Teliat RO *Pelagie Research Library* **2011**, 2(4), 480-490

[43]Tiwari RF, Sangeeta TH, *Solar Energy*. **1997** 24(6), 89 – 95.

_____

[44]Medugu DW, Yakubu D, *Advances in Applied Science Research*, **2011**, 2 (2), 414-421.

[45]Ogelman H, Ecevit A, Tasdemiroglu E, *Solar Energy*, **1984** 33, 619–25

[46]El-Metwally M, *Journal of Atmospheric and Solar-Terrestrial Physics*, **2005**, 67, 1331-1342.

[47]Bakirci K, *Energy*, **2009**, 34, 485–501.

[48]Besharat, F., Dehghan,A.A. and Faghih,A. R. *Proceedings of the "International Conference on Solar energy for MENA region (INCOSOL)". Amman, Jordan,* **2012**.