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Advances in Applied Science Research, 2014, 5(2):144-148

ISSN: 0976-8610
CODEN (USA): AASRFC

Evaluation of monthly total global and diffuse solar radiation in Ibi, Taraba state, Nigeria

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ABSTRACT

This study utilized monthly average daily values of global solar radiation and sunshine hour for Ibi, Taraba State, North-Eastern Nigeria to assess the applicability of solar energy utilization for this area. The clearness index K_T values indicate the clear sky in the months of February to July and October to December for Ibi (lat.8.11^{0}N). The result obtained shows the variation of direct and diffuse component of solar radiation in summer and winter months. In this area the diffuse radiations is maximum during the month of July and August and minimum during the months of November, December and January. The regression constants "a" and "b" for the location were also calculated to 0.31 and 0.50 respectively. From the studies it has been found that with the exception of monsoon months August and September, solar energy can be utilized throughout the year in Ibi.

Keywords: Diffuse radiation, Global Solar Radiation, Clearness Index, Sunshine Hour.

INTRODUCTION

The light we see when the break is what called the diffuse solar radiation. But for us to see the direct solar radiation we have to look into the sky which is not comfortable. Global solar radiation is the combination of these two.

Global solar radiation data are necessary at various steps of the design, simulation, engineers, agricultural scientists and performance evaluation of any project involving solar energy. Solar radiation provides the energy for photosynthesis and transpiration of crops and is one of the meteorological factors determining potential yields. Crop growth models, which have been developed since the 1960s, have been regarded as important tools of interdisciplinary research and have since been used in a number of areas such as the assessment of agriculture potential of a given region in the field of crop yield forecasting or as a climate change impact assessment tool.

Detailed information about the availability of solar radiation on horizontal surface is essential for the optimum design and study of solar energy conversion system. More recently global solar radiation has being studied due to its importance in providing energy for Earth's climatic system[2]. In some places where radiation measurements are scanty, theoretical forecast of the available of solar energy can be used to predict these measurements from standard weather parameters that are extensively measured (air temperature, relative humidity, effective sunshine duration and cloudiness) [9]. Several models for estimating the diffuse component based on the pioneer works of [4], [8] and developed by [7].Besides these, many other researchers have reported the estimation of Global and Diffuse solar radiation employing various climatological parameters [1],[11]; [10]. Solar radiation estimation have been done for the first time for Hyderabad Sindh, to utilize solar energy for useful purpose, Prior to estimation of wind energy potential has also been reported [2]; [3] perform estimation of solar radiation with input parameters for the estimation of monthly average daily global solar radiation at Hyderabad, from this it was observed that sunshine

duration is above 70 percent throughout the Year; with the exception of July-August where here in Nigeria it not true.

MATERIALS AND METHODS

STUDY AREA

Ibi of Taraba State, Nigeria is located Geographically, 8.11^0N latitude and 9.45^0E longitude.

DATA COLLECTION

The following parameters were collected from the Archives of Nigerian meteorological Agency, National Weather Forecasting and Climate Research Centre Abuja for the period of ten years, from two thousand and one to two thousand and ten (2001-2010).

1)The daily global solar radiation.
2)Sunshine hour

DATA ANALYSIS

The solar radiation outside the atmosphere incident on a horizontal surface (Extraterrestrial Radiation on a horizontal Surface) is given by the following expression.

$$H_o = \frac{24x3600}{\pi} I_{sc}\left[1 + 0.033\cos\left(\frac{360d}{365}\right)\right]\left[cos\Phi cos\delta \sin w_s + \sin\Phi sin\delta\left(\frac{2\pi w_s}{360}\right)\right] \quad (1)$$

H_0 is the extraterrestrial insolation on horizontal surface where I_{sc} is the solar constants having the recommended value of 1367Wm^{-2},[12] Φ the latitude, δ the solar declination, ws is the sunset hour angle [13].

$$S_{max} = \frac{2}{15} w_s \quad (2)$$

With S_{max} being the daylength [13].

In equation (1)

The declination angle is calculated as [14]:

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

And the sunshine hour angle as [13].

$$\cos w_s = -tan\Phi tan\delta \quad (4)$$

The Global Radiation At Horizontal Surface:

The monthly global solar radiation H/H_0 falling on a horizontal surface at particular location is given as below[15]

$$\frac{H_g}{H_o} = a + b\left(\frac{S}{S_{max}}\right) \quad (5)$$

where H_g is the monthly average daily global solar radiation falling on a horizontal surface at a particular location, H_0 the monthly mean daily radiation on a horizontal surface in the absence of atmosphere, S the monthly mean daily number of observed sunshine hours, S_{max} the monthly mean value of day length at a particular location and "a", "b" the climatologically determined regression constants to be determined as follows:

$$a = -0.110 + 0.235cos\Phi + 0.323\left(\frac{S}{Smax}\right) \quad (6)$$

$$b = 1.449 - 0.553cos\Phi - 0.694\left(\frac{S}{Smax}\right) \quad (7)$$

In equation (5) S/S_{max} is often called the percentage of possible sunshine hour [5].

$$K_T = \frac{H_g}{H_o} \quad (8)$$

Where K_T represents clearness index

Prediction of Diffuse Solar Radiation (H_d)

The diffuse solar radiation H_d can be estimated by an empirical formula which correlates the diffuse solar radiation component H_d to the daily total radiation H. The following correlation equations were widely used and was developed by[16],[17].

$$\frac{H_d}{H_g} = 1.00 - 1.13K_T \quad (9)$$

$$\frac{H_d}{H_g} = 1.390 - 4.027K_T + 5.531(K_T)^2 - 3.108(K_T)^3 \quad (10)$$

Where H_d is the monthly mean of the daily Diffuse solar radiation and H_g is the daily total solar radiation and K_T is the clearness index, [13].

Table 1. Solar Radiation for Ibi

Months	Sunshine Hour, S (hour)	Day length, Smax (hour)	Percentage Sunshine Hour,S/Smax	Hg (MJ/M^2/day)	Ho (MJ/M^2/day)	KT	D (MJ/M^2/day)	D/Hg	D/Ho
Jan.	7.9	12.35	0.64	18.4	32.26	0.57	6.57	0.49	0.20
Feb.	7.5	12.16	0.62	21.8	34.65	0.63	6.11	0.28	0.18
Mar.	6.5	11.93	0.55	22.8	36.93	0.62	6.41	0.28	0.17
Apr.	8.7	11.72	0.74	24.7	37.85	0.65	7.38	0.34	0.19
May	7.5	11.57	0.65	23.6	37.31	0.63	6.61	0.28	0.18
Jun.	6.7	11.53	0.58	21.2	36.68	0.63	6.41	0.28	0.18
Jul.	4.3	11.64	0.37	19.6	36.81	0.58	6.61	0.28	0.18
Aug.	5.3	11.85	0.45	20.4	37.40	0.55	7.35	0.36	0.19
Sep.	6.8	12.07	0.56	20.3	37.09	0.55	7.31	0.36	0.19
Oct.	6.8	12.28	0.55	21.1	35.29	0.60	5.66	0.25	0.16
Nov.	8.5	12.43	0.68	21.0	32.73	0.64	5.67	0.27	0.17
Dec.	6.4	12.44	0.52	18.4	31.36	0.59	5.71	0.31	0.18

Table (1) represents solar radiation parameters for Ibi. The first column gives the sunshine duration recorded by sunshine recorder, while fourth column is the measured global radiation recorded with the help of Pyranometer and the remaining are evaluated data obtained with the help of the above equations.

The monthly mean solar radiation data for Ibi is as shown in table 1. The sunshine duration of Ibi ranges from 55% to 75%, throughout a year. Using these parameters the regression constants 'a' and 'b' were evaluated to be "0.31" and "0.50" respectively. The values of H_g, K_T and H_d for Ibi of the North-Eastern Nigeria Were also estimated by Liu and Jordan and Page methods as no station in Nigeria reports diffuse solar radiations. From the calculated result it appears that the contribution of diffuse solar radiation is very low throughout the year in Ibi. From the observation of clearness index and ratio of diffuse to global, it concluded that the presence of clouds is very rare even in monsoon months. This is the favorable condition for solar energy utilization.

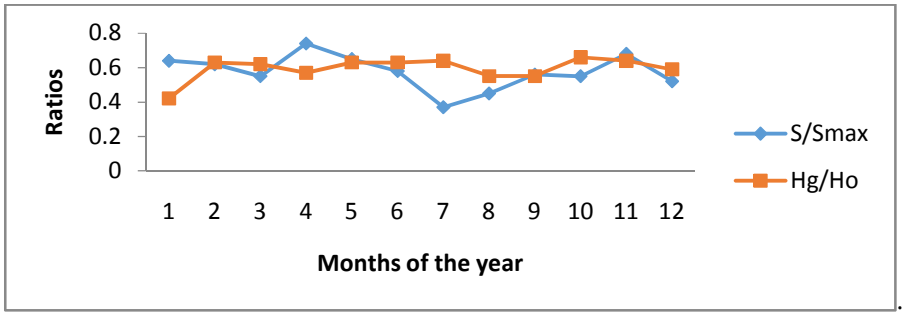

Fig.1.Variation of S/S_{max}andH_gH_0 (the clearness index) for Ibi, Nigeria

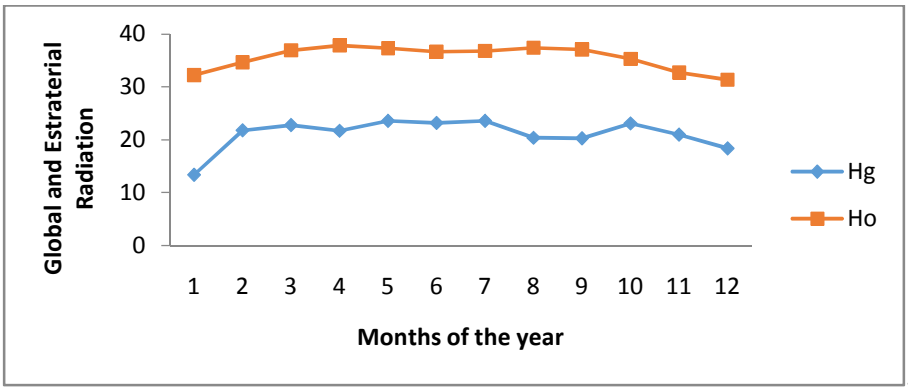

Fig. 2. Aplot of the monthly variation of Global and Estraterial radiation for Ibi, Nigeria

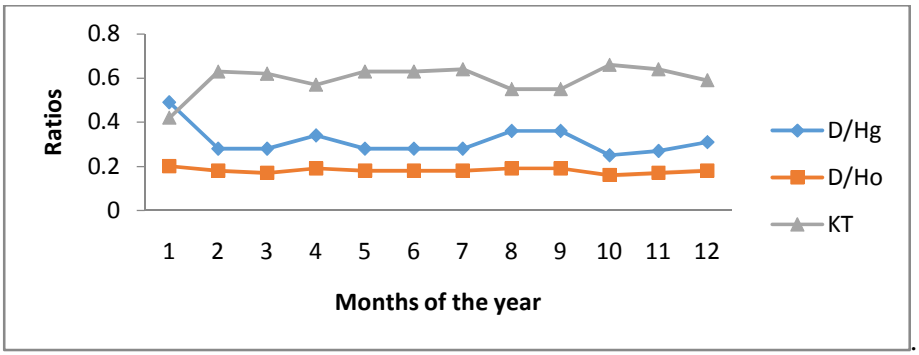

Fig. 3. Behaviour of the cloudness index Kt,D/H_g and D/H_0 during a year for Ibi, Nigeria

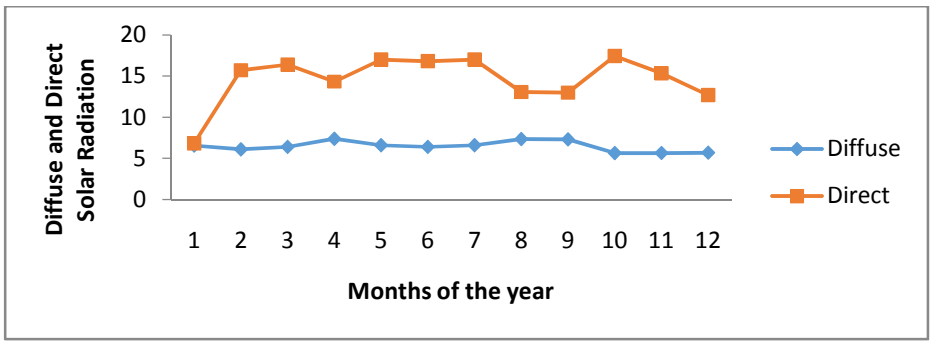

Fig. 4. Shows the variation of direct and diffuse radiation with months for Ibi, Nigeria

DISCUSSION

Solar energy is one of the most important alternative energy sources. For designing any solar energy device, solar energy parameters and components have important role. Solar energy offers us clean and sustainable energy for the future. Due to energy demand of the North Eastern Nigeria in these days, correct predictions and using solar energy models have big importance. It was aim at to supply correct models calculation in this study for using solar energy truly.

In this research a 10 years period was assumed to be sufficient to eliminate the possible effects due to changes in atmospheric transparency as a result of changes in air pollution. The values are low during June to September but high during October to February are shown in Figure. Different values of the clearness index at different stations may be as a result of different atmospheric contents of water vapour and aerosols.

CONCLUSION

The result obtained indicates that the solar energy utilization has bright prospects in this area. The estimated values of global and diffuse radiation can very efficiently be used to compensate for energy deficits. For the estimation of diffuse radiation lieu and Jordan and page methods were in good agreement. The global and diffuse solar radiation was carried out using sunshine hour data.

The result obtained shows the variation of direct and diffuse component of solar radiation in summer and winter months. In this area the diffuse radiations is maximum during the month of July and August and minimum during the months of November, December and January. The cloudiness index K_T values indicate the clear sky in the month of February to July and October to December for Ibi. From the studies it has been found that with the exception of monsoon months August and September solar energy can be utilized throughout the year in this area.

Hence the relationship below can be used in predicting the availability of solar radiation in Ibi of Taraba State, North Eastern Nigeria.

$$\frac{H_g}{H_o} = 0.31 + 0.50\left(\frac{S}{S_{max}}\right) \quad (5)$$

Acknowledgement
We are pleased to acknowledge the Nigerian Metrological Agency, Abuja office for providing solar radiation data for this work.

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