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Global solar radiation evaluation for some selected stations of north Eastern Nigeria

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ABSTRACT

This study utilized monthly average daily values of global solar radiation and sunshine hour for five stations of the North-Eastern Nigeria to assess the applicability of solar energy utilization for these areas. The clearness index K_T values indicates the clear sky in the months of February to July and October to December for Yola (lat.9.14^{0}N), February to July and September to November for Potiskum (lat.11.42^{0}N), February to July and September to December for Maiduguri (lat.11.51^{0}N), February to July and October to December for Ibi (lat.8.11^{0}N) and February to July and October to December for Bauchi (lat.10.17^{0}N) of the North-Eastern Nigeria. The regression constants "a" and "b" for each location selected were also calculated. 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 for North-East.

Keywords: Global Solar Radiation, Clearness Index, Sunshine Hour, Regression Constants.

INTRODUCTION

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

In the North East, we have six States; Adamawa, Bauchi, Gombe, Maiduguri, Taraba and Yobe State. But under this study, Bauchi of Bauchi State, Ibi of Taraba State, Maiduguri of Borno State, Potiskum of Yobe State and Yola of Adamawa State. The selection was done due to the availability of the solar data for these locations. Figure 1 below gives the geographical location of the stations selected in the North-Eastern Nigeria.

Table 1 Geographical location of the stations

Stations	Locations		Altitudes (m)
	LAT.	LONG.	
Bauchi	10.17^0N	9.40^0E	609.7
Ibi	8.11^0N	9.45^0E	110.7
Maiduguri	11.51^0N	13.05^0E	353.8
Potiskum	11.42^0N	11.02^0E	414.8
Yola	9.14^0N	12.28^0E	181.1

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.

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

H_0 is the extraterrestrial insolation on horizontal surface where I_{sc} is the solar constants, Φ the latitude, δ the solar declination, ws is the sunset hour angle,

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

With S_{max} being the daylength.

In equation (1)

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

and

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

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

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

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

RESULTS

Table 2 Solar Radiation for Bauchi

Months	Sunshine Hour, S (hour)	Day length, Smax (hour)	Percentage Sunshine Hour,S/Smax	Hg (MJ/M2/day)	Ho (MJ/M2/day)	KT
Jan.	6.9	11.56	0.51	11.54	32.21	0.34
Feb.	6.9	11.80	0.59	21.80	34.69	0.63
Mar.	8.5	12.09	0.70	24.70	36.97	0.67
Apr.	6.9	12.36	0.59	24.50	37.89	0.65
May	7.1	12.55	0.57	26.7	37.35	0.72
Jun.	6.6	12.59	0.52	24.24	36.72	0.66
Jul.	5.3	12.45	0.43	23.60	36.85	0.64
Aug.	5.0	12.20	0.41	20.10	37.44	0.54
Sep.	6.8	11.91	0.57	21.60	37.13	0.58
Oct.	8.7	11.64	0.75	26.60	35.33	0.75
Nov.	9.3	11.47	0.81	23.00	32.77	0.70
Dec.	8.3	11.44	0.73	18.30	31.31	0.59

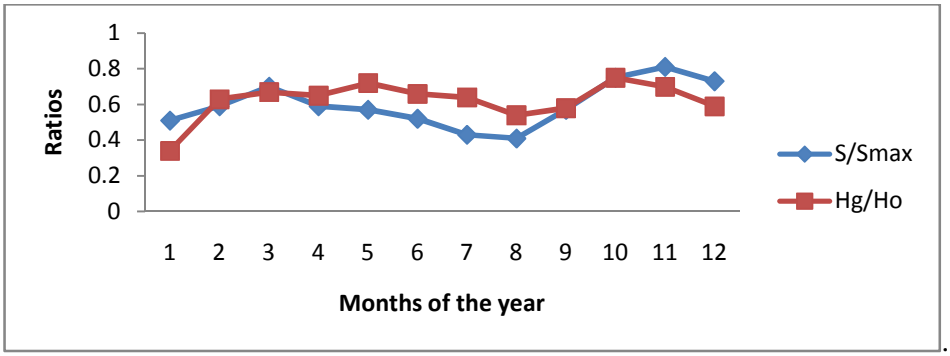

Figure1. Variation of $S/S_{max}$and H_gH_0 (the clearness index) for Bauchi, Nigeria

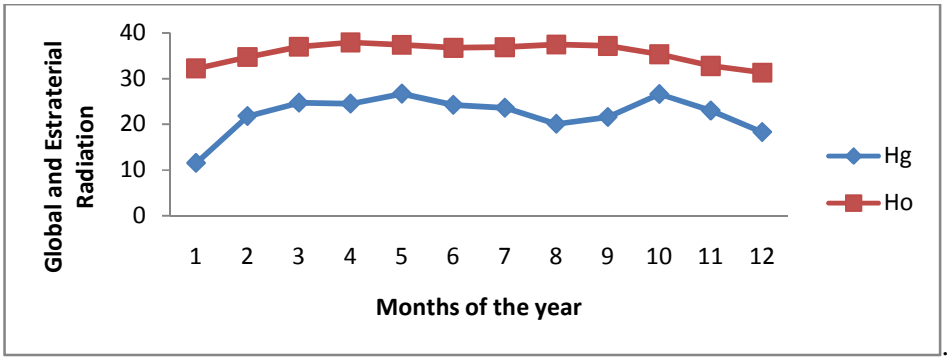

Figure:2 Aplot of the monthly variation of Global and Estraterial radiation for Bauchi(Latitude 10.17) Nigeria.

The monthly mean sunshine hour and day length for Bauchi is as shown in table 2. The sunshine duration of Bauchi ranges from 50% to 80%, throughout a year.

Table 3 Solar Radiation for Ibi

Months	Sunshine Hour, S (hour)	Day length, Smax (hour)	Percentage Sunshine Hour,S/Smax	Hg (MJ/M2/day)	Ho (MJ/M2/day)	KT
Jan.	7.9	12.35	0.64	13.4	32.26	0.42
Feb.	7.5	12.16	0.62	21.8	34.65	0.63
Mar.	6.5	11.93	0.55	22.8	36.93	0.62
Apr.	8.7	11.72	0.74	21.7	37.85	0.57
May	7.5	11.57	0.65	23.6	37.31	0.63
Jun.	6.7	11.53	0.58	23.2	36.68	0.63
Jul.	4.3	11.64	0.37	23.6	36.81	0.64
Aug.	5.3	11.85	0.45	20.4	37.40	0.55
Sep.	6.8	12.07	0.56	20.3	37.09	0.55
Oct.	6.8	12.28	0.55	23.1	35.29	0.66
Nov.	8.5	12.43	0.68	21.0	32.73	0.64
Dec.	6.4	12.44	0.52	18.4	31.36	0.59

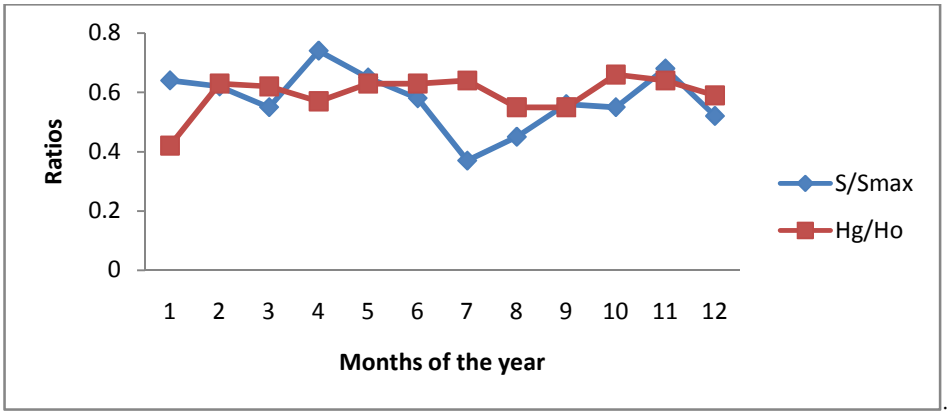

Figure 3. Variation of S/S_{max} and H_gH_0 (the clearness index) for Ibi, Nigeria.

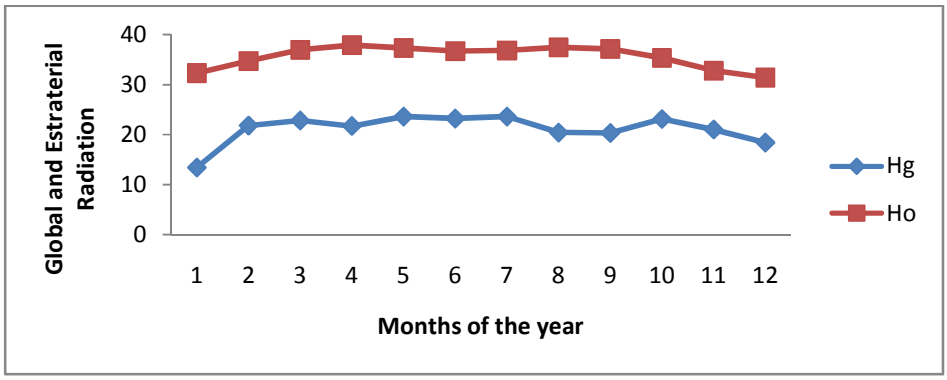

Figure:4. Aplot of the monthly variation of Global and Estraterial radiation for Ibi, Nigeria.

The monthly mean sunshine hour and day length for Ibi is as shown in table 3. The sunshine duration of Bauchi ranges from 55% to 75%, throughout a year.

Table 4 Solar Radiation for Maiduguri

Months	Sunshine Hour, S (hour)	Day length, Smax (hour)	Percentage Sunshine Hour,S/Smax	Hg (MJ/M2/day)	Ho (MJ/M2/day)	KT
Jan.	9.0	11.51	0.78	17.3	32.32	0.54
Feb.	9.7	11.76	0.83	21.5	34.71	0.62
Mar.	8.1	12.09	0.66	28.4	36.99	0.77
Apr.	8.3	12.40	0.67	26.8	37.91	0.71
May	8.9	12.63	0.71	28.1	37.37	0.75
Jun.	8.4	12.67	0.66	25.3	36.74	0.69
Jul.	6.6	12.51	0.53	24.2	36.89	0.66
Aug.	6.3	12.23	0.52	21.5	37.46	0.57
Sep.	7.5	11.89	0.63	23.4	37.16	0.63
Oct.	8.7	11.59	0.75	28.3	35.35	0.80
Nov.	10.0	11.40	0.88	24.8	32.79	0.76
Dec.	10.3	11.37	0.91	20.0	31.42	0.64

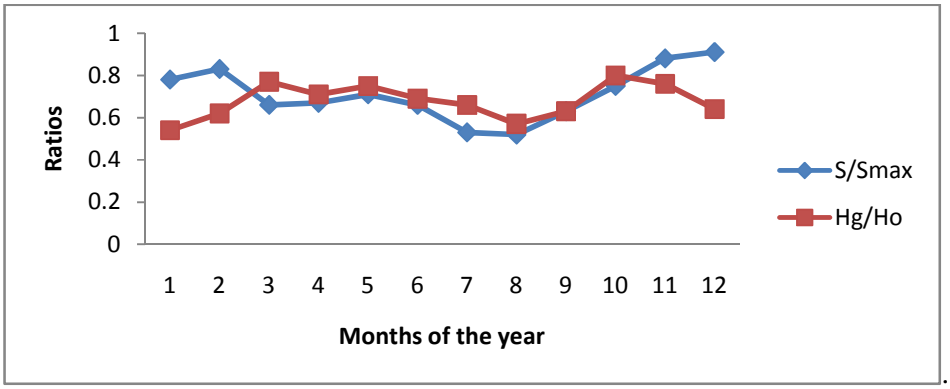

Figure 5. Variation of S/S_{max} and H_gH_0 (the clearness index) for Maiduguri, Nigeria.

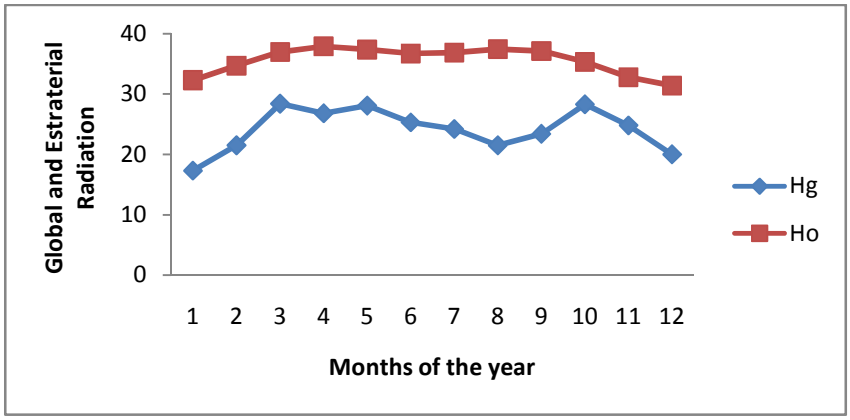

Figure:6 A plot of the monthly variation of Global and Estraterial radiation for Maiduguri, Nigeria.

The monthly mean sunshine hour and day length for Maiduguri is as shown in table 4. The sunshine duration of Maiduguri ranges from 50% to 90%, throughout a year.

Table 5 Solar Radiation for Potiskum.

Months	Sunshine Hour, S (hour)	Day length, Smax (hour)	Percentage Sunshine Hour,S/Smax	Hg (MJ/M2/day)	Ho (MJ/M2/day)	KT
Jan.	6.9	11.51	0.59	16.3	32.32	0.50
Feb.	8.8	11.76	0.75	22.4	34.71	0.64
Mar.	8.0	12.09	0.66	28.1	36.99	0.76
Apr.	6.8	12.28	0.55	26.1	37.91	0.69
May	8.3	12.61	0.66	27.9	37.37	0.75
Jun.	8.8	12.55	0.70	26.0	36.74	0.71
Jul.	6.6	12.51	0.53	24.8	36.89	0.67
Aug.	6.5	12.21	0.53	21.9	37.46	0.58
Sep.	7.1	11.89	0.51	22.8	37.15	0.61
Oct.	7.8	11.48	0.68	27.9	35.35	0.79
Nov.	9.4	11.41	0.82	21.4	32.79	0.65
Dec.	10.1	11.37	0.89	17.5	31.42	0.56

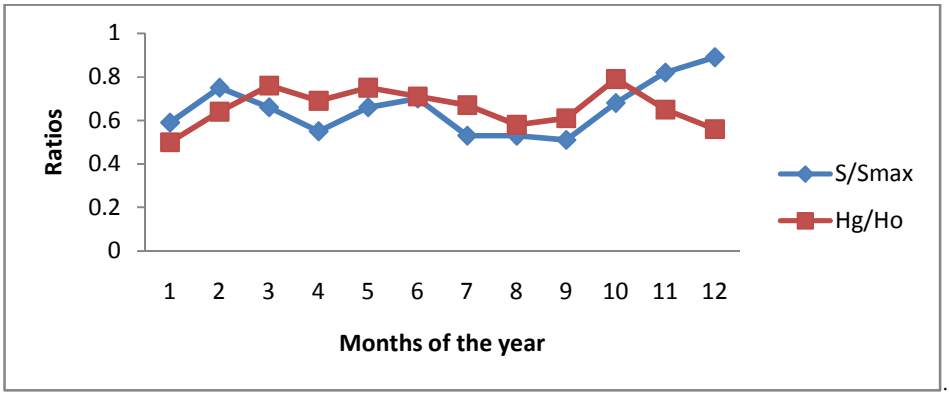

Figure 7. Variation of S/S_{max} and $H_g H_0$ (the clearness index) for Potiskum, Nigeria.

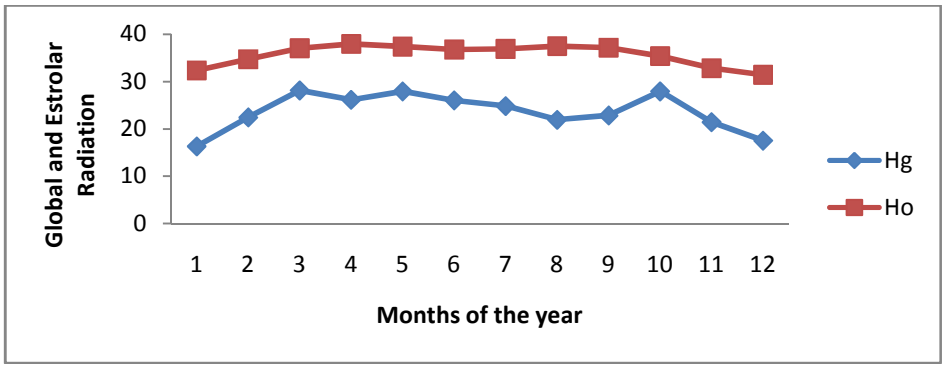

Figure:8 Aplot of the monthly variation of Global and Estraterial radiation for Potiskum, Nigeria.

The monthly mean sunshine hour and day length for Potiskum is as shown in table 5. The sunshine duration of Potiskum ranges from 50% to 90%, throughout a year.

Table 6 Solar Radiation for Yola.

Months	Sunshine Hour, S (hour)	Day length, Smax (hour)	Percentage Sunshine Hour,S/Smax	Hg (MJ/M2/day)	Ho (MJ/M2/day)	KT
Jan.	6.7	11.60	0.56	16.9	32.28	0.52
Feb.	6.4	11.81	0.54	21.3	34.67	0.61
Mar.	8.2	11.70	0.70	24.3	36.95	0.66
Apr.	8.1	11.92	0.68	24.8	37.87	0.66
May	7.9	11.68	0.68	24.4	37.33	0.65
Jun.	6.6	12.50	0.53	23.1	36.70	0.63
Jul.	6.6	12.49	0.53	22.4	36.83	0.61
Aug.	5.7	12.31	0.46	20.3	37.42	0.54
Sep.	6.5	12.05	0.54	20.8	37.11	0.56
Oct.	8.7	11.78	0.74	22.3	35.31	0.63
Nov.	10.1	11.57	0.87	21.1	32.75	0.64
Dec.	9.1	11.46	0.79	18.9	31.38	0.60

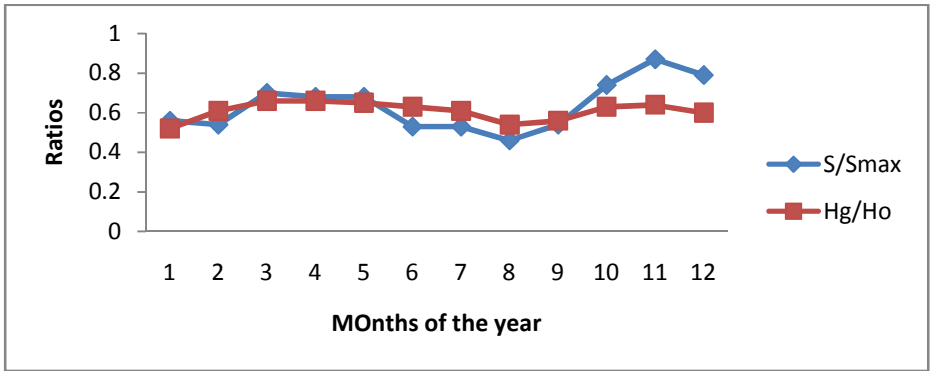

Figure 9. Variation of S/S_{max} and H_gH_0 (the clearness index) for Yola, Nigeria.

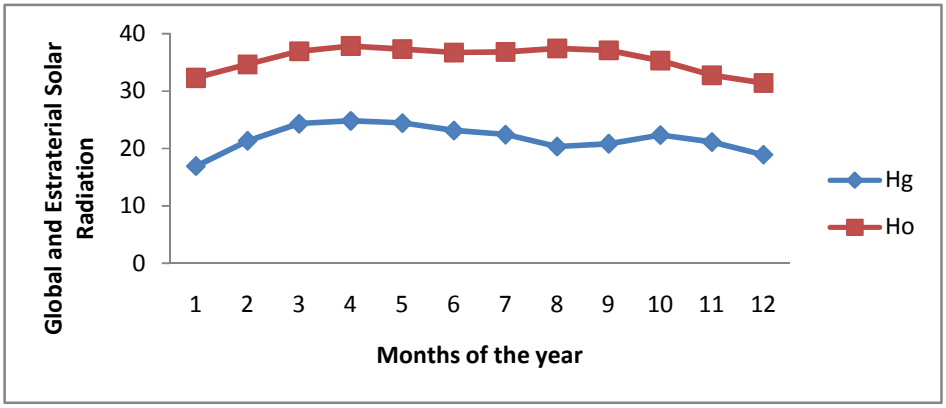

Figure:10 Aplot of the monthly variation of Global and Estraterial radiation for Yola, Nigeria.

The monthly mean sunshine hour and day length for Yola is as shown in table 6.
The sunshine duration of Yola ranges from 50% to 85%, throughout a year.

Table 7: Latitudes of the locations, annually averaged percentage of sunshine hour and the climatic factors of the locations.

Stations	Latitude	S/S_{max}	"a"	"b"
Bauchi	10.17^0N	0.51	0.32	0.49
Ibi	8.11^0N	0.58	0.31	0.50
Maiduguri	11.51^0N	0.71	0.35	0.41
Potiskum	11.42^0N	0.66	0.33	0.45
Yola	9.14^0N	0.64	0.33	0.46

RESULTS AND DISCUSSION

Using these parameters the regression constants 'a' and 'b' were evaluated (table 8). The values of H_g, K_T and H_o for for each location selected of the North-Eastern Nigeria Were also estimated. From the observation of clearness index, it concluded that the presence of clouds is very rare even in monsoon months. This is the favorable condition for solar energy utilization. Atmospheric clearness is indicated by fraction of extraterrestrial radiation that reaches the earth surface as global solar radiation k_t. The clearness index is the measures of the degree of clearness of the sky. From the estimated value of the global radiation, H_g, the clearness index, K_T, is calculated from equation (3.10). It is encouraging to note that the sky over Yola is very clear almost throughout the year which is very favorable condition for solar energy utilization.

CONCLUSION

Energy is a continuous steering power for the social and technological prospective development. Renewable energy is consider as the key source for the future as it is the vital and essential Ingredients for all Earthly activities and without them human activities of all kind will not be progressive at all.

The result obtained indicates that the solar energy utilization has bright prospects in the North-Eastern Nigeria. The estimated values of global radiation can very efficiently be used to compensate for energy deficits. 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 for North-Eastern region of Nigeria

From the above results and considerations, the maximum values of global solar radiation appear in March, April and May respectively during dry season while minimum values were observed in August and September, respectively during wet season.

Acknowledgement
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