



A Study of the Global Solar Radiation of Makurdi, Benue State, Nigeria

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Abstract: *Having the knowledge of global solar radiation of a particular location on the earth's surface will help in adequate planning by environmentalists, health officials, solar power personnel, irrigation farmers, and other users of such information. The aim of this research work is to estimate the global solar radiation of Makurdi, especially with a view to finding out if there was any change between the present value and the one(s) obtained sometimes ago.*

The data of maximum and minimum temperature for February 2017, obtained from the website of weather online limited was used with Hargreaves-Sammani model to estimate the global solar radiation. It was discovered from the result that the study location (Makurdi) has the maximum global solar radiation for February 2017 as 30.486 MJ/m²/day, minimum global solar radiation of 23.871 MJ/m²/day, and an average global solar radiation of 28.425 MJ/m²/day respectively.

Keyword: Global solar radiation, Sunset angle, Temperature, Hargreaves-Sammani.

I. Introduction

Solar radiation refers to the electromagnetic radiation that reaches the Earth from the Sun. At an average distance of 150 million kilometres from the Sun, the outer atmosphere of Earth receives approximately 1367 W/m² of insolation (World Meteorological Organisation).

According to Dictionary.com, Solar radiation is defined as the energy radiated from the sun in the form of electromagnetic waves, including visible and ultraviolet light and infrared radiation. That is; solar radiation is the total amount of radiations from the sun that reaches the earth's surface at a particular period of time.

The amount of solar radiations reaching different parts of the surface of the earth varies due to some factors ranging from atmospheric factors to geographical factors. Solar radiation distribution is affected by location; latitude and longitude, topography, temperature, pressure, relative humidity etc.

In the area of power supply, the amount of solar radiation available in an area is an important factor to be considered before the installation of solar power system in an area because the power output provided by a given installed solar photovoltaic system in one particular state in Nigeria may not be obtained when such system is installed in another state, with all other factors remaining constant. [Ayegba *et al.*, 2016]

This is as a result of variation of solar radiation with locations, as well as topography. The amount of this energy depends on the location, time of the year, and atmospheric conditions [Helena *et al.*, 2011]. Research outcomes on studies of global solar radiation have facilitated improvement in Agronomy, power generation, environmental temperature controls, etc. [Ugwu, A. I. and Ugwuanyi, J. U., 2011]. Therefore, there is need for this type of work. For many years now, related works have been done by various scientists, engineers and scholars. In 2008, Chiemeka, estimated the solar radiation at Uturu Abia state Nigeria, latitude 5.33°N and 6.33°N. He made use of the temperature data from 5th – 31st October 2007 obtained using the maximum and minimum thermometer placed in Stevenson screen at 1.5m. He used the Hargreaves-Sammani model for the work and found out that the mean global solar radiation obtained for the period was 1.89 - 0.82 kWh/day. The poor value gotten was attributed by him to the fact that Uturu is bounded on the west and south by a hilly escarpment.

Bernadette, *et al.*, 2007 did a similar work in Makurdi using the weather data between (1990 - 1991, 1995-2003). The work involved Testing of the Performance of Some Empirical Models such as Garcia's Model, Angstrom model and Hargreave sammani model. It was observed by them that the average Global solar radiation with Hargreave-Sammani model for February was 23.831 MJ/m²/day.

The work done in Makurdi above made use of the data which stopped at 2003, which is about fourteen years ago, therefore, there is need to carry out another work in the same area using the latest weather data such as that of 2017 which is used in this work. With this approach, the updated global solar radiation of the area can be estimated.

II. Study area

Benue state is one of the states in north central Nigeria, and shares boundaries with about six states. It has Nasarawa state to the north, Enugu and Kogi states to the west, Taraba state to the East, Ebonyi and Cross river states to the south.

The state lies between latitude $6^{\circ} 25'$ and $8^{\circ} 8'$ N and longitude $7^{\circ} 47'$ and $10^{\circ} 0'$ E. The state experiences two seasons- dry and rainy seasons; with rainy season from April to October, and dry season from November to March. The temperature of the state has the temperature range between $21 - 37^{\circ}\text{C}$ in a year. The state is known as the “food basket” of the nation because of their well-known in farming practices. Some of the agricultural produce of the state are yam, beans, rice, millet, vegetables, etc. The presence of river Benue also makes the state suitable for fishing and irrigation farming especially during dry season.

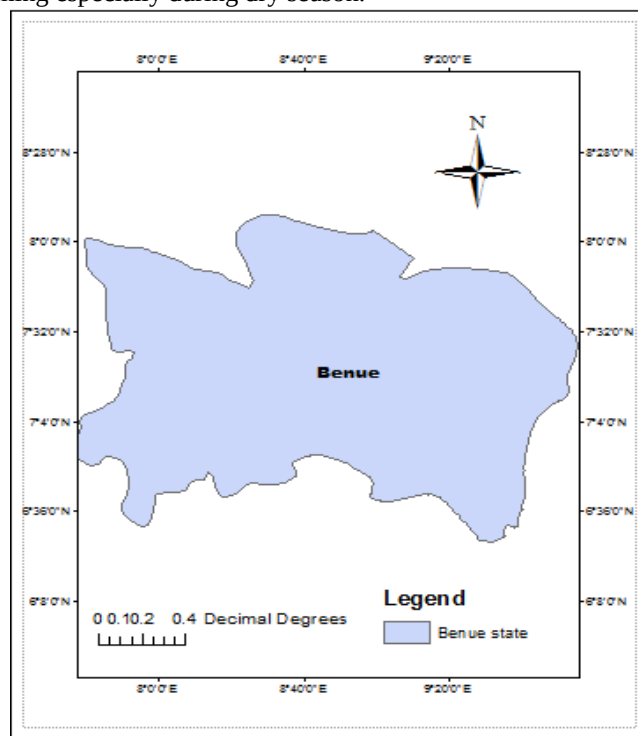


Fig. 2.1: Map of study area

III. Materials and Method

A. Materials

The research work made use of secondary data, which is the maximum and minimum temperatures data of the study location for the month of February, 2017. The primary data was the GPS coordinate point of the study location. The data maximum and minimum temperatures were obtained from the website of weather online limited. This work also made use ArcGIS software (version 10.1) and Microsoft excel package.

B. Method

The global solar radiation of the study location was estimated from the maximum and minimum temperature data using Hargreaves-Samanni model. The model has many parameters to be calculated before obtaining the global solar radiation using various mathematical formulas.

Microsoft excel package was used for the calculation of various parameters of the global solar radiation.

The procedures for using the Hargreaves-Samanni model equation in the prediction of global solar radiation are as follow:

B.1 Calculation of solar radiation declination (δ): Solar radiation declination is defined as the angle made between a ray of the sun, when extended to the centre of the earth and the equatorial plane. The solar radiation declination has the formula given as;

$$\delta = 0.409 \sin\left(\frac{2\pi}{365} J - 1.39\right) \text{ ----- } 3.1$$

Where J is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December) and δ is solar radiation declination in radian.

B.2. Calculation of inverse relative distance Earth-sun (d_r): Inverse relative distance Earth-sun is the inverse distance of the sun relative to the earth at a location. It is calculated using the formula given as;

$$d_r = 1 + 0.033 \cos\left(\frac{2\pi J}{365}\right) \text{ ----- 3.2}$$

B.3. Calculation of sunset angle (w_s): Sunset angle is the angle of the daily disappearance of the sun below the horizon due to the rotation of the earth. Sunset time is the time in which the trailing edge of the sun's disk disappears below the horizon. It is calculated using the formula given as;

$$\omega_s = \cos^{-1}(-\tan(\varphi)\tan(\delta)) \text{ ----- 3.3}$$

Where ω_s is the sunset angle (radian), δ is the solar radiation declination (radian), and φ is latitude angle of the location (radian).

B.4. Calculation of extraterrestrial solar radiation (R_a): Extraterrestrial solar radiation is the intensity or power of the sun at the top of the earth's surface. The extraterrestrial radiation is calculated using the formula given as;

$$R_a = \frac{24(60)}{\pi} G_{sc} d_r [w_s \sin(\varphi) \sin(\delta) + \cos(\varphi) \sin(w_s)] \text{ ----- 3.4}$$

where R_a is extraterrestrial radiation, d_r is the inverse relative earth-sun distance, φ is the latitude angle, w_s is the sunset angle, and G_{sc} is solar constant given as $0.0820 \text{ MJ m}^{-2} \text{ min}^{-1}$ or 1367 Wm^{-2} .

B.5. Calculation of Global Solar Radiation (R_s): Global solar radiation is the total amount of solar energy received by earth's surface. Global solar radiation is the sum of the direct, diffuse and reflected solar radiations, as is calculated using the formula given as;

$$R_s = K_{RS} (\sqrt{T_{\max} - T_{\min}}) R_a \text{ ----- 3.5}$$

Table 3.1: Maximum and minimum temperature data for February 2017 obtained from the website of weather online limited.

Tmax (°C)	Tmin (°C)
38	20
37	20
37	21
33	14
33	16
39	18
39	20
39	19
38	20
34	17
35	17
40	19
40	20
39	19
39	19
38	18
38	19
38	18
38	18
38	19
39	21
40	20
40	22
40	23
38	23
38	22
37	24
37	25

IV. RESULTS AND DISCUSSION

A. RESULTS

The location coordinate is Lat 7.7322°N and Long 8.5391°E .
Adjustment factor, $K_s = 0.19$

Table 4.1: Global solar radiation, inverse relative distance Earth-sun, sunset angle, solar radiation declination, extraterrestrial solar radiation of Makurdi for the month of February 2017.

S /N	dr (rad)	δ (rad)	Ws (rad)	Ra (MJ/m ² day)	Rs (MJ/m ² day)
1	1.0281	-0.304	1.528	34.114	27.499
2	1.0278	-0.300	1.529	34.194	26.787
3	1.0275	-0.295	1.530	34.274	26.048
4	1.0272	-0.290	1.530	34.355	28.453
5	1.0269	-0.285	1.531	34.437	26.978
6	1.0265	-0.280	1.532	34.519	30.055
7	1.0262	-0.275	1.533	34.601	28.656
8	1.0258	-0.269	1.533	34.683	29.471
9	1.0255	-0.264	1.534	34.766	28.025
10	1.0251	-0.259	1.535	34.849	27.300
11	1.0247	-0.253	1.536	34.931	28.158
12	1.0244	-0.247	1.537	35.014	30.486
13	1.0240	-0.242	1.537	35.096	29.822
14	1.0236	-0.236	1.538	35.179	29.891
15	1.0232	-0.230	1.539	35.261	29.961
16	1.0228	-0.224	1.540	35.342	30.030
17	1.0224	-0.219	1.541	35.423	29.337
18	1.0219	-0.213	1.542	35.504	30.168
19	1.0215	-0.207	1.542	35.584	30.236
20	1.0211	-0.200	1.543	35.663	29.536
21	1.0206	-0.194	1.544	35.742	28.812
22	1.0202	-0.188	1.545	35.820	30.437
23	1.0197	-0.182	1.546	35.897	28.937
24	1.0193	-0.175	1.547	35.974	28.181
25	1.0188	-0.169	1.548	36.049	26.527
26	1.0183	-0.163	1.549	36.123	27.454
27	1.0179	-0.156	1.549	36.196	24.796
28	1.0174	-0.150	1.550	36.268	23.871

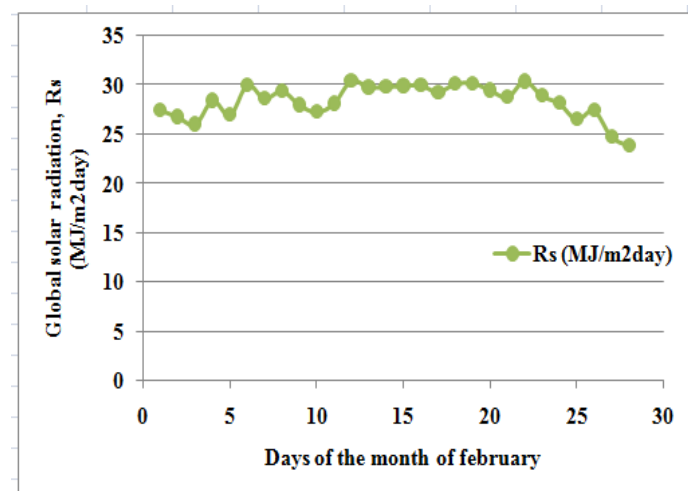


Fig. 4.1: Graph of global solar radiation

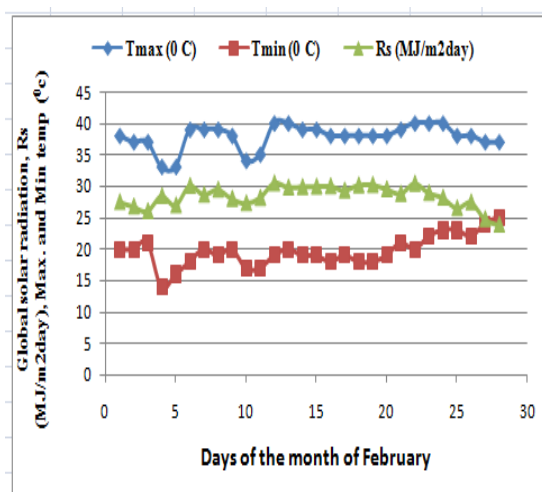


Fig. 4.2: Graph of global solar radiation, maximum and minimum temperature

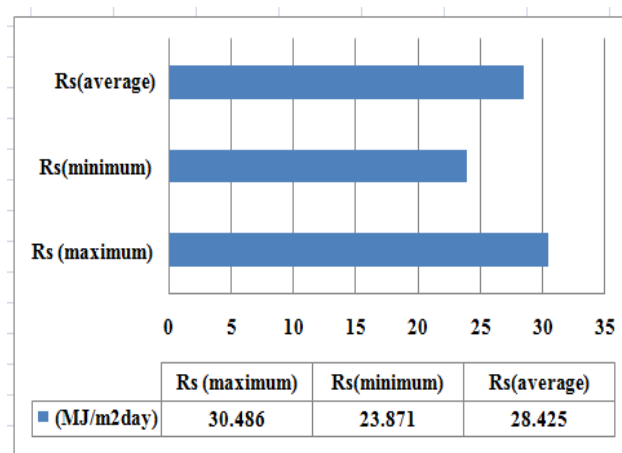


Fig. 4.3: Chart of maximum, minimum and average global solar radiation for February, 2017

B. DISCUSSION

Table 4.1 shows the Global solar radiation, inverse relative distance Earth-sun, sunset angle, solar radiation declination, extraterrestrial solar radiation of Makurdi for the month of February 2017. The result shows that there was mostly daily variation (increasing and decreasing), though not in a regular order of the global solar radiation for the month. The first ten days of the month display oscillatory values mostly, with the last few days of the month still behaving in the same way. However, the global solar radiation from 10th to 20th was to some extent stable, i.e. less noticeable oscillations. This is shown in fig. 4.1.

The relationship between the global solar radiation, maximum and minimum temperatures for the month is shown in figure 4.2. From the figure, it can be seen that maximum and minimum temperatures have influence on the global solar radiation on the area especially during the first half of the month.

In addition, from the result as shown in table 4.1, the study area has the maximum, minimum and average global solar radiation for February 2017 of 30.486 MJ/m²day, 23.871 MJ/m²day, and an average 28.425 MJ/m²day respectively (Fig. 4.3). The average global solar radiation of 28.425 MJ/m²day obtained in this work for Makurdi for the month of February is almost in agreement with the result of the work by Bernadette *et al.*, 2013. Their work made use of weather data from 1990 – 1991 and 1995-2003, and the average global solar radiation gotten for the month of February using the same Hagreaves-Sammani model for Makurdi was 23.831 MJ/m²day. The difference of 4.594 MJ/m²day between their result and our result shows the effect of global warming which is affecting almost all parts of the world today. The data of 2017 used for this our work is fourteen years after their own. This increment of 4.594 MJ/m²day after fourteen years should be a source of worries to environmentalists, agriculturists, horticulturists, ecologists, and most importantly health personnel. This change will in no doubt might have affected some species of plants and animals with some already depreciating in number or even on extinction. However, the development is an opportunity for the provision of solar power in the area as an alternative power supply since country's electrical power system is still epileptic.

V. CONCLUSION

The data of maximum and minimum temperatures for February, 2017 used for this work was obtained from the website of weather online. The estimation of global solar radiation was done using Hargreave-Sammani model, and the average global solar radiation as well as the maximum and minimum values were obtained. The results show that the maximum global solar radiation for February 2017 is 30.486 MJ/m²day, minimum global solar radiation is 23.871, and average global solar radiation is 28.425 MJ/m²day respectively. This average global solar radiation of 28.425 MJ/m²day obtained in this work for Makurdi for the month of February is in agreement with the result of the work by Bernadette *et al.*, 2013 in which the average global of 23.831 MJ/m²day was for February, using the data of between 1990 – 1991 and 1995-2003, and with Hargreaves-Sammani model. An increment of 4.594 MJ/m²day occurs in the present work which shows the impact of global solar warming on the earth surface. Environmentalists and other related personnel would find this information very paramount.

VI. RECOMMENDATION

The weather data of more than one month but which should be of recent years be used for the same estimation in the study location.

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