ISSN 2250-3153

Assessing the Seasonal Variation in Global Solar Radiation of Lagos State, Nigeria

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Abstract- The knowledge of the seasonal variation in global solar radiation reaching a location on the earth is an important information for Agriculturists, water sector personnel, electrical power sector, environmentalists, etc. The objective of this work is to determine how global solar radiation of Lagos state varies with dry seasons.

Hargreaves-Samani model of global solar radiation prediction was used for this work, making use of minimum and maximum air temperature data adopted from the website of Weather Online limited for the months of January and August 2016, with January representing the dry season and August representing the rainy season data. The result shows that there is variation in global solar radiations in the two seasons, with dry season having radiation than rainy season.

***Index Terms*-** Agriculture, Hargreaves-Samanni Model, Maximum Temperature, Seasonal Global Solar Radiation.

I. Introduction

A knowledge of spectral irradiance (direct and diffuse) arriving at the earth's surface is important for the design of many solar energy applications [S. O. Falodun and E. O. Ogolo, 2007].

The amount of global solar energy depends on the location, time of the year, and atmospheric conditions [Helena Mitasova *et al, 2011*]. In other words, the amount of solar energy available in a place or location depends on the time of the year; that is; rainy and dry season, and thus there is need for such a research to be carried out in a megacity such as Lagos state, Nigeria. 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].

Also, the amount of solar radiation over a place determines the type of crops that can survive in such a place as some crops have less resistance to hot environment.

The objective of this work is to assess the seasonal variation in global solar radiation of Lagos state, Nigeria, and it employs Hargreaves-Samanni model.

Hargreaves-Samanni (1985) model accounts for solar radiation using only temperature. Although relative humidity is not explicitly contained in the equation, it is implicitly present in the difference in maximum and minimum air temperature [Ugwu, A. I. and Ugwuanyi, J. U., 2011].

In some parts of the country, similar works have been carried out by various scientists and researchers. In 2015, Adedoja, O.S. Ayantunji, B.G. Saleh U.A. and Jatto. S.S carried out a work in Anyigba (7.486N, 7.1836E), Nigeria using Campbell automatic weather station. In their work, "Diurnal and Seasonal Variation of Global Solar Radiation at Anyigba, North-Central Nigeria", it was observed that solar activity was peak in February, which is dry season and low in months of rain.

S. O. Falodun and E. O. Ogolo in 2007 did similar work in Akure entitled "Diurnal and seasonal variation of Global Solar Radiation at Akure , South-Western Nigeria". It was also observed by them that there is seasonal variation in global radiation, and that the dry months have comparably larger values than wet months.

II. Methodology

i Study area: Lagos state is located in the South-Western Nigeria. The study location is between latitude 6.413N and 6.694N, and longitude 2.705E and 4.356E. Because water is the most topographical feature of Lagos state, water and wetlands cover 40% of the total land area [Albert Osei et al 2006]. The state is bounded from the West by the Republic of Benin, North and East by Ogun state, and South by the Atlantic Ocean. It has two seasons; (rainy and dry seasons) due to its tropical savanna climate. The rainy season is from April to September, but the intense rain is from April to July, and the dry season is from October to March. Lagos state has an average temperature of 27^0c.

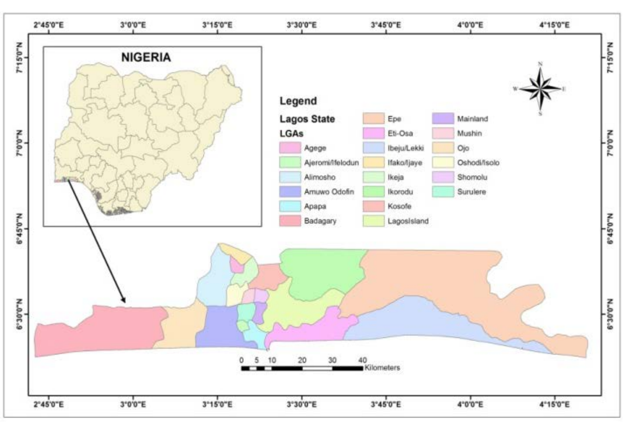

Fig. 1: Map of Nigeria showing the study area

ISSN 2250-3153

ii. Data acquisition: This study makes use of maximum and minimum temperature of Ikeja, Lagos state, Nigeria, for the months of January (dry season) and August (rainy season) for 2016. The data was obtained from the website (http://www.weatheronline.co.uk/weather/) of weather online limited.

ii. Method: In this work, the method used is Hargreaves-Samanni model of global solar radiation predictions. The model equation makes use of the maximum and the minimum temperature of the study area to predict the global solar radiation of the location. The Hargreaves-Samanni equation is given as: s

$$R_s = K_{RS}\left(\sqrt{T_{\max} - T_{\min}}\right)R_a \quad \text{-------- 1}$$

Where T_{max} is the maximum temperature, T_{min} is minimum temperature, R_a is the extraterrestrial solar radiation of the area and K_{Rs} is adjustment coefficient. It has different values for 'interior' and 'coastal' regions. For 'interior' locations, where land mass dominates and air masses are not strongly influenced by a large water body, it is approximately 0.16 and for 'coastal' locations, situated on the coast of a large land mass and where air masses are influenced by a nearby water body, its value is approximately 0.19. In this design, the value of K_{Rs} used is 0.19. because of the closeness of the study area to water body. Various parameters including the global solar radiation were calculated using Microsoft excel computations. Graphs were also plotted using excel worksheet as in figures 3-4.

Parameters for Global Solar Radiation

The parameters calculated before finding the global solar radiation of an area based on Hargreave-Samanni method are:

a. Solar Radiation Declination (δ): It is 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 is calculated using the expression give as;

$$\delta = 23.44Cos\left\{\left(\frac{360}{365}\right) * (J + 10)\right\} \quad \text{---------2}$$

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 degree.

Equation 3 represents the solar radiation declination in radians. That is;

$$\delta_{rad} = \frac{\delta \text{ x } \pi}{180} \quad \text{---------------------- 3}$$

b. Sunset Angle (ω_s): It is defined as 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. The sunset angle of a location is calculated using the formula given as;

$$\omega_s = Cos^{-1}\left(-\tan(\varphi)\tan(\delta)\right) \quad \text{------- 4}$$

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

c. Inverse Relative Distance Earth-sun (d_r): Inverse relative distance earth-sun is the inverse distance of the sun relative to the earth at the location. It is calculated using the expression given as;

$$d_r = 1 + 0.033Cos\left(\frac{2\pi J}{365}\right) \quad \text{-- 5}$$

d. Extraterrestrial Solar Radiation (R_a): Extraterrestrial solar radiation is the intensity or power of the sun at the top of the earth's surface. It is the solar radiation outside the earth's atmosphere. The extraterrestrial radiation is calculated using the formula;

$$R_a = \frac{24(60)}{\Pi} G_{sc} d_r \left[w_s Sin(\varphi)Sin(\delta) + Cos(\varphi)Sin(w_s)\right] \quad \text{----- 6}$$

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 Gsc is solar constant given as 0.0820 MJ m^{-2} min^{-1} (or 1367wm^{-2}).

e. Global Solar Radiation: Global solar radiation is the total amount of solar energy received by earth's surface. It is the addition of the direct, diffuse and reflected solar radiations. It is calculated using the formula given as;

$$R_s = K_{RS}\left(\sqrt{T_{\max} - T_{\min}}\right)R_a \quad \text{------------- 7}$$

Table 1: Temperature data for the month of January 2016

s/n	T_{max} (°c)	T_{min} (°c)
1	35	23
2	35	22
3	34	20
4	36	21
5	34	22
6	35	22
7	37	21
8	34	21
9	34	24
10	35	25
11	35	25
12	34	26
13	34	25
14	35	25
15	30	25
16	35	26
17	34	26
18	34	26
19	31	26
20	34	24
21	34	24
22	36	25
23	35	25
24	34	26
25	34	22
26	33	22

27	33	20
28	34	22
29	34	21
30	34	20
31	35	20

Source: Weatheronline.co.uk/weather/

Table 2: Temperature data for the month of August 2016

s/n	T_{max}(^{o}c)	T_{min} (^{o}c)
1	29	24
2	29	24
3	29	23
4	31	23
5	30	24
6	29	24
7	29	24
8	29	23
9	28	23
10	30	23
11	30	23
12	29	24
13	30	23
14	30	24
15	30	25
16	28	24
17	30	24
18	30	23
19	29	24
20	29	23
21	27	24
22	29	24
23	30	24
24	29	24
25	30	24
26	28	25
27	29	24
28	25	23
29	30	23
30	28	24
31	30	23

Source: Weatheronline.co.uk/weather/

Tables 1 and 2 show the temperature data (minimum and maximum) for the months of January (dry season) and August (rainy season), 2016 obtained from the websites of weather online limited (http://www.weatheronline.co.uk/weather/).

III. Results and Discussions

a. Results

Location parameters: Latitude, ϕ = 6.4 N, Longitude = 3.35E, K_{RS} = 0.19 (Coastal area), Month = January, Year = 2016

Table 3: Global Solar Radiations for January

J	Ws (rad)	R_a (KWH)	K_{RS}	T_{max} (^{o}c)	T_{min} (^{o}c)	Rs (KWH)
1	1.57158	41.992	0.19	35	23	27.638
2	1.57158	41.979	0.19	35	22	28.758
3	1.57158	41.965	0.19	34	20	29.834
4	1.57157	41.950	0.19	36	21	30.870
5	1.57157	41.934	0.19	34	22	27.600
6	1.57157	41.915	0.19	35	22	28.714
7	1.57156	41.896	0.19	37	21	31.841
8	1.57156	41.875	0.19	34	21	28.687
9	1.57155	41.853	0.19	34	24	25.147
10	1.57155	41.829	0.19	35	25	25.132
11	1.57155	41.804	0.19	35	25	25.117
12	1.57154	41.778	0.19	34	26	22.451
13	1.57154	41.750	0.19	34	25	23.798
14	1.57153	41.721	0.19	35	25	25.067
15	1.57152	41.690	0.19	30	25	17.712
16	1.57152	41.659	0.19	35	26	23.745
17	1.57151	41.625	0.19	34	26	22.370
18	1.57151	41.591	0.19	34	26	22.351
19	1.57150	41.555	0.19	31	26	17.655
20	1.57149	41.518	0.19	34	24	24.945
21	1.57149	41.479	0.19	34	24	24.922
22	1.57148	41.439	0.19	36	25	26.113
23	1.57147	41.398	0.19	35	25	24.873
24	1.57146	41.356	0.19	34	26	22.225
25	1.57146	41.312	0.19	34	22	27.191
26	1.57145	41.267	0.19	33	22	26.005
27	1.5714	41.221	0.19	33	20	28.23

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28	1.57143	41.174	0.19	34	22	27.100
29	1.57142	41.125	0.19	34	21	28.173
30	1.57141	41.075	0.19	34	20	29.201
31	1.57141	41.024	0.19	35	20	30.189

Location parameters: Latitude, ϕ = 6.4 N, Longitude = 3.35E, K_{RS} = 0.19 (Coastal area), Month = August, Year = 2016

Table 4: Global Solar Radiations for August

J	Ws(rad)	R_a (KWH)	K_{RS}	T_{max} (°c)	T_{min} (°c)	Rs (KWH)
214	1.57019	33.450	0.19	29	24	14.211
215	1.57020	33.499	0.19	29	24	14.232
216	1.57021	33.549	0.19	29	23	15.614
217	1.57022	33.600	0.19	31	23	18.057
218	1.57023	33.652	0.19	30	24	15.662
219	1.57024	33.706	0.19	29	24	14.320
220	1.57025	33.760	0.19	29	24	14.343
221	1.57026	33.815	0.19	29	23	15.738
222	1.57027	33.872	0.19	28	23	14.391
223	1.57028	33.929	0.19	30	23	17.056
224	1.57029	33.988	0.19	30	23	17.085
225	1.57030	34.047	0.19	29	24	14.465
226	1.57031	34.108	0.19	30	23	17.146
227	1.57032	34.169	0.19	30	24	15.902
228	1.57033	34.232	0.19	30	25	14.543
229	1.57035	34.295	0.19	28	24	13.032
230	1.57036	34.359	0.19	30	24	15.991
231	1.57037	34.425	0.19	30	23	17.305
232	1.57038	34.491	0.19	29	24	14.653
233	1.57039	34.558	0.19	29	23	16.083
234	1.57040	34.626	0.19	27	24	11.395
235	1.57042	34.694	0.19	29	24	14.740
236	1.57043	34.764	0.19	30	24	16.179
237	1.57044	34.834	0.19	29	24	14.799
238	1.57045	34.905	0.19	30	24	16.245
239	1.57047	34.977	0.19	28	25	11.511
240	1.57048	35.050	0.19	29	24	14.891
241	1.57049	35.123	0.19	25	23	9.438
242	1.57050	35.197	0.19	30	23	17.693
243	1.57052	35.272	0.19	28	24	13.403
244	1.57053	35.347	0.19	30	23	17.769

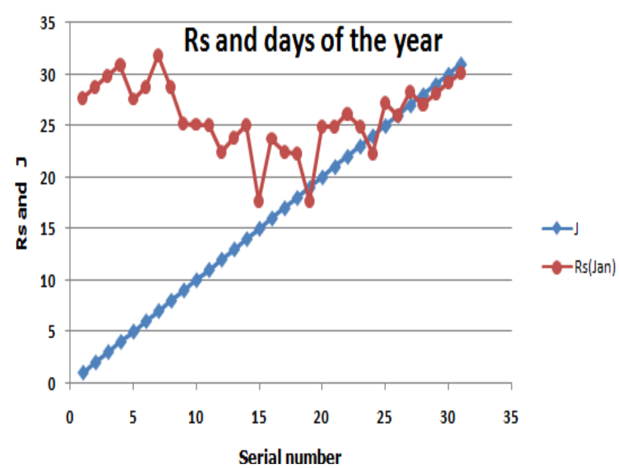

Fig. 2: Graph of January Global Solar Radiation and the days of the year.

($R_{s(Jan)}$ = Global solar radiation for the month of January, 2016 and J = Days of the year, i.e 1-31 for January)

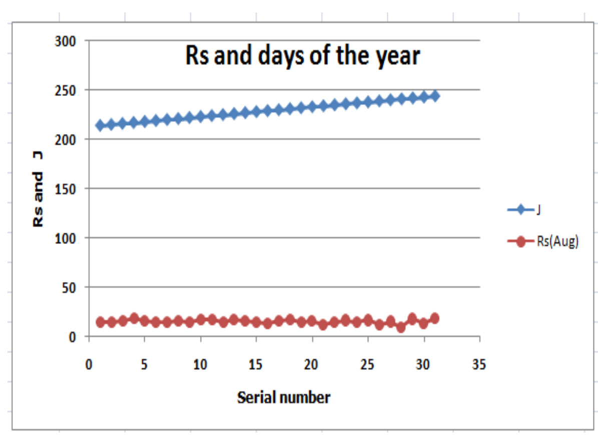

Fig. 3: Graph of August Global Solar Radiation and the days of the year.

($R_{s(Jan)}$ = Global solar radiation for the month of August, 2016 and J = Days of the year, i.e. 214 -244 for August)

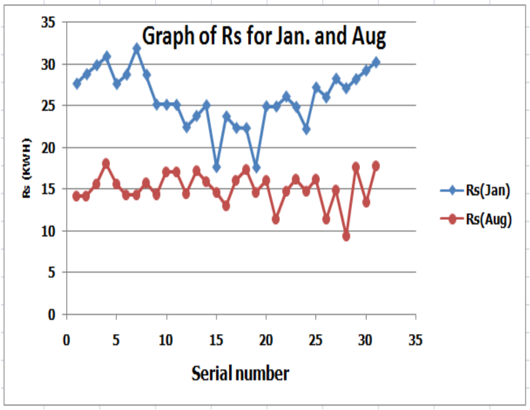

Fig. 4: Graph of Global Solar Radiations for the months of January and august.

($R_{s(Jan)}$ is the Global solar radiation for January and $R_{s(Aug)}$ is the Global solar radiation for August)

b. Discussions

Hargreaves-Samani model of global solar radiation estimation was used to determine the global solar radiation for both the rainy (August) and dry (January) seasons using the maximum and minimum temperature data obtained from the achieve of weather online limited from their website - http://www.weatheronline.co.uk/weather/. The data for the two months are shown in tables 1 and 2. The computations for various parameters were carried out using MS EXCEL package. Graphs were also plotted in the ms excel worksheet. Some of the parameters calculated are shown in tables 3 and 4.

The result shows that there is clear variation between the global solar radiation during rainy and dry seasons. It shows that global solar radiation is very high in dry season (January) than in rainy season (August) [Fig. 4]. The global solar radiation in January was seen to be generally high though oscillating, the behavior which is also observed in that of August, except at the middle of January which shows some deviation from its general trend. The sharp lowest values at two points in January solar radiation may be attributed to sudden change in weather conditions such as rainfall, humidity, or harmattan haze (that can affect air temperature) on those two days.

The maximum global solar radiations are 31.831kwh for January and 18.0057 kwh for August, with the average radiations of 25.926kwh and 5.0933kwh in January and August respectively. The minimum values are 17.655kwh and 9.438kwh in January and August respectively. In other words, even the minimum value for dry season is greater than the maximum value for rainy season. Although the global solar radiations for both rainy and dry seasons were oscillating, the correlation value of 0.06648 (6.65%) between the two shows that there is no relationship between the two (rainy and dry season). This is as shown in figure 3.

This information will be very important for irrigation farmers on the need to have manageable size of farm which can be taken care of carefully than having a large one without proper attention. In as much as irrigation is going to make water available to the crops, crops species that can withstand such solar radiation would be preferred. Solar power personnel will also find this information, (clear variation between the radiations in dry and rainy season) valuable especially that of the rainy season in which the average global solar radiation was 5.0933kwh. There will be need for more number of solar arrays for effective energy capturing which can be used for charging the batteries or powering the required appliances as the case may be. Furthermore, this difference between the radiation of rainy and dry seasons in which that of dry season (31.831kwh) almost doubles that of rainy season (18.0057 kwh) should be a thing of concern for environmentalists and water sectors personnel as many plants in the environment may not be able to able to adjust quickly to such as a sharp difference, hence the extinction of many species. Many ground waters such as ponds may likely dry up during the dry season; proper planning for future occurrence is to be put in place by respective bodies.

IV. Conclusion

From the results using Hargreaves-Samani model with the minimum and maximum temperature data which was adopted from Weather Online Limited, it can be observed that variation occurs between solar global radiation in rainy season and dry season, with the global solar radiation higher in dry season (January in this case) than in rainy season (August in this case). This is in accordance with the work by S. O. Falodun and E. O. Ogolo (2007), at Akure, South-west, Nigeria, in which it was stated that there is seasonal variation of global radiation, and that the dry months have comparably larger values than wet months. It can also be conclusively stated that although, the global solar radiations for both rainy and dry seasons change in almost the same trend, there is no significant relationship between the radiations in the two seasons especially with reference to their correction of 6. 65% gotten.

V. Recommendations

Although the result of this work using the data adopted from weather online limited (http://www.weatheronline.co.uk/weather/) conforms with related works already carried out especially that by S. O. Falodun and E. O. Ogolo (2007), the data for other geographical zone of Nigeria should be used for this similar work.

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