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Investigation of the Seasonal Variation of Global Solar Radiation Over Lokoja, Kogi State, Nigeria

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ABSTRACT

The aim of the work was to study the change in global solar radiation of Lokoja, Kogi State, seasonally. The research made use of weather data of maximum and minimum temperature of Lokoja, for the months of March, July and December, 2023 which was acquired from a weather station in a school in Lokoja. The calculation of the global solar radiation of the area was done using Hargreaves Samanni's model. The results showed that there was a daily change; increase and decrease, or increases on consecutive days or vice versa in all the months in which the global solar radiation has been studied. In addition, the global solar radiation was highest in December, followed by the radiation recorded in March and least in July. From the results, it was concluded that the global solar radiation in the area shows a seasonal variation, such that the global solar radiation was higher in dry season and lower in rainy season. The lower global solar radiation in rainy season was due to lower temperature generally experienced in rainy season since global solar radiation depends on temperature of the atmosphere. The result of this work will be valuable to some Scientists, Engineers, Agriculturists and other stakeholders in the fields that have something to do with solar energy, solar radiation and environmental condition.

KEYWORDS: *Crops, Energy, Health, Solar radiation, Sun*

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1. INTRODUCTION

Solar energy is the energy emitted from the sun to the surface of the earth. It is a free form of energy and is abundant in almost all parts of the world (Abdullahi, *et al.,* 2017). The global solar radiation is the sum total of all radiation reaching the earth surface i.e., it includes both the direct and the diffused solar radiation reaching the earth surface measured at any location (Adeniji, *et al.,* 2019). The estimation of the clear sky irradiance components of solar radiation is very important in many solar energy applications such as systems design and simulation, control process of the accuracy of radiometers, data quality control, gaps filling process, etc., as well as in routine engineering practice such as the peak cooling load of buildings is determined for a hot, cloudless, summer day) (Islahi, *et al.,* 2015). The amount of solar radiation over a place determines the type of crops that can survive in such a place as well as the type of animals or livestock that can be reared in the area since global solar radiation varies with location and topography (Ayegba *et al.,* 2016). Ogolo, (2010), reports that solar radiation is the major control of weather and climate since it is the only source of energy of the earth. This implies that with adequate information on daily or monthly solar radiation of a location, important deductions relating to health, power, environment, agriculture, etc. which are associated with weather and climate can be made. This work is done in Lokoja, Kogi state, with a view to determining the nature of the global solar radiation variation in the place which can help in some decisions making or proper planning before carrying out some projects.

2. Study location

Lokoja is the capital of Kogi state. It is the location or meeting point of river Niger and river Benue. That is why Kogi state is called the confluence state. Lokoja is located between Latitude 7.75ºN and 7.85 ºN and Longitude 6.68 ºC and 6.75ºC. The main vegetation of Lokoja is Guinea savanna with tall grasses and some trees (Nathaniel, 2012). The annual rainfall is about 1150 mm, while the average monthly temperature is about 30ºC. The rainfall begins, on average in March and peak in June to September, while the dry season begins at about November (www.fulokoja.edu.ng).

3. Materials and methods

3.1. Materials

The material used for this work is the data of maximum and minimum temperatures of March, July and December, 2023, obtained from the weather station in a school in Lokoja. Other materials used for the work are the online and library materials used as the literature materials.

3.2. Methods

The global solar radiation is defined as the total amount of solar energy received by earth's surface. The global solar energy potential of the study area was calculated using Hargreaves-Samanni model equation. The model uses data of minimum and maximum air temperatures on the location or study area. Hargreaves-Samanni model equation is represented as:

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

Where, T_{max} represents the maximum temperature, T_{min} represents minimum temperature, R_a represents the extraterrestrial solar radiation and K_{Rs} is the adjustment coefficient. K_{Rs} has an approximate value of 0.16 for 'interior' locations and 0.19 for 'coastal' locations, situated on the coast of a large land mass and where air masses are influenced by a nearby water body. The value of 0.16 was used for this work.

3.2.1. Model analysis

3.2.1.1. Global solar radiation

To calculate the Global solar radiation, the following steps are followed:

A. **Calculation of solar radiation declination:** 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;

$$\delta = 0.409 Sin\left(\frac{2\pi}{365}J - 1.39\right) \qquad (2)$$

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 radian.

B. **Calculation of inverse relative distance Earth-sun:** Inverse relative distance Earth-sun is the inverse distance of the sun relative to the earth at a location. It has the formula given as;

$$d_r = 1 + 0.033\, Cos\left(\frac{2\pi J}{365}\right) \qquad (3)$$

C. **Calculation of sunset angle:** 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;

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

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

D. **Calculation of extraterrestrial solar radiation:** Extraterrestrial solar radiation is the intensity or power of the sun at the top of the earth's surface. The extraterrestrial radiation has the formula given as;

$$R_a = \frac{24(60)}{\Pi} G_{sc} d_r \left[w_s Sin(\varphi) Sin(\delta) + Cos(\varphi) Sin(w_s)\right] \qquad (5)$$

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 = 0.0820 MJ m^{-2} min^{-1} or 1367wm^{-2}.

E. **Calculation of Global Solar Radiation:** 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;

$$R_s = K_{RS}\left(\sqrt{T_{\max} - T_{\min}}\right)R_a \qquad (6)$$

4. RESULTS AND DISCUSSIONS

Table 1.0 shows the Global solar radiation of the study area, Lokoja in March, July and December, 2023. Also, figures 1.0 – 3.0 show the graphical representations of the global solar radiation in March, July and December in that order, while figure 4.0 shows the combination of the global solar radiation in march, July and December, 2023. On the first day of March, the global solar radiation was 29.72 MJ/m^{2}day, on the second of March, the global solar radiation was 30.57 MJ/m^{2}day, on the third of March, the global solar radiation was 27.69 MJ/m2day, on the fourth and fifth of March, the global solar radiation were **27.69** MJ/m^{2}day and **29.48** MJ/m^{2}day respectively.

On the first day of July, the global solar radiation was **18.54**MJ/m^{2}day, on the second of July, the global solar radiation was **17.49** MJ/m^{2}day, on the third of July, the global solar radiation was **17.49** MJ/m^{2}day, on the fourth and fifth of July, the global solar radiation were **17.50** MJ/m^{2}day and **16.38**MJ/m^{2}day respectively.

On the first day of December, the global solar radiation was **29.63** MJ/m^{2}day, on the second of December, the global solar radiation was **30.69** MJ/m^{2}day, on the third of December, the global solar radiation was **30.71** MJ/m^{2}day, on the fourth and fifth of December, the global solar radiation were **30.73** MJ/m^{2}day and **17.75** MJ/m^{2}day respectively. It can be observed from the results that the global solar radiation of the study area varied daily in each of the three months understudy. It is also observed that though the global solar radiation varied daily, the nature of the variation is not regular as in some cases, it increases on one day, and decreases on the next day, and in some cases, the decrement or increment is consecutively. In other words, the global solar radiation of the study area in these months displayed a daily variation almost throughout the months period (Figs. 1 -3).

Table 1.0: Global solar radiation of Lokoja in March, July and December

Day	Rs Mar (MJ/m^{2}day)	Rs Jul (MJ/m^{2}day)	Rs Dec (MJ/m^{2}day)
1	29.72	18.54	29.63
2	30.57	17.49	30.69
3	27.69	17.49	30.71
4	29.54	17.50	30.73
5	29.48	16.38	17.75
6	29.42	19.59	29.73
7	30.26	18.59	29.75
8	26.40	16.40	28.68
9	27.34	16.41	31.83
10	27.28	17.56	29.79
11	29.11	17.57	27.59
12	25.15	18.65	27.60
13	26.12	17.60	29.83
14	27.05	15.25	29.84
15	26.99	18.70	30.90
16	26.93	17.64	29.86
17	26.87	17.66	31.93
18	27.75	17.67	30.92
19	23.71	17.69	30.92
20	20.18	16.57	31.94
21	14.24	17.73	30.93
22	18.79	16.60	30.93
23	23.50	17.77	29.89
24	18.70	14.06	32.93
25	21.16	16.66	32.93
26	22.26	17.83	33.89
27	24.32	16.70	31.94
28	25.26	16.72	32.92
29	27.07	15.50	32.92
30	24.16	16.77	32.91
31	26.04	16.79	31.92

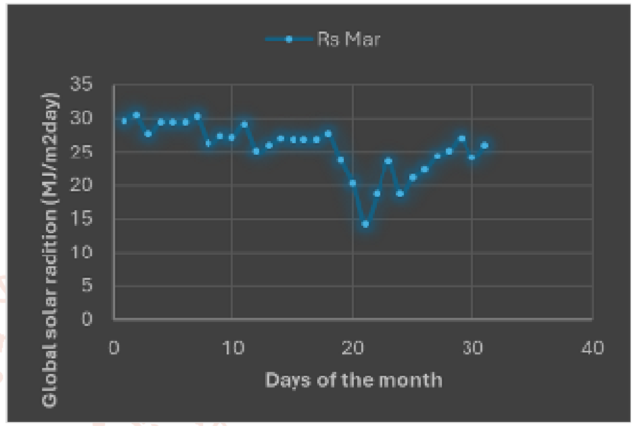

Fig. 1.0: Global solar radiation of Lokoja in March, 2023

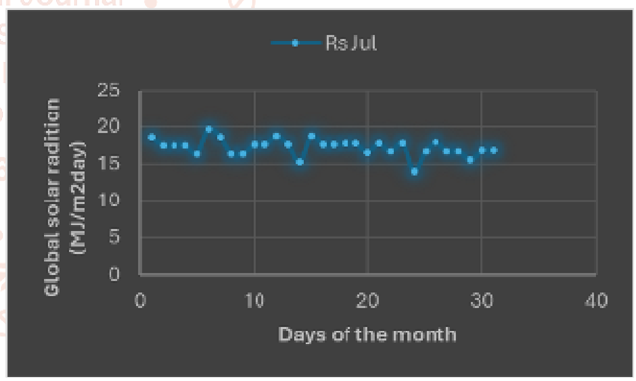

Fig. 2.0: Global solar radiation of Lokoja in July, 2023

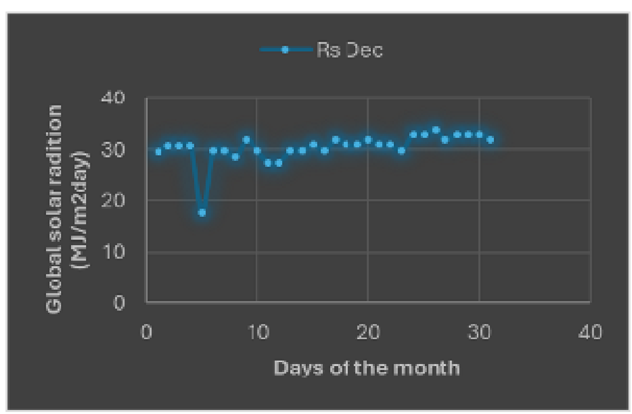

Fig. 3.0: Global solar radiation of Lokoja in December, 2023

Although the amount of solar radiation received in the area, that is, the global solar radiation oscillates at some points causing or creating a sharp fall or increase in value(s), the global solar radiation of the study area was lower in July, and followed by the global solar radiation in March. It is seen that the global solar radiation of Lokoja within the periods of study is higher in the month of December compared to the level or amount received in March and July (fig. 4.0). The results revealed that the average global solar radiation in March was 25.58 MJ/m^{2}day, the average global solar radiation in July was 17.23 MJ/m^{2}day and the average global solar radiation in December was 30.48 MJ/m^{2}day. Furthermore, the maximum global solar radiation in March was 30.57 MJ/m^{2}day, the maximum global solar radiation in July was 19.59 MJ/m^{2}day, and the maximum global solar radiation in December was 33.89 MJ/m^{2}day. The lower global solar radiation experienced in July was because of the rain which reduces the amount of temperature or sunlight in the area as July is one of the rainy season months of the study area. The higher level of the global solar radiation recorded in the area in March and December was because these two months are dry season period, hence adequate sunshine can be experienced in the area. However, even though the two months are dry season's months in the study area, the global solar radiation level experienced in March was lower than that in December. This might be that there was rainfall on some days in March as the main rainy season starts from April but in some years, rainfall or minor showers occur from March. This result is a confirmation of the works by Diaz-Torres *et al.*, 2017, Ayegba *et al.*, 2017, and Nicholas *et al.*, 2022, done in Guadalajara- Mexico, Lagos –Nigeria, and Rivers- Nigeria.

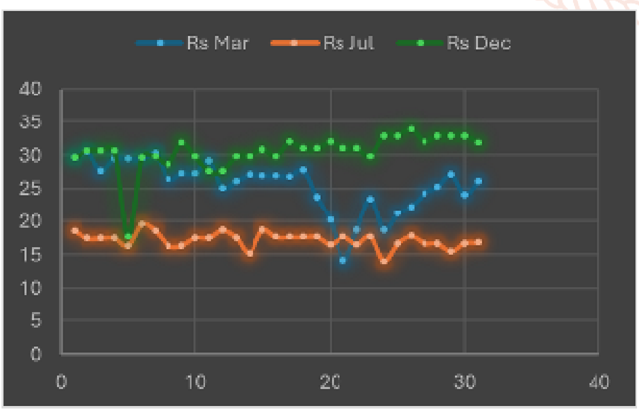

Fig. 4.0: Global solar radiation of Lokoja in March, July and December, 2023

5. Conclusion

The weather data- maximum and minimum temperature data of the study area, Lokoja, Kogi state, for the months of March, July and December, 2023 which was acquired from a weather station in a school in Lokoja was used to determine the daily global solar radiation of Lokoja in March, July and December. This was done using Hargreaves Samanni's model of global solar radiation prediction. The results showed that there was a daily change; increase and decrease, or increases on consecutive days or vice versa in all the months which the global solar radiation has been studied. In addition, the global solar radiation was highest in December, followed by the radiation recorded in March and least in July. From the results, it can be concluded that the global solar radiation in the area display a seasonal variation, such that the global solar radiation in the area was higher in dry season and lower in rainy season. The result of this work will be valuable to some scientists, engineers, Agriculturists and other stakeholders in the fields that have something to do with solar energy, solar radiation and atmospheric temperature.

6. Recommendation

We recommend that the global solar radiation in more number of months in the area be studied in future woks.

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