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The Analysis Of The Monthly Global Solar Radiation On The Campus Of The Federal Polytechnic, Idah, Kogi State, Nigeria

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Abstract— **It is certain that the global solar radiation of any location will vary with time and season, thus the mode of variation of it should be known for effective planning as this radiation has many applications in the daily lives of human beings. This research work is aimed at finding out the monthly global solar radiation on the campus of the Federal Polytechnic Idah, Kogi state, with the view to providing information for effective planning on some areas like environment, solar power systems, agriculture, and other related applications within and around Idah community.**

The work employed the use of two models - Hargreaves-Samanni and Angstrom models, using the data of average monthly maximum and minimum temperature, and daylight hours (July1, 1983 – June 30, 2005) obtained from earthdata.nasa.gov. It was observed from the results that there was variation in the average monthly global solar radiation on the campus with the two models. It was also observed that the maximum global solar radiation value with Hargreaves-Samanni model was bigger than that with Angstrom model. However, in terms of the minimum global solar radiation value, that of Angstrom model was greater than the one with Hargreaves- Samanni model.

Index Terms— **Angsrtom model, Global solar radiation, Solar photovoltaic, Sunset angle, Temperature**.

I. INTRODUCTION

The knowledge of solar radiation at any given place is relevant for several applications including architectural designs, solar radiation and irrigation system, crop growth models and evapotranspiration estimates [Okogbue and Adedokun, 2002, Falodun & Ogolo, 2011].

Solar radiation is the largest energy source and is capable of affecting large quantities of events on the Earth's surface including climate, existence and so on. Research outcomes on studies of global solar radiation have facilitated improvement in Agronomy, power generation, environmental temperature controls, etc. [Ugwu, and Ugwuanyi, 2011]

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].

Thus, having the real knowledge of the variation of the global solar radiation of an area, especially on monthly basis will help in proper planning in the area of environmental management, and solar power system design, which is currently the alternative power source in many parts of the world. This idea necessitated the carrying out of this research work.

Some related works in this area which were reviewed in the course of this work are the works by Bernadette , *et al.,* 2007. They 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, Ansgtrom model and Hagreave-Sammani model. It was observed by them that there was variation in the monthly global solar radiation of the area. Ayegba *et al*., 2016 did a work in Abuja using the data of maximum and minimum temperature (February 1 – 29, 2016) obtained from weather online limited. The work employed the use of Hagreave-Sammani model, and it was discovered that the maximum and minimum global solar radiation for the month were 29.609 MJ/m^2day and 12.044 MJ/m^2day respectively for the month of February.

Fig. 1.1: Picture of one of the school gates (Source: t0.gstatic.com)

II. STUDY AREA

The Federal Polytechnic Idah is located in Idah, kogi state, North-central Nigeria. The school is located on Latitude 7.1437^0 N and longitude 6.7902^0 E. It is a few kilometers away from Ajaka, the head quarters of Igalamela/Odolu local government, and almost the same distance from Attah Igala's palace, Idah. The school has Ajaka, the head quarters of Iagalamela/Odolu local government at the eastern side, Idah and River Niger at the Western side, Ogbogbo to the southern side and Okenya to the Northern part.

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The school was established in 1977, as one of the seven polytechnics established by the federal military government by Obasanjo administration as Idah College of Technology then. The Federal Polytechnic Idah currently has six schools which are; school of engineering, school of technology, school of business, school of environmental, school of general studies and school of continuing education [Abu and Ayegba, 2017].

Fig.2.1: Google map of some features on the school campus

III. Materials and Methods

3.1 Materials

The material used in this work is a secondary data of average monthly maximum and minimum temperature, and daylight hours (July1, 198 – June 30, 2005) obtained from earthdata.nasa.gov. Other materials used are Microsoft excel package, and Google map software as well the primary data which is the GPS coordinate points of the study area and some structures on the campus.

3.2 Method

a. Hargreaves-Samanni's model: This model makes use of maximum and minimum air temperature of the atmosphere and the calculated extraterrestrial solar radiation of the study area. The model is represented by the equation given as:

$$R_s = K_{RS}\left(\sqrt{T_{\max} - T_{\min}}\right)R_a \quad \text{--------- 3.1}$$

b. Angstrom model: This model makes use of the measured and calculated sunshine period or duration and the calculated extraterrestrial solar radiation of the study area. Angstrom model is represented by the equation given as:

$$R_s = R_a\left(0.281 + 0.414\left[\frac{S}{So}\right]\right) \quad \text{------ 3.2}$$

Calculation Analysis/Procedures:

The following procedures lead to calculation of extraterrestrial radiation, and then the global solar radiation.

i. 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;

$$\delta = 0.409 Sin\left(\frac{2\pi}{365}J - 1.39\right) \quad \text{----------- 3.3}$$

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.

ii. 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;

$$d_r = 1 + 0.033 Cos\left(\frac{2\pi J}{365}\right) \quad \text{------ 3.4}$$

iii. Calculation of sunset angle (ω_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;

$$\omega_s = Cos^{-1}\left(-\tan(\varphi)\tan(\delta)\right) \quad \text{-- 3.5}$$

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

iv. 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:

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

------ 3.6

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}.

v. Calculation of day length (S_o): The day length or sunshine hour is calculated using the formula given as:

$$S_o = \frac{2}{15} w_s \quad \text{--- 3.7}$$

where w_s is the sunset angle.

Table 3.1: Data of average daylight hours, average maximum and minimum temperatures

S/N	Month	Tmax (^{o} c)	Tmin (^{o} c)	Daylight hours, S (Hr))
1	JAN	41.1	21.1	11.7
2	FEB	41	22.1	11.9
3	MARCH	36.4	23.1	12
4	APRIL	33.7	23.3	12.2
5	MAY	32.3	23.1	12.4
6	JUNE	30.3	22.4	12.5
7	JULY	29.1	21.5	12.4
8	AUGUST	29.5	21.1	12.3
9	SEPT	30.1	21.5	12.1
10	OCT	31.1	21.6	11.9
11	NOV	32.9	20.6	11.8
12	DEC	37.6	20.3	11.7

IV. RESULT AND DISCUSSIONS

4.1 RESULT

Location coordinate point: Latitude: 7.1437^0 N and longitude: 6.7902^0 E

Table 4.1: Calculated Global Solar Radiation with Hargreaves-Samanni and Angstrom models

Month	Tmax (^{o} c)	Tmin (^{o} c)	Daylight hours (S)	Harg-Rs (MJ/m^2 day)	Angtr-Rs (MJ/m^2 day)
JAN	41.1	21.1	11.7	27.66	22.75
FEB	41	22.1	11.9	28.37	24.11
MARCH	36.4	23.1	12.0	25.27	25.53
APRIL	33.7	23.3	12.2	23.12	26.39
MAY	32.3	23.1	12.4	21.51	26.13
JUNE	30.3	22.4	12.5	19.38	25.36
JULY	29.1	21.5	12.4	18.86	25.01
AUG	29.5	21.1	12.3	20.21	25.50
SEPT	30.1	21.5	12.1	20.80	25.91
OCT	31.1	21.6	11.9	21.46	25.43
NOV	32.9	20.6	11.8	23.10	24.16
DEC	37.6	20.3	11.7	25.87	22.86

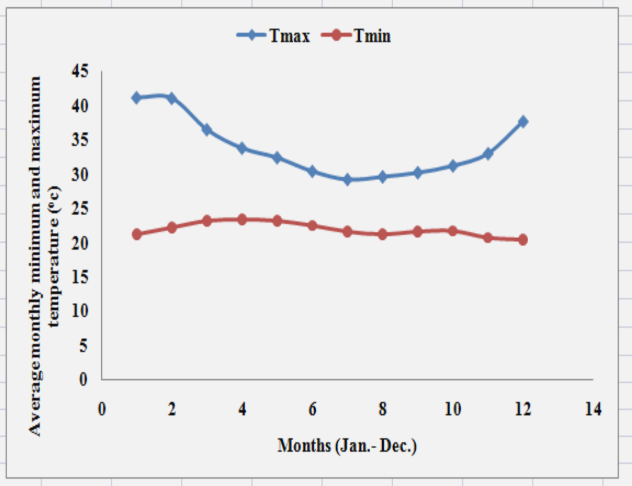

Fig. 4.1: Graph of average monthly maximum and minimum temperature

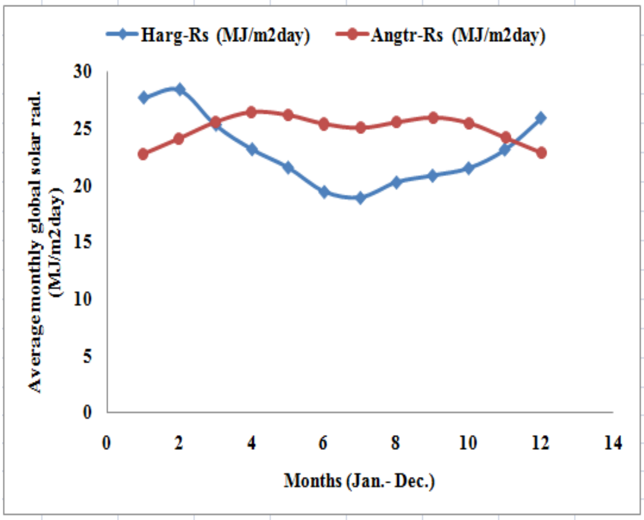

Fig. 4.2: Graph of monthly global solar radiation using Hargreaves- Samanni and Angstrom models

Table 4.2: Maximum, average and minimum global solar radiation with Hargreaves- Samanni and Angstrom models

Rank	Harg-Rs (MJ/m2day)	Angtr-Rs (MJ/m2day)
Max	28.37	26.39
Min	18.86	22.75
Average	22.97	24.93

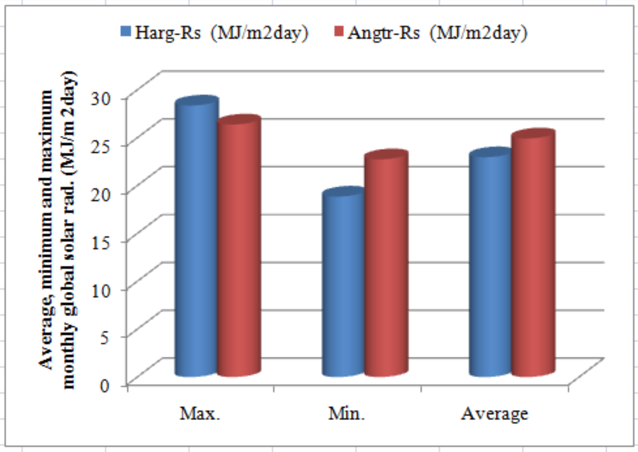

Fig. 4.3: Bar chart of average, minimum and maximum monthly global solar radiation with Hargreaves- Samanni and Angstrom models

Tables 4.1 and 4.2 show the calculated monthly global solar radiation, and maximum, minimum & average global solar radiation respectively. According to the two models, there was variation in the monthly global solar radiation, though slightly different trends were observed in the two models. From the result, it was observed that maximum, average and minimum global solar radiation with Hargreaves- Samanni's model are 28.37MJ/m^{2}day, 22.97 MJ/m^{2}day and 18.86 MJ/m^{2}day, while with Angstrom model, the values are 26.39 MJ/m^{2}day, 24.93 MJ/m^{2}day, and 22.75 MJ/m^{2}day [Table 4.2].

Also, from table 4.1, it can be observed that highest global solar radiation on the school campus occurred in February with Hargreaves- Samanni's model, while the lowest occurred in July, whereas in the case of Angstrom's model, highest global solar radiation for the year occurred in May and lowest occurred in January.

Figure 4.1 represents the graphs of monthly minimum and maximum temperature, while Figure 4.2 is the graphical representation of the monthly global solar radiation for the two models. From figure 4.2, the results from the two models seem to be inverse of each other. In other words, when the result from the Hargreaves- Samanni's model was high, the one of and Angstrom's model was low and vice versa. However, irrespective of these differences, the correlation between the results from the two models shows 0.98165 (98.17%) relationship. As it can be seen in figure 4.3, the maximum global solar radiation with Hargreaves- Samanni's model is higher than that with Angstrom's model but the values of the minimum and average global solar radiation with Angstrom's model is higher than that with Hargreaves-Samanni's model. This observation is in conformity with the result by Bernadette , *et al.,* 2007, in which the maximum global solar radiation (24.423 MJ/m^{2}day) predicted by Hargreaves- Samanni's model was greater than the one (23.989 MJ/m^{2}day) with Angstrom's model. In the same way, the minimum global solar radiation (15.140 MJ/m^{2}day) gotten with Hargreaves- Samanni's model was smaller than the minimum value (15.430 MJ/m^{2}day) gotten with Angstrom's model.

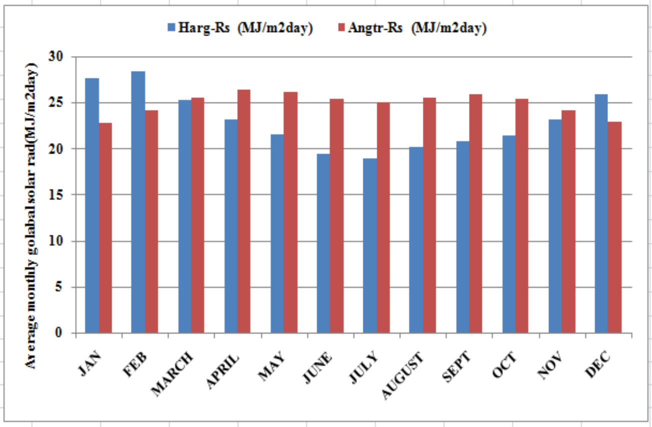

Fig. 4.4: Bar chart of monthly global solar radiation with Hargreaves- Samanni and Angstrom models

Figure 4.4 shows the bar chart of the monthly global solar radiation values for the two models. In the first two and last one month (January, February and December), the global solar radiation calculated with Hargreaves- Samanni's model were greater than the ones calculated with Angstrom's model. It also shows that the global solar radiation calculated with Angstrom's model was higher than the values obtained with Hargreaves- Samanni's model from march to November, though not too pronounced in the month of march.

V. CONCLUSION

The monthly global solar radiation of the study area has been calculated with two different models- Hargreaves- Samanni's and Angstrom's models using the data of average monthly maximum and minimum temperature as well as average daylight hours which were averaged over the period of 22 years (July1, 1983– June 30, 2005) obtained from the database of nasa.gov.

The result shows that there was variation in the monthly global solar radiation obtained by both models, but with different trend in their variations. From the result, it can be concluded that Hargreaves- Samanni's model has higher value of maximum global solar radiation than Angstrom's model model, but Angstrom's model has higher minimum and average global solar radiation than that of Hargreaves- Samanni's model [fig. 4.3].

The variation, thus is such a way that when the global solar radiation gotten with Hargreaves- Samanni's was increasing, that with Angstrom's model was decreasing, and vice versa. This observation calls for an investigation for the determination of the most suitable model for the prediction of global solar radiation in the area

VI. RECOMMENDATION

From the results obtained, it was found out that the global solar radiation calculated with both models varied monthly, but the variations between the two results are inversely related. Although there is higher correlation of 98.17% between the results of the two models, there is need for future work in determining the most suitable global solar radiation prediction model in the study location.

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