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Impacts of Relative Humidity and Mean Air Temperature on Global Solar Radiations of Ikeja, Lagos, Nigeria

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Abstract- This study was aimed at the determination of the relationships between the global solar radiation, relative humidity and mean air temperature of Ikeja, Lagos state Nigeria, for the month of June, 2016. The data of minimum and maximum temperature as well as the relative humidity and Microsoft excel tool was used for this work. From the study, it was observed that global solar radiation is affected by both the mean air temperature and relative humidity. The positive correlation of 0.460648 (46.648%) shows that global solar radiation increases with increase in mean air temperature. While global solar radiation increases with decrease in relative humidity based on its negative correlation value of -0.47686 (-47.686%). An accurate knowledge of solar radiation distribution at a particular location is very useful in the sizing of the thermal solar systems to estimates their performances.

Index Terms- Seasonal Global solar radiation, relative humidity, mean temperature, correlation.

I. INTRODUCTION

The weather conditions of any given location is often described in terms of the meteorological elements which include the state of the sky, temperature, winds, pressure, precipitation, and humidity. These factors initiate and influence the atmospheric processes (Ayoade, 1993).

Solar radiation is the most important parameter in the design and evaluation of solar energy devices. An accurate knowledge of solar radiation distribution at a particular geographical location play a vital role in the surveys of agronomy, hydrology, ecology and sizing of the photovoltaic or thermal solar systems and estimates of their performances (Ituen, *et.al*.(2012)). Research outcomes on studies of global solar radiation have facilitated improvement in Agronomy, power generation, environmental temperature controls, etc. (Ugwu, & Ugwuanyi, (2011)). For instance, knowing how some of these metrological elements-the state of the sky, temperature, winds, pressure, precipitation, and humidity affect the amount of solar radiation reaching a particular place at a particular time of the year will in no small way help for proper planning in the area of solar power generation. The knowledge of when less solar radiation or solar energy will be less will aid in adequate planning such as having other backup power such to supplement for the insufficiency of the installed solar power system. Irrigation farmers will also know when to apply less water to their crops which may results in excess water in the soil, hence causing adverse effects to the crops.

According to Dimas*et.al*. (2011), in their report, two methods were used, (building a decision matrix, and finding the correlation between relative humidity, clearness index and beam transmittance), and was observed that during the dry season, the solar radiation was high on the most of the days and the estimated results show good compromise with the measured results. In other words, when there is high relative humidity (wet period), solar radiation will be low while in dry season, the solar radiation will be high, showing that relative humidity has effects on solar radiation of a place.

Olusola & Babatunde (2014), made use of Hargreaves-Samanni model and observed that strong correlation exists between solar radiation and air temperature together with latitude and longitude of the selected stations. It made use of only maximum and minimum air temperature but with little element of relative humidity in it.

Solar energy has many applications some of which are generation of electricity for rural areas, powering of satellites in space, and the advantages of solar energy includes environmental friendliness, noise free, pollution free, renewable, always available, and easy to maintain (Mathias, 2014).

II. MATERIALS AND METHOD

2.1 Materials

The materials used for this work are the data of minimum and maximum temperature as well as the relative humidity of Ikeja, Nigeria, for June 2016obtained from the achieve of weather online limited, and the Microsoft excel software. The study area is Ikeja, the capital of Lagos state, Nigeria. Lagos state is located in the South-Western Nigeria. The study location is within latitude and longitude 6.4N and 3.35E respectively. Because water is the most topographical feature of Lagos state, water and wetlands cover 40% of the total land area in the state (Albert *et al.*(2006)). Lagos state is bounded from the North and East by Ogun state, West by the Republic of Benin, 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. It has an average temperature of 27^0c.

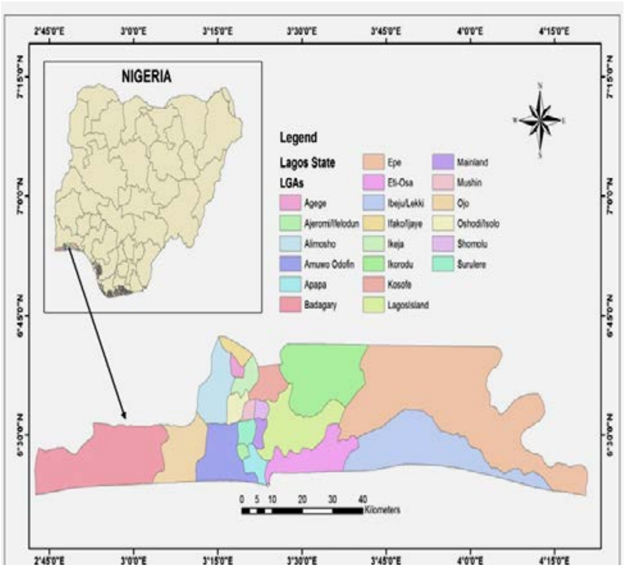

Fig. 1: Map of Nigeria showing the study area

2.2 Methods

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

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

Where, T_{max} represents the maximum temperature, T_{min} represents minimum temperature, R_a represents the extraterrestrial solar radiation of the area and K_{Rs} is a constant called adjustment coefficient. It has an approximate value of 0.16 for 'interior' locations (where land mass dominates and air masses are not strongly influenced by a large water body), and 0.19for '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 0.19 was used for this work as a result of the location of the study area (Lagos state) in the coastal area.

2.2.1 Calculation processes

2.2.1.1 Global solar radiation

To calculate the Global solar radiation, the following parameters were first calculated using the following steps:

(i) Calculation of solar radiation declination: It 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 of the area is given by the formula;

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

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 .

Solar radiation declination is to be in radians, thus (2) is converted to radian as in (3).

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

(ii) Calculation of sunset angle: 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. It is determined using the expression given as;

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

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

(iii) Calculation of inverse relative distance Earth-sun: It is defined as the inverse distance of the sun relative to the earth at the location. It is calculated using the expression given as;

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

(iv) Calculation of extraterrestrial solar radiation: It is defined as the solar radiation outside the earth's atmosphere. The extraterrestrial radiation is calculated using the expression given as;

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

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

(v) Calculation of global solar radiation: The global solar radiation is now calculated using the formula given as;

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

2.2.1.2. Mean air temperature (T_{Av})

The mean air temperature is the average of the maximum and minimum air temperatures. It was calculated from the average of the minimum and maximum temperatures of the study area.

Tav = (Tmax + Tmin)/2 ------------------ 8

Table 1: Relative humidity, minimum and maximum air temperatures for June, 2016.

s/n	T_{max} (0c)	T_{min} (0c)	RH (%)	T_{av} (0c)
1	33	24	65	28.5
2	29	24	50	26.5
3	33	24	70	28.5
4	33	24	65	28.5
5	33	26	80	29.5

6	33	25	75	29.0
7	28	25	90	26.5
8	33	22	60	27.5
9	30	24	85	27.0
10	32	22	75	27.0
11	32	24	70	28.0
12	28	22	90	25.0
13	33	24	75	28.5
14	30	25	80	27.5
15	27	25	90	26.0
16	31	22	75	26.5
17	30	21	85	25.5
18	32	24	75	28.0
19	32	22	80	27.0
20	26	23	95	24.5
21	29	22	95	25.5
22	31	22	83	26.5
23	31	23	83	27.0
24	30	24	75	27.0
25	30	23	85	26.5
26	30	23	85	26.5
27	29	24	85	26.5
28	30	23	80	26.5
29	30	23	75	26.5
30	31	23	65	27.0

III. Result and Discussions

Table 2: Calculated global solar radiation

J	**T_{min} (0c)**	**T_{max} (0c)**	**T_{av} (0c)**	**RH (%)**	**Ra (kwh)**	**Rs(kwh)**
153	24	33	28.5	65	32.800	18.696
154	24	29	26.5	50	32.773	13.924
155	24	33	28.5	70	32.746	18.665
156	24	33	28.5	65	32.722	18.651
157	26	33	29.5	80	32.698	16.437
158	25	33	29.0	75	32.676	17.560
159	25	28	26.5	90	32.654	10.746
160	22	33	27.5	60	32.635	20.565
161	24	30	27.0	85	32.616	15.180
162	22	32	27.0	75	32.599	19.586
163	24	32	28.0	70	32.583	17.510
164	22	28	25.0	90	32.568	15.157
165	24	33	28.5	75	32.554	18.556
166	25	30	27.5	80	32.542	13.826
167	25	27	26.0	90	32.531	8.741
168	22	31	26.5	75	32.521	18.537
169	21	30	25.5	85	32.513	18.532
170	24	32	28.0	75	32.506	17.469
171	22	32	27.0	80	32.500	19.527
172	23	26	24.5	95	32.495	10.694
173	22	29	25.5	95	32.492	16.334
174	22	31	26.5	83	32.490	18.519
175	23	31	27.0	83	32.489	17.460
176	24	30	27.0	75	32.490	15.121
177	23	30	26.5	85	32.492	16.333
178	23	30	26.5	85	32.495	16.335
179	24	29	26.5	85	32.500	13.808
180	23	30	26.5	80	32.505	16.340
181	23	30	26.5	75	32.512	16.344
182	23	31	27.0	65	32.521	17.477

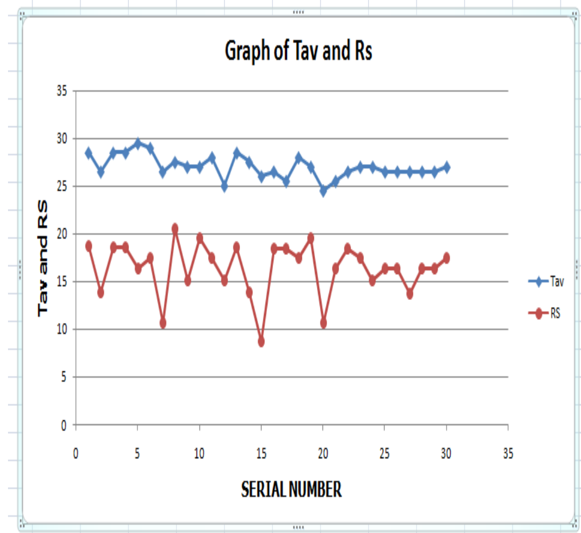

Fig 2: Graph of mean air temperature and global solar radiation

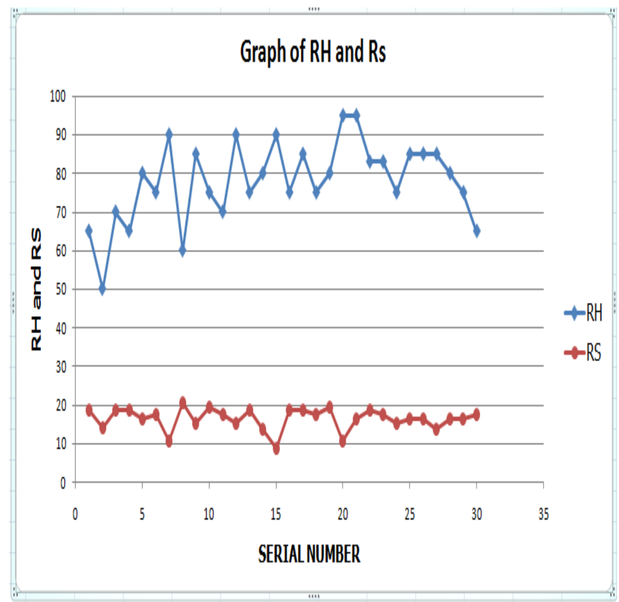

Fig 3: Graph of relative humidity and global solar radiation

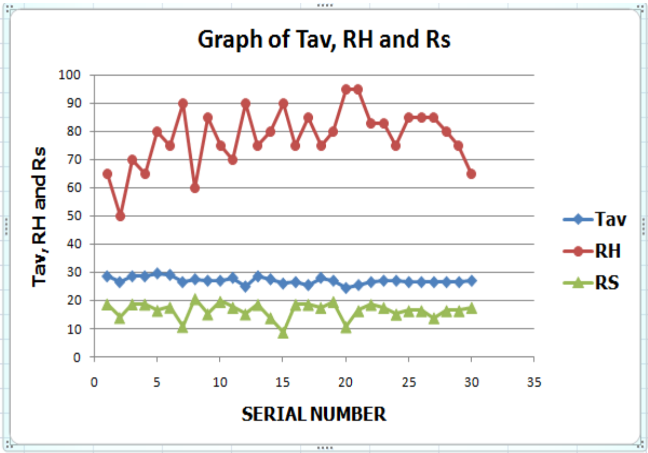

Fig. 4: Graph of mean air temperature, relative humidity and global solar radiation

IV. Discussions

The relationship between global solar radiations, relative humidity and mean air temperature of the study area was determined using the data of minimum and maximum temperature obtained from archive of weather online and a Microsoft excel tool, and the results is presented in Table 2. Hargreaves –Samanni model of global solar radiation was used for the prediction of the global solar radiation using the maximum and minimum temperature data for the month of June, 2016. Mean temperature was gotten from the maximum and minimum data already acquired and the relative humidity for the month of June, 2016 was obtained from the same achieve of weather online limited. From Table 2, it was observed that, the mean air temperature (Tav) has effect on the global solar radiation(Rs) to some extent. The comparison between the two quantities shows the positive correlation coefficient of 0.460648 (46.06%), implying that the two quantities would increase and decrease in the same way, but not in all the values due to the correlation coefficient value that is below average, i.e. 50%. Okonkwo & Nwokoye (2014), reported that, global solar radiation was highest in the month of November, while the lowest value was recorded in August. This is attributed to the highest and lowest values of clearness index obtained for these months respectively. Also, from Table 2, it was observed that relative humidity has effects on global solar radiation to some extent. The comparison between the two quantities shows a negative correlation of -0.47686 (-47.69%), implying that when one quantity is increasing, the other will be decreasing and vice versa, though not in all the values due to the correlation value that is below average, i.e. 50%. According to Fatayi (2013), cloud cover and relative humidity are higher in wet than in dry season, meaning more rainfall between the months of May and October, with low surface temperature, high relative humidity and low cloud cover.The effects of mean air temperature and relative humidity on global solar radiation is shown Figures 2 and 3 respectively. But relative humidity has more impacts on global solar radiation than mean air temperature. This is also displayed in figure 4, in which the trend of change of global solar radiation and relative humidity are very close when compared to the graph of mean temperature.

V. Conclusion

In this work, the relationship between the global solar radiation, relative humidity and mean air temperature of Ikeja, Lagos State Nigeria, was determined for the month of June, 2016. It can be said that global solar radiation is affected by both the mean air temperature and relative humidity as given by the correlation results. However, the positive correlation between the average or mean temperature shows that global solar radiation increases with increase in mean temperature, while global solar radiation increases with decrease in relative humidity based on its negative correlation value (-0.47686).In other words, high relative humidity is associated with low global solar radiation and low relative humidity is associated with high global solar radiations. Also, high average temperature is associated with high global solar radiations and low average temperature is also associated with low global solar radiation. Conclusively, relative humidity and mean air temperature have effects on global solar radiation of an area, but with that of relative humidity more pronounced than that of mean air temperature.

VI. Recommendation

It has been concluded that global solar radiation is affected by both mean air temperature and relative humidity using Hargreave-Samanni model with the minimum and maximum temperature data for rainy season (June), as obtained from achieve of weather online limited from their website, similar method should be employed using the data (relative humidity, maximum and minimum temperature) for dry season.

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