**International Journal of Recent Trends in Electrical & Electronics Engg.,Dec., 2017.**
**©IJRTE ISSN: 22316612**

# Assessing the Suitability of Udo's and Fagbenle's Global Solar Radiation Prediction Models in Akure, Ondo State

Ale Felix[1], Abdullahi Ayegba[2] and Wysenyuy Desmond Fonyuy[3]
[1,2]Engineering and Space Systems Department, National Space Research and Development Agency (NASRDA), Abuja, Nigeria, [3]Consultancy Department, African Regional Institute of Geospatial Information and Technology, Ile-Ife, Nigeria,
[1]University of Abuja, Nigeria, [2]Mathson Research Centre -A division of Mathson Group of schools, Nigeria.
Corresponding email[2]: mathsongroup@gmail.com

***ABSTRACT***

*There are many models for the prediction of global solar radiation, but the suitability of these models varies with locations and other factors. Knowing a particular model(s) suitable for the prediction of the global solar radiation in a place will allow a reliable result to be obtained, hence proper planning. The aim of this work is to determine the best model among Udo's and Fagbenle's models, which is most suitable for Akure.*
*The global solar radiations for the five years (2001-2005) were calculated using the two models, and the standard error and root mean square error were calculated. From the result, it was observed that Fagbenle's model has less error compared to Udo's model for the area under study. It was then concluded that Fagbenle's model is most suitable for the prediction of global solar radiation in Akure.*

***KEYWORDS:*** *Sunshine duration, Global solar radiation, Sunset angle, Standard error.*

## 1. INTRODUCTION

The amount of this energy available in a place depends on the location, time of the year, and atmospheric conditions [Helena *et al., 2011*]. In other words, the data of solar insolation recorded or measured varies from place to place, as well as time. In this, the model developed using a data of one particular place may not work in another location.
Research outcomes on studies of global solar radiation have facilitated improvement in Agronomy, power generation, environmental temperature controls, etc. [Ugwu and Ugwuanyi, 2011]. This is because the availability of the result of such works will help in adequate planning and management in these important areas- power generation, environmental temperature controls, water resources management and telecommunication.

## 2. RELATED WORKS

Many works in this research area have been done in many parts of the country, including Akure, such as the works by Falodun and Ogolo in 2007. In their work, the meteorology data between 1975 and 2006 collected from the Archive of Nigeria Meteorological agency (NIMET) was used. It was observed from their result that there is seasonal variation in global radiation, and that the dry months have comparably larger values than wet months.
Chiemeka and Chineke, 2009, tried to estimate the solar radiation at Uturu Abia state Nigeria, latitude 5.33˚N and 6.33˚N. He obtained temperature data from 5th – 31st October 2007 using the maximum and minimum thermometer placed in Stevenson screen at 1.5m after which he used the Hargreaves equation to obtain the estimate.
Ojo and Babatunde (2014) made use of the data of 1970 -1990 to develop monthly models for the evaluation of solar radiation data over Nigeria. They used contour method to observe the monthly latitudinal distribution of solar radiation over Nigeria. Their result showed that solar radiation increases with latitude.
Ayegba and Gazere (2017) studied the Suitability of Some Global Solar Radiation Prediction Models in Jos, Plateau State, Nigeria using Hargreaves-Samanni's model, Angstrom model, Torgul and Torgul's model, Oz's model, Udo's model, Fagbenle's model and Akinoglu and Ecevit's model. The

result shows that Udo's model has the least standard error and mean bias error, and Hargreave-Samanni model has the least root mean square error according to the result.

The approaches used in the previous works done in this same study area are different from this one as they seek to determine the global solar radiation of the area. In addition, the work done in Plateau state may be similar to this work but such work has not been done in Akure the study area, thus making this work necessary.

## 3. MATERIALS AND METHOD

**3.1 Materials:** The materials which are the sunshine duration, average monthly global solar radiation and maximum and minimum temperature data of the study area was used for the research work. The data covers five years (2001 -2005), and was obtained from the archive of Nigeria meteorological agency (NIMET), Oshodi, Lagos state. Microsoft excel package was used for the computations.

**3.2 Method**

The research work will make use of Udo's and Fagbenle's models. The models make use of data of maximum and minimum temperatures as well as sunshine duration of the study area. It will also make use of Microsoft excel package for the computation of the parameters. Fagbenle's models was the model developed and recommended for Nigeria environment in 1993, while Udo's model was developed for Ilorin, north-central Nigeria in 2002. The two models are given as follow:

**I. Udo's model:** The model is represented by the equation given as:

$$R_s = R_a\left(0.053 + 1.280\left(\frac{S}{S_O}\right) - 0.830\left(\frac{S}{S_O}\right)^2\right) \text{ -------- } 1$$

**II. Fagbenle' model:** The model is represented by the equation given as:

$$R_s = R_a\left(0.375 + 0.128\left(\frac{S}{S_O}\right) + 0.660\left(\frac{S}{S_O}\right)^2\right) \text{ ---------- } 2$$

**3.3: Calculation procedure**

**a. Calculation of solar radiation declination ( $\delta$ ):** 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;

$$\delta = 0.409 Sin\left(\frac{2\pi}{365} J - 1.39\right) \text{ ----------- } 3$$

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

**b. 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;

$$d_r = 1 + 0.033 Cos\left(\frac{2\pi J}{365}\right) \text{ -- } 4$$

**c. 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;

$$\omega_s = Cos^{-1}\left(-\tan(\varphi)\tan(\delta)\right) \text{ -- } 5$$

where $\omega_s$ is the sunset angle (radian), $\delta$ is the solar radiation declination (radian), and $\varphi$ is latitude angle of the location (radian).

**d. 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;

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

$R_a$ is extraterrestrial radiation ,$d_r$ is the inverse relative earth-sun distance, $\varphi$ 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 1367$wm^{-2}$.

**e**. **Calculation of day length:** The day length, *So*, is calculated using the formula given as:

$$So = \frac{2}{15} w_s \text{ ------------- } 7$$

where $w_s$ is the sunset angle.

## 4. Results and Discussion

**Table 1.0**: Calculated Global solar radiation for the study area using Udo's model

| Month/year | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|
| Jan | 14.65 | 14.65 | 16.37 | 16.57 | 11.83 |
| Feb | 15.95 | 16.77 | 14.98 | 17.34 | 15.80 |
| Mar | 17.75 | 17.88 | 14.41 | 16.53 | 13.03 |
| Apri | 16.44 | 17.82 | 16.25 | 17.82 | 16.25 |
| May | 14.52 | 17.84 | 15.17 | 17.38 | 17.05 |
| June | 11.70 | 13.83 | 14.47 | 12.69 | 12.45 |
| July | 7.07 | 6.43 | 11.85 | 4.77 | 10.01 |
| Augu | 12.13 | 7.23 | 6.91 | 9.39 | 11.35 |
| Sept | 8.07 | 7.42 | 10.51 | 6.06 | 10.51 |
| Oct | 13.77 | 16.57 | 15.85 | 10.98 | 15.66 |
| Nov | 15.60 | 16.65 | 16.78 | 17.15 | 15.77 |
| Dec | 13.25 | 16.13 | 16.83 | 14.95 | 15.10 |

Table 1.0 represents the calculated global solar radiation of the study area from 2001 to 2005 using Udo's model. From the result, it was observed that in 2001 and 2002, the maximum global solar radiation (17.75 MJ/$m^2$day and 17.88 MJ/$m^2$day) occurred in March, but in 2003, the maximum global solar radiation (16.83MJ/$m^2$day) occurred in December. In 2004 and 2005, the maximum global solar radiation (17.82 MJ/$m^2$day and 17.05 MJ/$m^2$day) occurred in April and May respectively. This means the maximum monthly global solar radiation varies from year to year. However, the minimum global solar radiation over this period was found to take place in August, probably as a result of more rainfall in the month of August in the study area than in other months.

**Table 2.0:** Calculated Global solar radiation for the study area using Fagbenle's model

| Month/year | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|
| Jan | 17.98 | 17.98 | 20.79 | 21.27 | 15.40 |
| Feb | 19.63 | 20.99 | 18.40 | 22.21 | 19.42 |
| Mar | 22.13 | 22.38 | 18.11 | 20.29 | 17.09 |
| Apri | 20.21 | 21.97 | 20.00 | 21.97 | 20.00 |
| May | 18.39 | 22.05 | 18.93 | 21.37 | 20.93 |
| June | 16.34 | 17.68 | 18.18 | 16.91 | 16.76 |
| July | 14.48 | 14.32 | 16.34 | 13.97 | 15.47 |
| Augu | 16.67 | 14.75 | 14.66 | 15.43 | 16.27 |
| Sept | 15.16 | 14.98 | 16.04 | 14.64 | 16.04 |
| Oct | 17.65 | 20.33 | 19.50 | 16.00 | 19.30 |
| Nov | 19.15 | 20.67 | 20.91 | 21.62 | 19.36 |
| Dec | 16.50 | 20.31 | 22.01 | 18.36 | 18.57 |

Table 2.0 shows the calculated global solar radiation using Fagbenle's model. It was observed that the result of the global solar radiation calculated with Fagbenle's model has higher values compared to that of the Udo's. In terms of the monthly variation of the peak global solar radiation over this period, the same trend as observed in the Udo's model was observed here to some extent. The peak values of the global solar radiation occurred in March and April in 2001 and 2002, while it occurred in December, February and April in 2003, 2004 and 2005 respectively. But in terms of the minimum global solar radiation, it was not constant in August throughout the study period as seen in Udo's model. It was found to alternates between June, August and July. However, in both models, there were variations in the monthly global solar radiation of the area for the study period.

**Table 3.0: Standard error and root mean square error**

| Years | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|
| SD Error (Udo) | 1.694 | 1.676 | 1.553 | 1.465 | 1.245 |
| SD Error(Fagb.) | 1.116 | 1.053 | 1.084 | 0.959 | 0.848 |
| RMSE (Udo) | 2.810 | 2.530 | 2.336 | 1.885 | 1.889 |
| RMSE (Fagbe.) | 1.604 | 1.174 | 1.242 | 0.749 | 0.935 |

Both the standar error and root mean square error can be used to determine the extent of deviation of the calculated global solar radiation from the measured (recorded) global solar radiation in the study area. This is shown in table 3.0. From the table, it was shown that the standard error of Fagbenle's model was found to be less than that of Udo's model. Fagbenle's model has the minimum standard error of 0.848 MJ/m$^2$day while that of Udo's model was 1.245 MJ/m$^2$day. Also, in the case of root mean square error (RMSE), the minimum value obtained with Fagbenle's model was 0.749 MJ/m$^2$day, while that of Udo's was 1.885 MJ/m$^2$day.

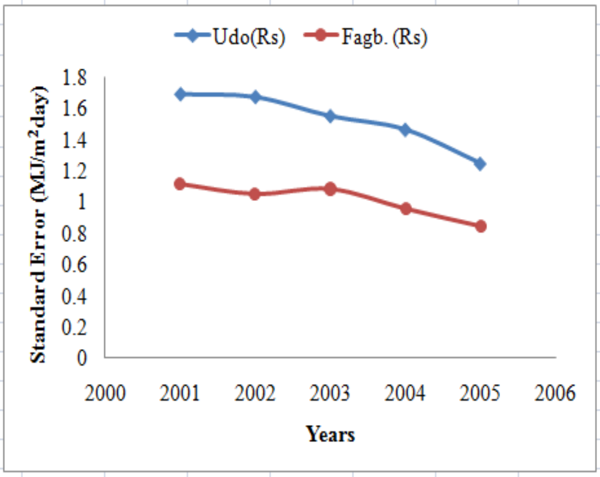


**Fig. 1:** Graph of standard errors for the two models

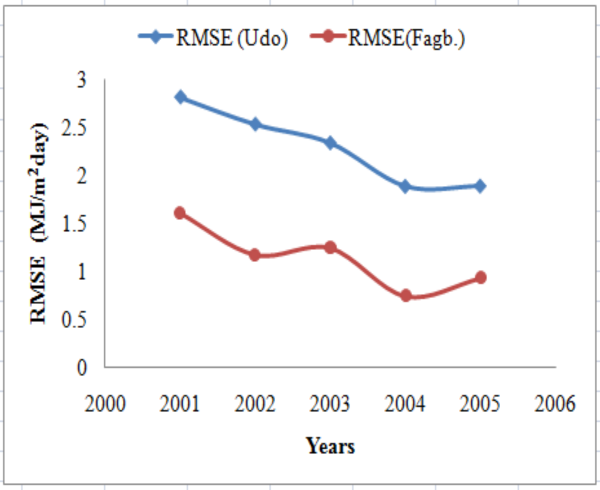


**Fig. 2:** Graph of root mean square errors for the two models

Fig. 1 and 2 represent the graphical illustration of the standard error and root mean square error respectively. The standar error for both models decresed from 2001 to 2005, while the root mean square error for Fagbenle's model decreased from 2001 to 2004, and it increased in 2005, while for Udo's model, it was found to increase and decrease from one year to the other throughout the study period. The two graphs show that the Udo's model has higher errors than Fagbenle's model in the prediction of global solar radiation in Akure, the study area.

## 5. CONCLUSION

The global solar radiation of Akure has been calculated using the data of minimum and maximum temperature, and sunshine duration for five years (2001 to 2005), obtained from the archive of Nigeria meteorological agency (NIMET), Oshodi, Lagos state. The global solar radiation was calculated using two models- Fagbenle's and Udo's models. In addition, the standard error and root mean square error of the two models were found in order to determine the model that is most suitable for the prediction of global solar radiation for the study area.

From the result, Fagbenle's model is found to have minimum standard error and root mean square error compared to Udo's model. Therefore, based on the minimum standard error of 0.848 MJ/m$^2$day and minimum RMSE of 0.749 MJ/m$^2$day for Fagbenle's model compared to 1.245 MJ/m$^2$day and 1.885 MJ/m$^2$day in that order for Udo's model, Fagbenle's model is most suitable than Udo's model, and can be conclusively recommended for the prediction of global solar radiation in Akure, the study area.

## 6. FUTURE WORK

There are several models for global solar radiation prediction but only two models were tested in this work; it is recommended that the suitability of other models for global solar radiation prediction in the study area be carried out in future work. In addition, the data used for this work was from 2001 – 2005, recent meteorological data should be used for future work using these same models.

## REFERENCES

[1]. Albert Osei, Edmud C Merem and Yaw A. Twumasi (2006). Use of GIS and Remote Sensing Technology as a Decision Support Tool in Land Administration-The Case of Lagos, Nigeria, Regional Conference, Accra, Ghana.
[2]. Adedoja, O.S., Ayantunji, B.G. Saleh U.A. and Jatto. S.S (2015). Diurnal and Seasonal Variation of Global Solar Radiation at Anyigba, North-Central Nigeria, International Journal of Engineering Science and Innovative Technology
[3]. Akpabio, L. E., Udo, S. O and Etuk, S. E. (2004). Empirical correlation of Global Solar Radiation with Meteorological Data for Onne, Nigeria. Turkish Journal of Physics.
[4]. C. O. Osueke, P. Uzendu and I. D. Ogbonna (2013). Study and Evaluation of Solar Energy Variation in Nigeria. International Journal of Emerging Technology and Advanced Engineering.
[5]. D. O. Akpootu and S. Aruna (2012). Diurnal and Seasonal Variations of Global Solar Radiation in Akure, Ondo State, South Western Nigeria. The International Journal Of Engineering And Science.
[6]. E. N. Gajere and Abdullahi Ayegba (2017). "Assessing the Suitability of Some Global Solar Radiation Prediction Models in Jos, Plateau State, Nigeria", International Journal of Trend in Research and Development.
[7]. E. O. Falayi, J. O. Adepitan, and A. B. Rabiu, "Empirical models for the correlation of global solar radiation with meteorological data for Iseyin, Nigeria," International Journal of Physical Sciences.
[8]. E. O. Ogolo (2014). Estimation of global solar radiation in nigeria using a modified Angstrom model and the trend analysis of the allied meteorological components. Indian journal of Radio and Space physics.
[9]. Ekwe, M. C., Joshua, J. K and Igwe, J.E. (2014). Estimation of Daily Global Irradiation at Owerri, Imo State (Nigeria) from Hours of Sunshine, Minimum and Maximum Temperature and Relative Humidity. International Journal of Applied Research and Studies
[10]. Falayi, E. O., Rabiu, A. B and Teliat, R. O. (2011). Correlations to estimate monthly mean of daily diffuse solar radiation in some selected cities in Nigeria, PelagiaResearch Library.
[11]. Hargreaves, G. and Samani, Z.(1982). Estimating potential evapotranspiration. Journal of Irrigation and Drainage Engineering.
[12]. Iqbal M. (1983). An introduction to solar radiation, first ed. Academic press, New York.
[13]. I. U. Chiemeka1 and T. C. Chineke (2009). Evaluating the global solar energy potential at Uturu, Nigeria. International Journal of Physical Sciences.
[14]. José Álvarez, Helena Mitasova, and H. Lee Allen (2011). Estimating monthly solar radiation in South-Central Chile. Chilean Journal Of Agricultural Research
[15]. Olusola Samuel Ojo and Babatunde Adeyemi (2014). "Estimation of Solar Radiation using Air Temperature and Geographical Coordinates over Nigeria", The Pacific Journal of Science and Technology.
[16]. Olusola Samuel Ojo and BabatundeAdeyemi (2014). Estimation of Solar Radiation using Air Temperature and Geographical Coordinates over Nigeria. The Pacific Journal of Science and Technology.
[17]. Fagbenle RO (1990). Estimation of total solar radiation in Nigeria using meteorological data Nig. J. Renewable Energy.
[18]. S. O. Falodun and E. O. Ogolo (2007). Diurnal and seasonal variation of Global solar radiation at Akure , South-western Nigeria. Journal of engineering and applied sciences.
[19]. S. A. Ayegba N. O. Sampson Ibileke J. O Akintulerewa O. S L. S. Owa W. Desmond Fonyuy David-Ndahi A (2016). "Assessment Of Global Solar Radiation: A Case Study Of Abuja, Nigeria". International Journal of Innovative Research and Advanced Studies.

[20]. Ugwu, A. I. and Ugwuanyi, J. U. (2011). Performance assessment of Hargreaves model in estimating solar radiation in Abuja using minimum climatological data, International Journal of the Physical Sciences.

## BIOGRAPHIES

**Dr. Ale Felix** graduated with a Doctor of Philosophy (PhD) in Systems Engineering in 2014 from the University of Lagos. He has BSc (1998) and MSc (2005) degrees in Computer Engineering and Computer Science respectively from the Obafemi Awolowo University, Ile-Ife. Dr. Ale Felix is a Chief Engineer with the National Space Research and Development Agency. He undertakes joint research between the academia and the industry in area of High-Performance computing applications and support systems, Distributed and parallel computing. Dr. Ale Felix is also apart-time lecturer in the Department of Electrical/Electronics Engineering, University of Abuja, Nigeria. He specializes in Software, OBDH satellite subsystem and Systems engineering with broad interest in embedded systems and software design and development. He has several publications to his credit. He is a registered member of many professional bodies in Nigeria.

**Abdullahi, Ayegba** who was born in Okpachala-Igalamela, Kogi state, Nigeria, holds HND, Elect/Elect Eng'g of Federal Polytechnic Idah, Kogi state, PGDE of NTI, Kaduna, PGD, Satellite Communication of ARCSSTEE, OUA Campus, Ile-Ife, has rounded up his masters degree programme in Space Science and Technology ARCSSTEE/FUTA Nigeria. He is a prospective PhD student of communication physics at Federal University of Technology Akure (FUTA), Nigeria. Ayegba, a former associate lecturer with Kogi state College of Health Science and Tech. Idah, and a former instructor of Space Science and Technology and a GIS application trainer with National Centre for Remote Sensing, Jos computer school, has published many academic textbooks as well as about thirty five research papers in International Journals. He presently works with the Engineering and Space Systems Dept. of National Space Research and Development Agency, Abuja, Nigeria. His areas of research interest are satellite communication, radio propagation, antenna, satellite power system, solar power system/radiation. Ayegba is a member, International Society for Development and Sustainability (ISDS), Institute for Engineering Research and Publications (IFERP), International Association of Engineers (IAENG) and International Association For Engineering and Technology (IAET).

**Wysenyuy Desmond Fonyuy** is born in Bamenda, Cameroon in 1990. He received B. Sc. in Electrical and computer engineering with specialty in telecommunications engineering from the Catholic university of Buea, in Cameroon 2014. Currently, he is pursuing M. Tech. in Satellite communications from African Regional Center for Space Science and Technology, Nigeria. He currently works as a scientific officer at the African Regional Institute for Geospatial information science and technology (AFRIGIST), Nigeria. His current interest include self-organized mobile communication systems for Disaster scenarios, cognitive management of transport resources, communication systems, electronic and computer science etc. He has published some papers in international journals.