International Journal of Informatics and Data Science Research
ISSN 2997-3961 (Online)
Vol. 2, No. 11, Nov 2025,
Available online at: https://scientificbulletin.com/index.php/IJIDSR

Assessment of Monthly Variations in Global Solar Radiation Over Abuja, Nigeria

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Article information:
Manuscript received: 7 Sep 2025; **Accepted:** 13 Oct 2025; **Published:** 11 Nov 2025

Abstract: This study assesses the global solar radiation of Abuja, located in north-central Nigeria, using maximum and minimum temperature data for the period of January to December 2024. The Hargreaves–Samani model was employed to estimate the monthly global solar radiation. Results revealed that global solar radiation was generally higher during the dry season (January–March and October–December) and lower during the rainy season (May–September). The study further indicated that global solar radiation varies with the maximum temperature, regardless of the season. It was observed that the global solar radiation in Abuja fluctuates almost every month, implying that the amount of energy expected from solar energy systems in the area also varies monthly. The lowest radiation value was recorded in August (14.99 kWh). These findings are valuable to solar power users, as they highlight the need to manage energy consumption during periods of low radiation and to consider backup power options during the rainy season. Additionally, the results will assist solar energy designers, installers, and policymakers in proper planning, system sizing, and component selection. Given that this research utilized average monthly data for only one year, it was recommended that future studies incorporate data spanning two or more years to achieve more reliable and comprehensive assessments of global solar radiation in the study area.

Keywords: Atmosphere, Temperature, Solar energy, Global solar radiation

1.0 Introduction

According to Falodun and Ogolo (2007), a knowledge of spectral irradiance (direct and diffuse) arriving at the earth's surface is important for the design of many solar energy applications. Also, Femi et al. (2023) said that solar energy has emerged as one of the most promising sustainable resources, capable of bridging the energy demand gap while mitigating climate change problems. The availability of it as well as the accessibility in virtually every region of the world have made it a dependable energy source.

Thus, for reliable evaluation, planning, and deployment of a solar energy system, a good knowledge of the global horizontal irradiance data is very paramount.

The amount of global solar energy depends on the location, time of the year, and atmospheric conditions (Helena *et al., 2011*). This implies that the amount of solar energy available in a place or location depends on the time of the year, that is, the rainy and dry seasons, and thus there is a need for such 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 and Ugwuanyi, 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 environments. There are rising concerns over the air pollution generated by burning conventional fuel, which have sped up the search for cleaner energy resources, and for this to be reduced, relevant stakeholders are working broadly on the development of effective technologies to produce clean power from renewable resources (Ardhya et al., 2023). The sun is considered the main source of renewable energy, either in direct form or indirectly. However, among all the renewables, solar energy is considered a promising energy source, both in terms of reliability and harvesting potential (Al-Ghriybah et al., 2020). Although some similar works have been done in some parts of Nigeria including Abuja, the assessment of the monthly global solar radiation in 2024 has not been carried out as done in this work.

2.0. Study area

The study area, Abuja, is located between latitude 8.25° and 9.20° North of the equator and longitude 6.45° and 7.39° East of the Greenwich meridian. It is located in the North-Central geographical zone of Nigeria and bounded by Kaduna State to the Northeast, Niger State to the West and North, Kogi to the Southwest, and Nasarawa State to the East and South. It has the Savannah Woodland region, which covers about 12.8% of the territory and occurs mostly on the Gurara, Robo, and Rubochi plains and surrounding hills. Common tree species found in this region include Afzelia africana, Anogeissus leiocarpus, Daniellia oliveri, and Khaya senegalensis. The rainy season of Abuja is between April and September, while the dry season is between October and March. Abuja has a temperature range of around 26°C to 40°C and around 20°C to 30°C in the rainy season.

3.0 Materials and method

The materials utilized in this research comprised secondary data of maximum and minimum temperatures obtained from a verified online weather archive. The dataset consisted of average monthly maximum and minimum temperature values for the year 2024, covering the period from January 1 to December 31. Microsoft Excel software was employed for data analysis, computation, and graphical visualization. In addition, relevant peer-reviewed and online published research works in related subject areas were consulted to support the study framework and analysis. The Hargreaves–Samani model was adopted for estimating global solar radiation in the study area. The detailed procedure for the application of the Hargreaves–Samani model is outlined below.

Method: The work makes use of Hargreaves-Samani model of global solar radiation prediction. Hargreaves-Samani model is the model which is used to estimate reference evapotranspiration of an area if maximum and minimum temperatures are the only available data. Microsoft excel worksheet was used for the mathematical computations to obtain the necessary parameters, and plotting of graphs.

The Hargreaves-Samani reference evapotranspiration model is given (Hargreaves and Samani, 1985) as:

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

i. Solar radiation declination: Solar radiation declination refers to 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 represented mathematically (Iqbal, 1983) as;

$$\delta = 0.409 Sin\left(\frac{2\pi}{365}J - 1.39\right) \quad 3.2$$

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.

ii. **Inverse relative distance Earth-sun:** Inverse relative distance Earth-sun refers to the inverse distance of the sun relative to the earth at a location. It is represented (Iqbal, 1983) as;

$$d_r = 1 + 0.033 Cos\left(\frac{2\pi J}{365}\right) \quad 3.3$$

iii. **Sunset angle:** Sunset angle refers to 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 formula given (Iqbal, 1983) as:

$$\omega_s = Cos^{-1}\left(-\tan(\varphi)\tan(\delta)\right) \quad 3.4$$

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.

iv. **Extraterrestrial solar radiation:** Extraterrestrial solar radiation refers to the intensity or power of the sun at the top of the earth's surface. The extraterrestrial radiation is calculated using the formula given (Iqbal, 1983) as:

$$R_a = \frac{24(60)}{\Pi} G_{sc} d_r \left[w_s Sin(\varphi) Sin(\delta) + Cos(\varphi) Sin(w_s)\right] \quad 3.5$$

where R_a is extraterrestrial radiation , d_r is the inverse relative earth-sun distance, φ is the latitude angle of the study area, w_s is the sunset angle, and Gsc is solar constant = 0.0820 MJ m^{-2} min^{-1} or 1367wm^{-2}.

v. Global Solar Radiation: Global solar radiation refers to the total amount of solar energy received by earth's surface. It is the sum of the direct, diffuse and reflected solar radiations. It is found using the formula given (Hargreaves and Samani, 1985) as:

$$R_s = K_{RS}\left(\sqrt{T_{\max} - T_{\min}}\right) R_a \quad 3.6$$

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. For 'interior' locations, where land mass dominates and air masses are not strongly influenced by a large water body, K_{Rs} 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, K_{Rs} is approximately 0.19 (Hargreaves and Samani, 1985). This work makes use 0.16 for K_{Rs}.

4.0 Results and Discussion

Table 1.0 presents the monthly extraterrestrial solar radiation and global solar radiation for Abuja from January to December 2024. The results show that both the global and extraterrestrial solar radiation values varied from month to month throughout the year. For instance, the global solar radiation decreased from 30.19 kWh in January to 25.79 kWh in February and 23.08 kWh in March, reaching a minimum of 14.99 kWh in August before rising again to 16.02 kWh in September, and so on. Similarly, the extraterrestrial solar radiation changed from 41.02 kWh in January to 39.18 kWh in February and 36.62 kWh in March, dropping to 35.27 kWh in August and increasing to 37.72 kWh in September. This pattern indicates that both quantities fluctuate with time, or as the months progress.

It was also observed that the extraterrestrial solar radiation remained higher than the global solar radiation throughout most months. This occurs because extraterrestrial solar radiation represents the total amount of solar energy reaching the Earth's atmosphere from the sun before undergoing any atmospheric scattering or absorption, whereas global solar radiation refers to the portion that actually reaches the Earth's surface after partial absorption and scattering by the atmosphere.

Consequently, within the study period, the minimum and maximum global solar radiation values were 14.99 kWh and 30.19 kWh, respectively, while the minimum and maximum extraterrestrial solar radiation values were 32.51 kWh and 42.00 kWh. This confirms that global solar radiation is always, or in most cases, lower than extraterrestrial solar radiation.

Fig. 1.0 shows the monthly global solar radiation of Abuja from January 1 to December 31, 2024. The results show that there was a monthly variation in the global solar radiation of Abuja during the study period. It means that the amount of solar energy received on the surface of the earth in Abuja varied almost monthly. As in the figure, the global solar radiation was high in the beginning of the year as well as the end of the year. The global solar radiation of Abuja slopes downward from January to May and rises briefly before decreasing again. It maintains almost the same level in September when it starts rising again, and this time, the increase or slope continues upward until it reaches December. The lower value of the global solar energy between April and September could be as a result of that period being a rainy season period in the study area, Abuja.

Table 1.0: Monthly Extraterrestrial solar radiation and global solar radiation

Months	Ra (kwh)	Rs (kwh)
Jan	41.024	30.19
Feb	39.180	25.79
March	36.623	23.08
April	34.357	18.46
May	32.858	15.29
Jun	32.512	16.34
July	33.356	15.52
Aug	35.272	14.99
Sep	37.711	16.02
Oct	40.109	21.55
Nov	41.642	23.74
Dec	42.003	28.77

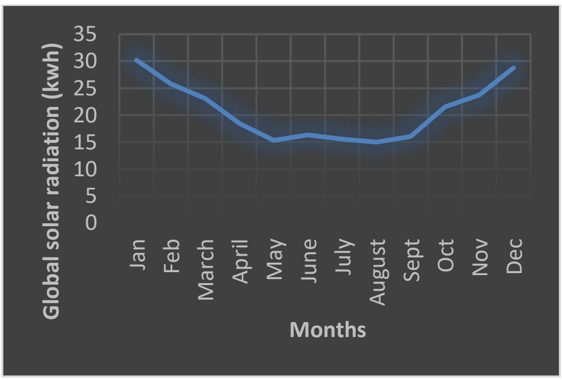

Fig. 1.0: Monthly global solar radiation of Abuja from January 1 to December 31, 2024.

Fig. 2 represents the monthly maximum and minimum temperatures of Abuja from January 1 to December 31, 2024. It was observed from the figure that the monthly maximum and minimum temperatures of the study area also showed a monthly variation just like the global solar radiation. In the case of minimum temperature, it was high between around April and May and moderate around November. In the case of the maximum temperature, it was high from around January to April and from October to December. The maximum temperature was less from around May to September. This could also be as a result of the rainfall in the area around that time, thus reducing the strength of the sun or not encouraging maximum temperature at all. This, in a way, will affect the solar energy output at this particular period. Figure 3.0 shows the monthly global solar radiation and maximum and minimum temperatures of Abuja from January 1 to December 31, 2024.

The global solar radiation was low from April to September. The maximum temperature showed similar variations throughout the year, with little change from the beginning to the end. However, the minimum temperature exhibited the opposite trend. The monthly maximum temperature increased as the global solar radiation increased, and decreased when the global solar radiation decreased. In simple terms, the global solar radiation in Abuja rises as the maximum temperature rises, and vice versa. This indicates that global solar radiation is directly proportional to temperature. From the figure, the maximum temperature was higher between January and April, and again from October to December. A similar pattern was observed for global solar radiation, which was high between January and May, and from September to December. This suggests that although other factors such as rainfall may influence global solar radiation, it is primarily affected by atmospheric temperature.

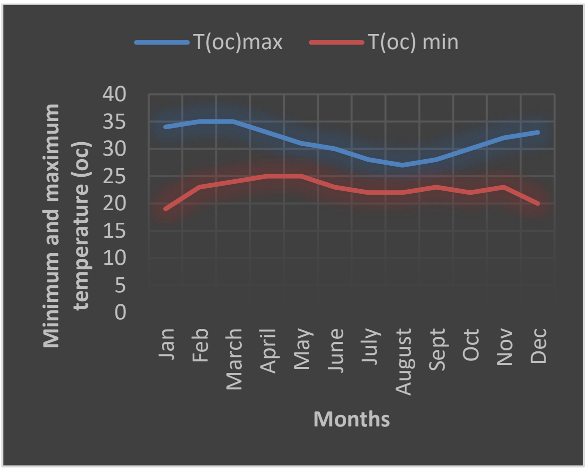

Fig. 2.0: Monthly maximum and minimum temperatures of Abuja from January 1 to December 31, 2024.

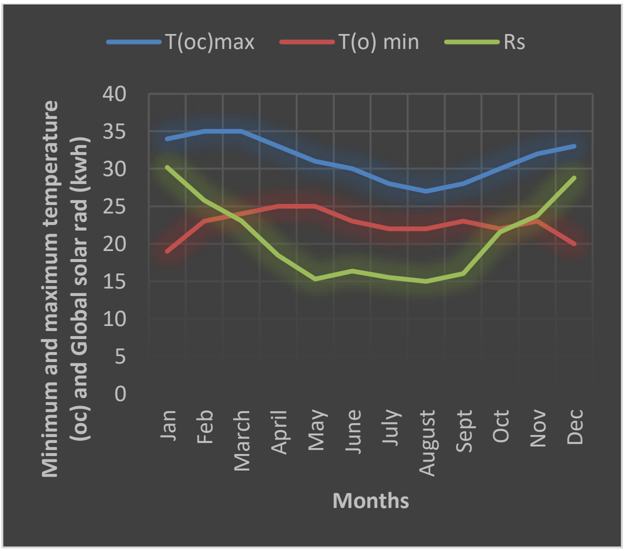

Fig. 3: Monthly global solar radiation and maximum and minimum temperatures of Abuja from January 1 to December 31, 2024.

5.0 Conclusion

The research work on the assessment of monthly global solar radiation in Abuja was conducted using maximum and minimum temperature data. The analysis was carried out with the Hargreaves-Samani model for determining global solar radiation. The results revealed that both the global solar radiation and the extraterrestrial solar radiation in the study area (Abuja) exhibited variations in almost every month of the year 2024. However, the monthly extraterrestrial solar radiation was higher than the global solar radiation because the latter represents the total amount of radiation received on the Earth's surface after atmospheric scattering and absorption.

The findings further showed that global solar radiation was higher during the dry season (January to March and October to December) and lower during the rainy season (May to September). This pattern is attributed to the lower average temperatures experienced in the rainy season compared to the dry season.

From the results, it can be concluded that the global solar radiation in Abuja, the Federal Capital Territory, varies significantly across the months of the year. Consequently, the amount of energy expected from solar energy systems in this location also fluctuates monthly. It can also be concluded that global solar radiation is lowest during the rainy season, with the lowest value recorded in August (14.99 kWh). This result provides valuable insight for users of solar power systems, enabling them to manage energy consumption during the rainy season — for instance, by limiting the use of multiple electrical appliances or maintaining a standby power source in case of insufficient solar radiation. Furthermore, the findings will be beneficial to solar energy experts, designers, and installers in Abuja and its environs for better planning during system design, installation, and component selection.

6.0 Recommendation

This research utilized the average monthly data for one year (January–December 2024). It is recommended that data spanning two or more years be used to carry out the same assessment of global solar radiation in the study area.

References

1. Al-Ghriybah M., Zulkafli M.F., Didane D.H., and S. Mohd (2020): "Performance of the savonius wind rotor with two inner blades at low tip speed ratio," CFD Letters, 12 (3) 11–21. doi:10.37934/cfdl.12.3.1121.
2. Ardhya Fadhila Pachman, Djamal Hissein Didane, Wijianto Mohanad (2023): A Study of Global Solar Radiations Measurement in Java Island, Indonesia. EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 10, Issue 01, pp212-218.
3. Falodun S. O. and Ogolo E. O. (2007). Diurnal and seasonal variation of Global solar radiation at Akure , South-western Nigeria , journal of engineering and applied sciences.
4. Femi Ikotoni Bawondaa,b, Joseph Yakubu Orichab, Shereefdeen Oladapo Sanni (2023): Estimating Global Horizontal Irradiance in Nigeria: An Empirical Modelling Perspective. Journal of Solar Energy Research Volume 8 Number 4 Winter (2023) 1701-1714
5. Hargreaves, G. and Samani, Z. (1982). Estimating potential evapotranspiration. Journal of Irrigation and Drainage Engineering.
6. Iqbal M. (1983). An introduction to solar radiation, first ed. Academic press, New York
7. José Álvarez, Helena Mitasova, and H. Lee Allen (2011). Estimating monthly solar radiation in South-Central Chile. Chilean Journal Of Agricultural Research
8. 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.