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Computer Modelling For Determining the Global Solar Radiation for Lafia Location, Nasarawa State, Nigeria

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Abstract

A computer model for estimating the global solar radiation for the Lafia location (Lat. 9.5°N and long. 8.9°E) was developed using the Angstrom-page linear equation. The model was developed from measured solar radiation and sunshine hours for the months of January to December, 2025. Solar radiation (W/m²), wind speed (m/s), maximum and minimum temperature (°C), hours of sunshine (hr), and relative humidity were collected from the Lafia Cargo Airport meteorological unit, Kwadere - Lafia North Dev Area. The highest solar radiation of 350 W/m² and the corresponding highest sunshine hours of 10.81 hrs occurred in March 2025, while the lowest occurred in August, 2025. The average measured solar radiation was 297.08 W/m². The average relative humidity of 46% was determined from the average ambient temperature of 28.16°C and average minimum temperature of 16.19°C. The average wind speed was 28.33 m/s. The constants ‘a’ and ‘b’ of the Angstrom-Page equation were determined by plotting the clearness index (H/Ho) on the Y-axis and the fractional possible sunshine hours (ns/N) on the X-axis to obtain the line of best fit. The slope of this line is the value of the constant 'b'=0.83, while the intercept of this line on the y-axis is the value of the constant ‘a’=-0.11 with a coefficient of correlation of r=54% and a coefficient of determination of R^2=0.292. The developed computer model can therefore be used to determine the global solar radiation at the Lafia location, Nigeria.

Keywords: Computer, Modeling, Regression Constants, Global Solar Radiation, Lafia.

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1.0 INTRODUCTION

Solar energy, as a renewable energy source, is the most important resource for humanity and is essential for sustaining one square meter (1 m²) of human life, which is measured in terms of problems related to W/m². Solar energy is therefore important (Hanna, 2010). The solar photovoltaic (PV) cell is one of the most significant and rapidly developing renewable energy technologies, and its potential future uses are notable. With the growing significance of environmental issues, clear energy generation has become increasingly important. Solar radiation is a sustainable energy source, but it does not continue for long durations at a given location (Joshi 2006, Joshi *et al.,* 2009). Solar energy is incident on the earth at the rate of 2.0 x 1015 kWh/day. Nigeria is in the high solar radiation belt of the world. It receives an annual average of about 3.5 kWh/m²/day in the far north of the country (Umar *et al.,* 2000). Nigeria enjoys abundant sunshine throughout the year. One square meter (1 m²) received as much as 490 W/m² day (Bamiro and Ideira, 1985; Yohanna *et al.,* 2011). This cheap energy can be harnessed and stored during the night for continuous drying.

Solar energy is the most promising of the renewable energy sources in view of its apparent limitless potential. Studies relevant to the availability of solar energy resources in Niger, complete knowledge, and detailed analysis of the site's potential have fully indicated its viability for practical use (Sambo, 1995). Solar energy utilization is usually classified with solar thermal and solar photovoltaic. Solar thermal conversions are based on flat plate or concentrating collectors. This classification is the basis of such systems as solar dryers, solar cookers, solar water heaters, and solar stills for the production of distilled water (Egbo *et al.,* 2003). In the photovoltaic cell, solar radiation is converted to electricity by devices called solar cells put in the form of modules or panels, which are mounted together into a supporting structure and wired together in a series or parallel configuration so as to produce the required output. Photovoltaic application includes its use for providing continuous electricity to power water supply and for the normal electrification of remote villages (Little, 2004; Rai, 2004; Sharp Cooperation, 2005).

Solar radiation is the sun's radiant heat energy, which travels through space at light speed. Solar radiation varies with season, time of day, cloud cover, albedo, dust, and aerosol content of the atmosphere (Iloeje, 1997; Yohanna, 2010). Global or total solar radiation consists of the direct and diffuse components. The direct component has suffered no change in durations from the sun, while the diffuse is made up of shattered and reflected radiation (Habou *et al.,* 2005; Dandakouba *et al.,* 2006).

Solar radiation at the earth's surface is essential for the development and utilization of solar energy. It is required for designing collectors for solar heaters and other photovoltaic equipment that depend on solar energy. Incoming solar radiation has a significant role in hydrological and crop growth modeling. It is a key input (Al. 2004) for estimating potential evapotranspiration, which plays a major role in designing water supply reservoirs and irrigation systems (Sanusi and Abisoye, 2011). In spite of the importance of global solar radiation data, its measurements are not frequently available in developing countries like Nigeria. Akpabio et al. (2004) observed that few meteorological stations in developing countries measure solar radiation data. This situation can be solved by using empirical models, which estimate global solar radiation based on the relationships with frequently measured climatic variables. Researchers have conducted numerous studies to estimate incoming solar radiation in Nigeria (Bamiro, 1983; Akpabio *et al.,* 2004; Yohanna, 2011). Angstrom (1924) was the first scientist known to suggest a simple linear relationship to estimate global solar radiation.

Solar energy applications require a complete knowledge and detailed analysis of the potential of the site, so a database at ground level is an important feature of solar energy systems (Gairaa and Bakelli, 2013). Measurements of global solar radiation reaching the surface of the earth and its two components—direct and diffuse—are essential in most research fields of solar energy. The daily values as well as the monthly ones are needed to evaluate the performance of existing solar devices and estimate the efficiency of the future installations (Gairaa and Benkaicale, 2011; Desouza *et al.,* 2009). When the site under consideration is equipped with a radio metric station operating regularly for several years, it will be easier to exploit solar energy resources. However, in most cases, local measurements are unavailable, and ground-measured solar radiation is rarely accessible for sites where solar systems are planned; therefore, we must use approximate methods to predict solar radiation characteristics (Gairaa and Bakelli, 2013). Additionally, using satellite data alongside quality solar ground data sets and other meteorological information has proven to be an effective approach for developing site-specific resource assessments over large areas (Zarzalejo, 2006; Polo et al., 2006).

Knowledge of the local global solar radiation is required by most models that estimate crop growth and is essential for many applications, including evapotranspiration estimates, architectural design, and planning any solar energy systems at a given location (Zarzalejo *et al.*, 2009). Designing a solar energy system requires precise knowledge regarding the availability of global solar radiation at the location of interest. Since the global solar radiation reaching the earth's surface depends on the local meteorological conditions, a study of solar radiation under local climatic conditions is essential (Ahmed and Ulfat, 2005). For locations where measured values are not available, solar irradiance can be estimated using empirical models (Almorox, 2011).

Daily solar radiation data are often required in agro-meteorological calculations to compute (1954). The water budget for irrigation or crop growth simulations is often calculated using daily solar radiation data, but these measurements are only available at a limited number of weather stations. When radiation records are not available, these can be estimated by means of an empirical relation using the measured duration of bright sunshine or cloudiness (Black *et al.,* 1954). Keulen and Heemst (1986) and Bindi and Miglietta (1991) conducted studies related to this topic Bindi and Miglietta (1991).

The scantiness of hourly data in Nigeria and many other countries in Africa makes it necessary to resort to empirical models to evaluate hourly inputs of diffuse and beam radiation for the design and optimisation of solar devices (Maduekwe *et al.,* 1999). Solar energy is an abundant, clear, pollution-free, and never-ending source of energy (Jiya and Alfa, 1999; Yohanna, 2010). The growing population, fast-depleting reserves of fossil fuels (petrol, diesel, and kerosene), and Nigeria's location on the globe have led researchers in the field of energy resources and development to pursue the development and use of solar energy devices.

Solar energy devices, such as solar dryers, can only be properly harnessed with accurate values of solar radiation in that location, since solar radiation varies from one Angstrom to another all year (Yohanna et al., 2011). The Angstrom-Page equation is a widely accepted numerical method for determining the monthly daily global solar radiation in a location. The regression coefficients 'a' and 'b' are specific to every location, and accurately determining the coefficients will result in accurately determining the coefficients will result in the accurate determination of the global or total solar radiation of that location. The coefficient 'a' refers to the fraction of extraterrestrial radiation that is diffused (scattered), which is called diffuse radiation, and the coefficient 'b' refers to the fraction of the extraterrestrial radiation that is direct (beam), which is called beam radiation.

The Angstrom equation can be used to determine total radiation on a horizontal surface if the ns, Ho and N are known as shown in equations 1 and 2.

$$H/_{Ho} = a + b\ (^{ns}/_{N}) \quad (1)$$

$$H = Ho\ [a + b\ (^{ns}/_{N})] \quad (2)$$

Where. H = monthly average daily global radiation on a horizontal surface, W/m^2

Ho = monthly average daily extraterrestrial radiation W/m^2,

ns = monthly average daily number of hours of bright sunshine, hr.

H= monthly average daily number of possible sunshine, hr.

'a' and 'b' – Regression constants or coefficients.

The performance of any solar system depends on the available solar radiation at the location. The best solar radiation information Measurements of global solar radiation at a location provide the best solar radiation information. from measurements of global solar radiation at a location. The problem here is that there is no such station in Lafia, and there is no existing model developed for estimating total solar radiation for Lafia and its environs. Lafia, lat. 8.4939°N and long. 8.5153°E is a tropical location with abundant global solar radiation. Solar radiation is therefore abundant for such agricultural businesses as crop drying and refrigeration for cold storage of fruits and vegetables. The abundant solar radiation can be converted into electricity by photovoltaic devices for operating water pumps for irrigation, operating machines such as threshers, mills, etc., and electricity operation for other purposes. Hence, to design solar devices, the correct values of solar radiation for the location must be available and known. The Angstrom-Page equation that will This study will determine the Angstrom-Page equation, which from this study will enable the prediction and determination of total solar radiation for the Lafia location. Also, the determination of the regression coefficients of the Angstrom-Page equation will enable the direct computation of solar radiation for the location and facilitate the design of solar devices for the Lafia location and its environs. There is a lack of adequate conventional energy in Lafia and its surrounding areas, which creates a need for solar energy as an alternative source to complement conventional energy; therefore, it is important to quantify solar resources based on the availability of sunshine hours.

The study is limited to the collation of data on solar radiation, relative humidity, maximum and minimum temperature, wind speed, and hours of sunshine for 12 months (i.e., 1 year) from January to December. The data were collected from Kwadere, Cargo Air Port, in the Lafia North Development Area of Lafia LGA.

Determination of the regression coefficients and hence the Angstrom-Page equation for the Lafia location was from the data collected from the airport.

The study covered the months of January to December, 2025 (i.e., 1 year).

The objective of the project was to develop a computer model for determining the global solar radiation for the Lafia location and its environs using the Angstrom–Page equation.

2.0 MATERIALS AND METHODS

2.1 Description of the Study Area

The study was carried out at Lafia L.G.A. of Nasarawa State. It lies between latitude 8.4939°N and longitude. 8.5153°E with an average altitude of 1515 meters above mean sea level (Wikipedia, 2015). It has an estimated population of 175,267 inhabitants. The local government area is bounded in the north by Nasarawa Eggon LGA, in the east by Obi LGA, in the west by Keffi LGA, and in the south by Doma LGA. **(Fig. 1).** Lafia has a land area of 1,032 km². The local government Solid mineral and agricultural resources, along with resourceful, industrious, and hospitable people, bless the local government (Wikipedia, 2015) with solid mineral resources and agricultural resources, coupled with resourceful, industrious, and hospitable people (Wikipedia, 2015). The climate of the area is tropical with two distinct seasons: the rainy and the dry seasons.

The temperature throughout the year ranges from 16°C to 28°C, while humidity is relatively high, from 42 to 45%. The mean annual total rainfall varies from 1520 mm to 2050 mm. The local government area enjoys luxuriant vegetation and is an agrarian area; hence, agriculture has always played a leading role in the lives of the people. The geographical location of the area makes it a veritable agricultural zone for the cultivation of diverse crops. The predominant crops grown include maize (Zea *mays)*, groundnut *(Arachis hypogaea),* guinea corn *(Sorghum bicolor or Sorghum saccharatum),* millet (Pennisetum *typhoides)*, Irish potatoes *(Solanum tuberosum),* sweet potatoes *(Ipomoea batatas)*, tomatoes *(Solanum lycopersicum),* onions *(Allium cepa),* peanuts *(Arachis hypogaea),* cabbage *(Brassica oleracea),* acha/hungry rice *(Digitaria exilis),* okro/okra *(Abelmoschus escutentus),* vegetable leaves *(Amaranthus),* cowpea/beans *(Vigna unguiculata),* pepper *(Capsicum annuum),* millet *(Setaria italic),* carrot *(Daucus carota),* soybean *(Glycine max),* spinach *(Spinacia oleracea), amaranth (Amaranthus cruentus),* water leaf *(Talinum triangulare),* bitter leaf *(Vernonia amygolalina),* etc.

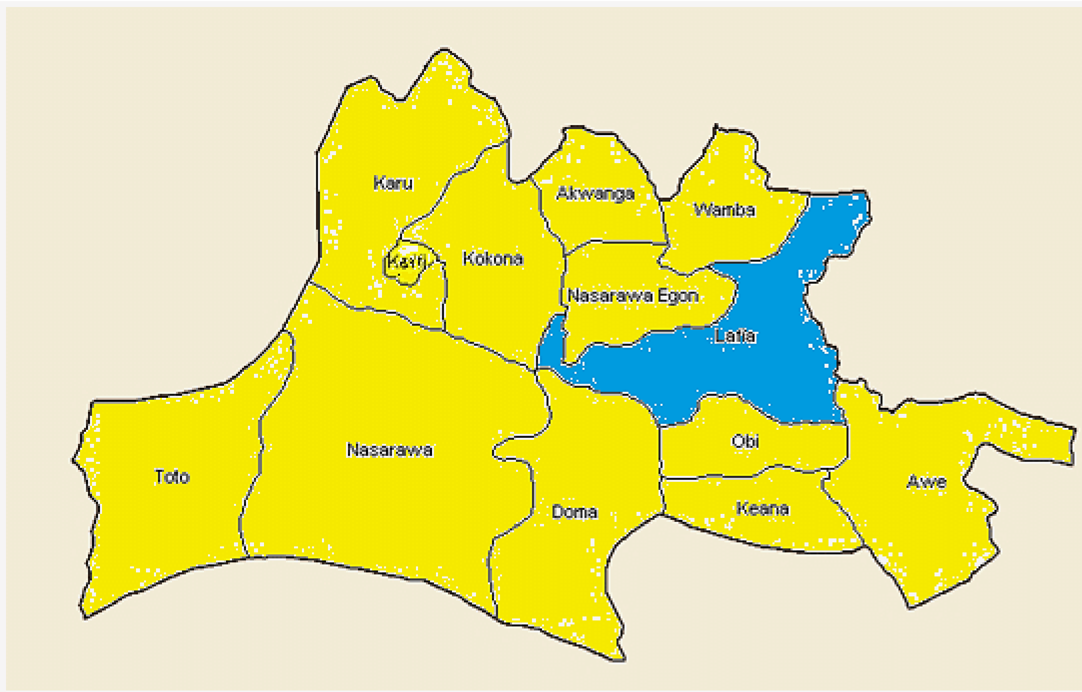

Figure 1: Map of Nasarawa State of Nigeria showing the thirteen (13) local government areas. NB. The shaded LGA is the area of study.

2.2 Data Collection and Measurements/Instrumentations

The thermal analysis of solar energy requires the knowledge of direct and diffuse components of solar radiation in order to estimate the total solar radiation quantity in a locality. The data for the development of an empirical model for estimating the solar radiation in Lafia were obtained from the Kwadere Cargo Airport Meteorological Unit located at Lafia North Development Area.

The data collected included mean monthly values of the following:

(i) The solar radiation measured from a Gun-Bellani instrument graduated in milliliters (ml) and converted to watts per square meter (W/m²) using the formula 1 ml = 1.357 + 0.176 mJ/day m² = 15.706 W/m² (Okonkwo and Akubuo, 2001; Yohanna *et al.,* 2015).

(ii) Maximum and minimum temperatures measured from a thermometer in degrees Celsius or centigrade (°C).

(iii) Relative humidity obtained using the maximum and minimum temperature from the humidity slide rule UK BA in percentage.

(iv) Wind speed measured from a digital cup anemometer graduated in knots, km/hr, m/s, miles/hr, and miles/sec. The scale used was in m/sec.

(v) Station surface pressure = 12.90 HPa above mean sea level measured from an aneroid barometer graduated in millibars or pascals.

(vi) Hours of bright sunshine (i.e., sunshine duration) taken from the Cassela card paper graduated in hours or the sunshine Trinidal recorder in hours.

Sunshine is the sum of all the time periods during the day when the direct solar radiation measured equals or exceeds 120 W/m² (Coulson, 1975). This implied that at any point in time that the solar radiation was less than 120 W/m², it was an hour of cloudiness, and when it was equal to or greater than 120 W/m², it was taken as a bright sunshine hour.

2.3 **Determination of Angstrom-Regression Coefficients**

The Angstrom regression constants ‘a’ and ‘b’ of the Angstrom-Page linear equation were determined using the clearness index (H/Ho) on the y-axis and the y-axis and fractional possible sunshine hour (ns/N) on the x-axis to obtain the line of best fit. The intercept of this line in the y-axis is the constant 'a,' while the slope of this line is the constant 'b.'.

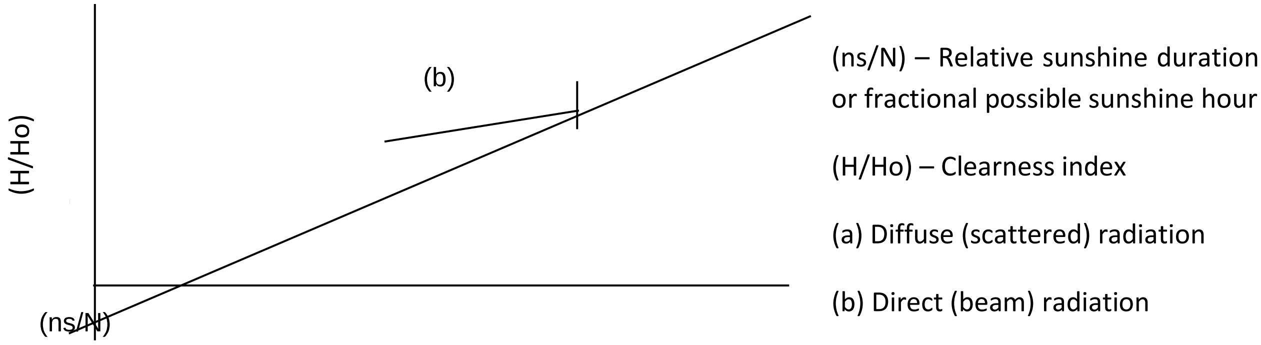

Fig. 2: Plot of (H/Ho) vs (ns/N) showing how to determine regression coefficients 'a' and 'b'

2.4 Determination Of Extra Terrestrial Radiation (Ho), Hour Angle (ω), Declination Angle (б) and Average Monthly Number Of Hours Of Possible Sun Shine (N).

The extra terrestrial radiation, Ho, is the sun energy or radiation expected if the atmosphere were perfectly transparent or it is the solar radiation incident outside the earth's atmosphere. The above parameters were respectively obtained from the following equations.

$Ho = {}^{24}/_{\pi}\ 1sc\ [1 + 0.033 \cos (\frac{360}{365}\ ny)]\ [\cos \varphi \cos \delta \sin \omega + \pi/180\ \omega \sin \varphi \sin \delta]\ kJ/m^2\ day$ ---------------------3

$\cos \omega = -\tan \varphi \tan \delta$ ------4

$\delta = 23.45 \sin [360/365\ (284 + ny)]$ ---------8

$N = 2\omega/15$ ------------------------5

3.0 RESULTS AND DISCUSSION

3.1 Results Presentation

Table 1 is the summary of measured monthly average solar radiation parameters. Table 2 is the summary of calculated solar radiation parameters for the Lafia location. Table 3 is the average determined by the Angstrom-Page equation and correlation coefficient. Table 4 is a summary of other calculated monthly solar radiation parameters using the latitude of the study area and the day number in the year. Figure 2 is a plot of clearness index versus relative sunshine duration to determine the regression coefficients "a" and "b." Figure 3 is a plot of the Angstrom-Page linear equation for the Lafia location based on monthly means. Figure 4 is a plot of measured and calculated global solar radiation against months of the year for the Lafia location.

Table 1: Summary of measured monthly average daily Total solar Radiation parameters

Month /year	**Measured solar radiation H(W/m^2)**	**Wind speed V (m/s)**	**Air Temperature T_{max}(^{0}c)**	**T_{min} (^{0}c)**	**Relative Humidity R.H (%)**	**Sunshine duration ns (hr)**
Jan 2025	331	26	28.3	10.0	20	9.17
Feb	349	20	31.2	14.7	27	8.18
Mar	350	29	31.7	15.5	26	10.18
Apr	289	34	29.9	18.5	37	5.43
May	248	32	27.7	17.7	58	5.70
Jun	278	39	26.2	16.6	65	6.19
Jul	284	28	24.0	16.4	75	3.38
Aug	237	27	28.8	16.8	73	4.00
Sep	275	20	24.9	16.9	62	4.50
Oct	262	23	28.5	17.0	53	3.75
Nov	324	28	28.2	17.2	35	4.13
Dec 2025	338	34	28.5	17.0	21	5.95
TOTAL	3565	340	337.9	194.3	552	72.39
AVERAGE	297.08	28.33	28.16	16.19	46	6.03

Table 2: Summary of calculated monthly average daily total solar radiation parameters

Month /year	Measured solar radiation H(W/m^2)	Calculated extraterrestrial radiation Ho (W/m^2)	Sunshine duration ns (hr)	Hrs. of possible sunshine N (hr)	Clearness index (H/Ho)	Fractional possible sunshine hr (ns/N)
Jan 2025	331	385.45	9.17	11.59	0.86	0.79
Feb	349	408.10	8.18	11.81	0.86	0.69
Mar	350	435.75	10.81	12.08	0.80	0.89
Apr	289	437.17	5.43	12.33	0.66	0.44
May	248	428.68	5.70	12.51	0.58	0.46
Jun	278	425.43	6.19	12.55	0.65	0.49
Jul	284	481.31	3.38	12.42	0.66	0.27
Aug	237	433.53	4.00	12.18	0.55	0.33
Sep	275	420.53	4.50	11.92	0.65	0.38
Oct	262	392.22	3.75	11.66	0.67	0.32
Nov	324	366.81	4.13	11.48	0.88	0.36
Dec 2025	338	363.12	5.95	11.46	0.93	0.52
TOTAL	3565	4928.10	72.39	143.99	8.75	5.94
AVERAGE	297.08	410.68	6.03	12.00	0.73	0.50

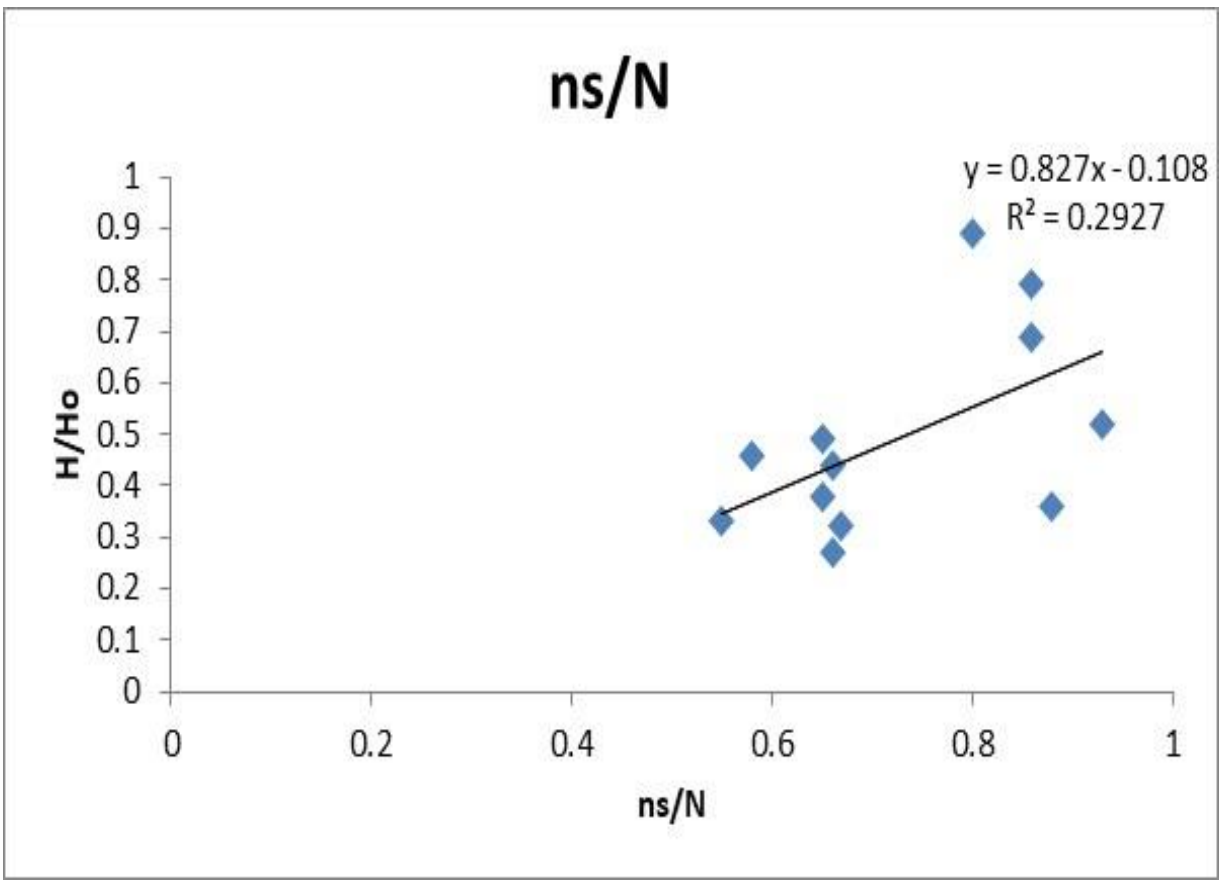

Figure 3: Plot of Angstrom-Page equation for Lafia Location based on monthly means.

Table 3. Summary of the average determined Angstrom- Page equation and correlation coefficient for the study area.

Month/ year	H/Ho	ns/N	Regression constants 'a' 'b'		Equation	Coef of det R^2	Coef of corr. r
Jan–Dec.2025	0.73	0.50	-0.11	0.83	H=Ho[-0.11+0.83(ns/N)]	0.292	0.54

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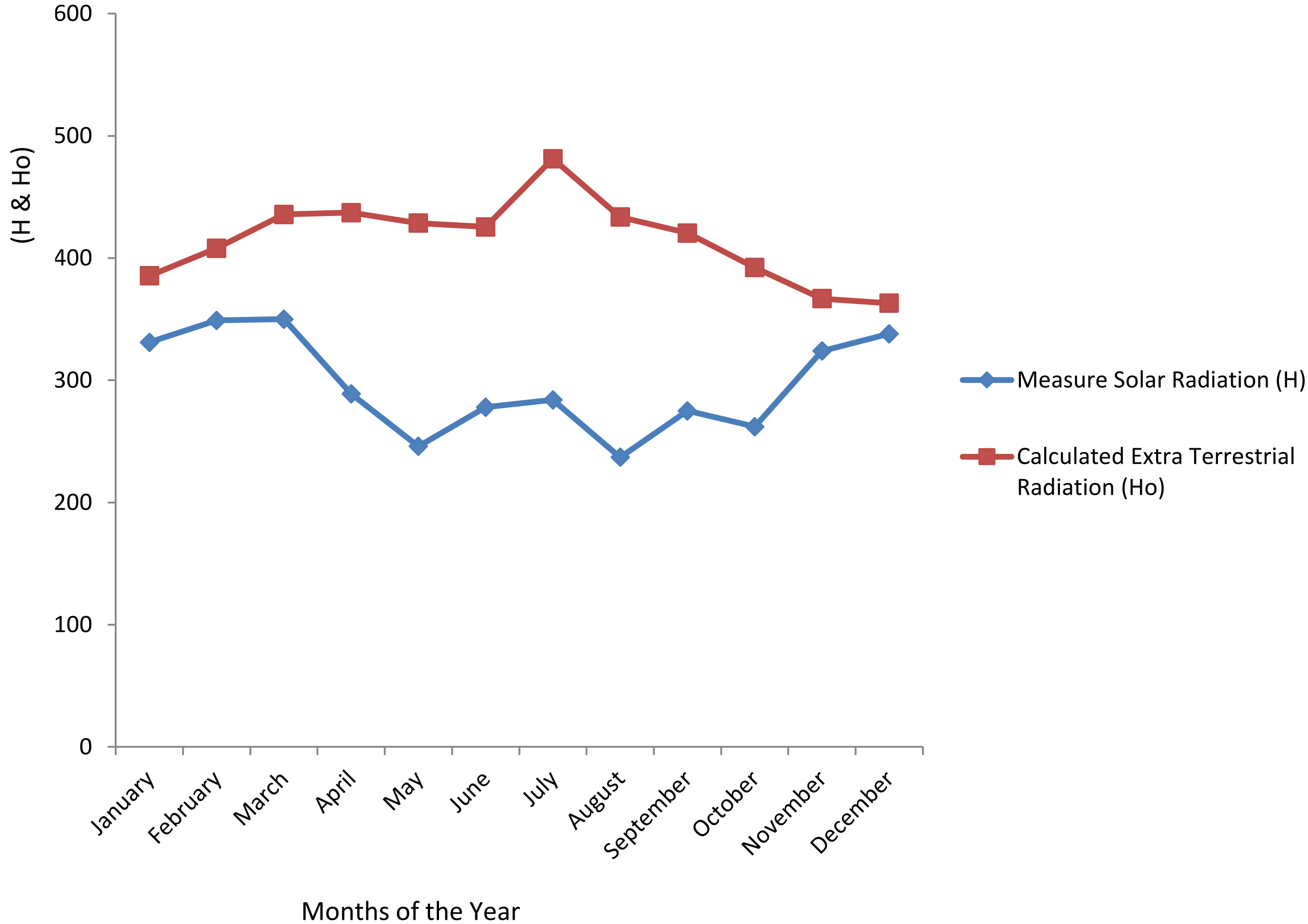

Figure 4: Plots of Measured and Calculated Total solar Radiation versus months of the year for Lafia location

Table 4: Summary of other calculated monthly solar radiation parameters using the latitude (φ) of the study area and day number (ny) of the year

Month/year	**Day number ny**	**Declination angle, б, deg**	**Latitude, φ Deg.**	**Hour angle, ω Deg.**
Jan	31	-17.78	9.5	86.93
Feb	59	-8.67	"	84.54
Mar	90	3.62	"	90.61
Apr	120	14.59	"	92.50
May	151	21.90	"	93.86
Jun	181	23.18	"	94.11
Jul	212	18.17	"	93.15
Aug	243	8.10	"	91.37
Sep	273	-3.82	"	89.36
Oct	304	-15.06	"	87.42
Nov	334	-21.97	"	86.13
Dec	365	-23.09	"	85.91
Total	-	-	"	1075.86
Average	-	-	"	89.66

3.2 Discussion of Results

Table 1 is the summary of the measured average solar radiation parameters. The average solar radiation, wind speed, maximum and minimum temperatures, relative humidity, and duration of bright sunlight were recorded as 297.08 W/m², 28.33 m/s, 28.16°C, 16.19°C, 46%, and 6.03 hours, respectively, and this data will be permanently logged into a computer that can read and record solar radiation hourly. It can be seen that the highest measured solar radiation (350 W/m²) and the highest ambient temperature (31.70°C) were recorded in March 2013. This implied that solar radiation increases as temperature increases (Sanusi and Abisoye, 2011), corresponding to the highest measured solar radiation of 350 W/m² in March. This trend is expected because the amount of solar radiation on a flat surface depends on the weather, latitude of the location, and surface orientation (Yohanna, 2010), and Lafia's location (lat 9.50N) is within the equatorial belt. However, the solar radiation measurement of 237 W/m² in August 2025 may have been affected by dusty cloud cover and interruptions from passing clouds during that time, as solar energy is only available when the sun is shining (Yohanna, 2010; Yohanna et al., 2011). Also, under heavy cloud conditions, no direct radiation reaches the horizontal surface (Stine and Harrigan, 1985). The hours of bright sunshine are the hours during which the sun's disk is visible, and this depends on the length of the solar day (Anderson, 1983). The mean sun's rays so that it will be permanently or otherwise logged into a computer that can read and record the solar radiation hourly. The shine hours (ns) recorded were 6.03 hrs. Table 1 also shows the monthly distribution of sunshine hours (10.81 hrs) corresponding to the highest measured solar radiation of 350 W/m² in the month of March, 2025. This agreed with the work of Zarzalejo (2006) and Zarzalejo *et al. (2009),* which states that the solar radiation increases with the duration of sunshine. Generally, the Lafia location has a very low humidity level as measured in this study, with an average relative humidity of 46%. The average wind speed for the period of the study was 28.33 m/s (Table 1). This wind speed can support any meaningful wind project in the location since the average speed of the wind is more than 10 m/s (Yohanna, 2010).

Table 2 showed the calculated average extra-terrestrial solar radiation (Ho), hours of possible sunshine (N), clearness index (H/H_0), and fractional sunshine duration (ns/N) to be 410.68 W/m², 12.00 hrs, 0.73, and 0.50, respectively. Table 4 is the summary of the calculated average clearness index and fractional sun's rays so that it will be permanently or otherwise logged into a computer that can read and record the solar radiation hourly and shine hours, while Fig. 3 is a plot of the Angstrom-Page equation for the Lafia location based on monthly means.

Table 3 is the summary of the average determined Angstrom-Page equation and correlating coefficient for the study period. The determined Angstrom-Page linear equation for predicting the monthly average daily total solar radiation for Lafia is H = Ho [-0.11 + 0.83 (ns/N)]. The constant 'a,' which is the fraction of the extraterrestrial global radiation component of the location that is diffuse, is -0.11. This value is within the accepted range (Stine and Harrigan, 1985). The constant 'b,' which is the fraction of the extraterrestrial total radiation component of the location that is direct, is 0.83. The value is also within the acceptable range, as it is highest during clear day conditions but lowest during cloudy conditions. The coefficient of correlation of 0.54 for the prediction equation showed that 54% of the variation in the measured solar parameters was explained by the developed model, leaving 46% to be explained by other factors (Yohanna, 2010), such as light intensity, temperature variations, humidity, etc., which may change with time and location. Fig. 4 is a plot of measured and calculated solar radiation against months of the year for the Lafia location.

Table 4 is a summary of other calculated monthly solar radiation parameters using the latitude of the study area and the day number of each month of the year. The negative declination angles showed that the sun was in the southern hemispheres or latitudes, while the positive declination angles showed that the sun was in the northern latitudes, as stated in Anderson (1983), Hungerfold *et al. (1989),* and Lawrence (2006). Table 4 shows that all the positive declination angles have higher hour angle values than the negative declination angles. This phenomenon occurs because during May, June, July, and August, the sun is vertically overhead at the Tropic of Cancer, which is farther from the equator and the study area, while in January, February, November, and December, the sun is vertically overhead at the Tropic of Capricorn, making it far from both the study area and the equator.

4.0 CONCLUSION AND RECOMMENDATIONS.

There is a scarcity of hourly data in Nigeria, so it is necessary to resort to computer modeling to evaluate hourly inputs of diffuse and direct radiation for the design

global solar radiation in Lafia, which is located at latitude 8.4939°N and longitude 8.5153°E, based on measured data collected from Kwadere Cargo Airport in the Lafia North Development Area using the Angstrom-Page linear equation type. 8.5153oE has been developed from measured data collected from Kwadere Cargo Airport Lafia North Development Area using the Angstrom-Page linear equation type.

It is recommended that:

estimate the efficiency of future installations. However, most places, like Lafia, lack local measurements, so we must use approximate methods to predict solar radiation. A computer model has been developed to estimate the

i. The developed computer model should be used to estimate global solar radiation for now, since no model has been developed for this location.measure the total solar radiation reaching the earth’s surface, along with its two components (direct and diffuse), as daily and monthly values are necessary to evaluate the performance of existing solar devices and

The application of solar energy requires comprehensive knowledge of a site's potential, making it essential to

and optimization of solar devices such as solar collectors, solar heaters, photovoltaic equipment, etc.

ii. The College of Agriculture, Science and Technology, Lafia, should establish a meteorological unit far from obstructions that will block the sun rays so that it will be permanently or otherwise logged into a computer that can read and record the solar radiation hourly as well as other parameters such as maximum and minimum temperatures, wind speed, and relative humidity, thereby reducing the rigour of the work or hardship in taking the hourly readings. This system will help researchers in the field of solar energy in collecting solar radiation data or parameters for determination of an empirical formula/equation for a location, which can be used for the next 5–10 years, since every year has different climatological effects and depletion of the ozone layer also affects solar radiation falling on the earth's horizontal surface.

iii. Further study should be undertaken to obtain direct hourly daily measured or observed solar radiation parameters for at least five (5) years, and the average taken to enable the development of a more accurate or established predictive empirical model for the Lafia location, as the readings obtained from the airport were inconsistent, were mean monthly values, and were not hourly.

iv. The very high average wind speed for the location (28.33 m/s) recommends the use of wind machines, since this speed can support a meaningful wind project in the area since this speed can support a meaningful wind project in the location.

REFERENCES

References (Arranged Alphabetically in APA Order)

Ahmed, F. and I. Ulfat (2005). Estimation of Global solar Radiation. Turk. Journal of Physics. 29:63.

Akpabio, L. E; Udo, S.O., S.E. Etuk (2004). Empirical correlation of Global Solar Radiation with meteorological Data for Onne, Nigeria. Turk. J. Physics. 28: 205–212.

Almorox, J. (2011). Estimating Global solar Radiation from common meteorological data in Aranjeuz, Spain. Turk. J. Physics. 35: 53–64.

Anderson, E.E. (1983). Fundamentals of solar energy conversion. Addison Wesley Publishing Company, London.

Angstrom, A. (1924). Solar and Terrestrial Radiation. Quarterly Journal of the Royal Meteorological Society. 50: 121–125.

Bamiro, O.A. (1983). Empirical relation for the determination of solar radiation in Ibadan. Nigerian Journal of Solar Energy. Vol. 3(1): 85–94.

Bamiro, O.A. and F.J.K. (1985). Optional collection of solar energy in Ibadan. Nigerian Journal of Solar Energy. Vol. 4: 20–22.

Bindi, M. and F. Miglietta (1991). Estimating daily global radiation from air temperature and rainfall measurements. Climate Research Journal. Vol. 1: 117–124. Germany.

Black, J.N., Bonython, C.W. and G.A. Prescott (1954). Solar radiation and the duration of sunshine. Q. J.R. Meteorol. Soc. 231–235.

Coulson, K.L. (1975). Solar and Terrestrial Radiation: Methods and Measurements. Academic Press Inc., New York.

Dandakouba, H., Egbo, G. and A.A. Asere (2006). The effect of Anisotropic multiple scattering of solar radiation on the performance of a solar water heater. Proceedings of the International Conference of Solar Energy Society of Nigeria. Vol. 1: 244–249.

Desouza, J.L., K.M. Nicaciob and M.R.L. Mouraa (2005). Global solar radiation measurement on Maceio, Brazil. Renewable Energy. Vol. 30: 1203–1220.

Egbo, G., Sambo, A.S. and A.S. Asere (2003). Solar steam generation using parabolic collectors. A Review: Nigerian Journal of Renewable Energy. Vol. 2(1 & 2): 136–144.

Gairaa, K. and S. Benkaicale (2011). Analysis of solar radiation measurement in Ghardaia Area, South Algeria. Energy Procedia. Vol. 6: 122–129.

Gairaa, K. and Y. Bakelli (2013). A comparative study of some regression models to estimate the Global solar Radiation in a Horizontal surface from sunshine duration and meteorological parameters for Ghardaia Site, Algeria. ISRN Renewable Energy Journal. Pp. 1–11.

Habou, D., Sambo, A.S. and A.A. Asere (2005). The effect of Turbidity of Particles on the thermal performance of a solar Heater. Botswana Journal of Technology. Vol. 14(2): 44.

Hungerfold, R.D., Nemani, R.R., Running, S.W. and J.C. Coughlam (1989). A mountain micro climatic simulation model. USDA Forest Service, Intermountain Research Station, Research Paper INT-414.

Iloeje, O.C. (1997). Potentials for Renewable Energy Applications in Nigeria. Energy Commission of Nigeria, Gilsper Co. Ltd., Lagos, Nigeria.

Jiya, J.D. and B. Alfa (1999). Parameterization of Solar Radiation Using Neural Network. Nigerian Journal of Renewable Energy. Vol. 10(1 & 2): 6–10.

Joshi, A.S. (2006). Evaluation of cloudiness/haziness factor and its application for Photovoltaic Thermal (PVT) system for Indian climate condition. IIT Delhi, New Delhi, India.

Joshi, A.S., Dinier, I. and Raddy, B.V. (2009). Thermodynamic Assessment of Photovoltaic systems. Solar Energy. Vol. 83(8): 1139–1149.

Keulen, H.V. and Heemst, V.H.D.J. (1986). Meteorological data. In Keulen, Van H. and Wolf J. (eds), Modelling of Agricultural Production: Weather, Soils and Crops. Simulation Monographs, Pudoc, Wageningen. Pp. 35–42.

Lawrence, D.M. (2006). Solar Radiation at the Earth's Surface. USDA Forest Service, USA/Robert E. Kniger Publishing Company, Florida, U.S.A.

Little, E.L. (2004). Encyclopedia Americana International Edition. Vol. 25. Scholastic Publishing Inc., Connecticut. Pp. 190.

Maduekwe, A.A., Iheonu, E.E. and Akingbade, F.O.A. (1999). Verification of Some simple solar radiation models in the Nigerian Environment. Nigerian Journal of Renewable Energy. Vol. 10(1 & 2): 11–14.

Okonkwo, W.I. and Akubuo, C.O. (2001). Thermal Analysis and Evaluation of Heat requirement of a passive solar energy poultry chick Brooder. Proceedings of International Conference of Nigerian Institution of Agricultural Engineers, Enugu. Vol. 23: 374–385.

Polo, J., Zarzalejo, L.F., Ramirez, I. and Espinar, B. (2006). Iterative Fittering of Ground Data for quatifying statistical models for solar Irradiance Estimation from satellite data. Solar Energy. 80: 240–247.

Rai, G.D. (2004). Solar Energy Utilization. Romesh Chart, Khana Publishers, New Delhi.

Sambo, A.S. (1995). Application of physics of Renewable energy sources and Implementation strategy. Symposium on the Role of Physics in the Development of Local Technology, State House, Kaduna. April 11th.

Sanusi, Y.K. and Abisoye, S.G. (2011). Estimation of solar radiation at Ibadan, Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS). 2(4): 701–705.

Sharp Cooperation (2005). Sharp Cooperation Solar

Systems: Introduction to PV Power Generation Systems. Japan.

Stine, W.B. and Harrigan, R.W. (1985). Solar Energy Fundamentals and Design with Computer Applications. John Wiley and Sons, New York.

Umar, I.H., Iloeje, O.C. and Bala, E.J. (2000). Review of Renewable energy Technologies in Nigeria. Nigerian Journal of Renewable Energy. Vol. 8(1 & 2): 99–109.

Wikipedia (2015). The Free Encyclopedia. Wikimedia Foundation Inc., U.S.A.

Yohanna, J.K. (2010). An empirical mathematical model for determining the monthly average daily Global solar Radiation for Makurdi, Benue State, Nigeria. Ph.D Thesis, Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi.

Yohanna, J.K. and Umogbai, V.I. (2010). Solar energy Potentials and Utilization in Nigerian Agriculture. Journal of Environmental Issues and Agriculture in Developing Countries. Vol. 2(2 & 3): 10–21.

Yohanna, J.K., Itodo, I.N. and Umogbai, V.I. (2011). A model for determining the solar radiation for Makurdi, Nigeria. Renewable Energy Journal. 36(7): 1989–1992.

Yohanna, J.K., Ode, S., Agontu, J.A. and Golkus, J.I. (2015). A mathematical model for estimating the total solar irradiance for Lafia, Nigeria. NSUK Journal of Science and Technology. Vol. 5(1 & 2): 2015.

Zarzalajo, L.F. (2006). Irradiance Solar Global Horaria a partir de Imagines de Satellite. Coleccion Documentos CIEMAT-Editorial CIEMAT, Madrid, Espana.

Zarzalejo, L.F., Polo, J., Martin, Z., Ramirez, L. and Espinar, B. (2009). A New Statistical Approach for deriving Global solar radiation from satellite Images. Solar Energy. Vol. 83(4): 444–454.