Evaluation of Clearness Index of Four Locations in Northern Nigeria using Real-Time Terrestrial Based Solar Radiation Data

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Abstract

The ever-growing number of distributed photovoltaic (PV) systems expected to be connected to the power grid will continue to make system planning and performance evaluation a challenging task in Nigeria. Solar irradiance data are known to possess the characteristic of high uncertainty, due to the random nature of cloud cover and atmospheric conditions. This paper presents the studies on the characterization of solar irradiance data measured and collected in Bauchi, Jos, Maiduguri and, Yola localities to calculate the clearness index at those locations. The diurnal characterization method developed in MATLAB 2018a was used for the analysis of the resources to achieve the desired results. The clearness index for the study areas are Bauchi 53%, Jos 41%, Maiduguri 61%, and Yola 58%, these values are compared with the values obtained from the NASA website for the locations in reference and the percentage deviations are as follows; 10.17% in Bauchi, 26.79% in Jos, -1.89% in Maiduguri and 0% in Yola. The key results presented here have conclusively revealed that microclimate conditions occurring at different locations, due primarily to global climate change and desert encroachment, are not uniform but should be considered in PV design optimization for maximum energy delivery.

Keywords: *Clearness Index, Diurnal, Natural Environment, Photovoltaic (PV), Solar Radiation*

1. INTRODUCTION

SOLAR energy for electricity generation and other applications is an environmental friendly and, abundant energy re-source, therefore, its harnessing and, use would be a sustainable and without any impacts on degradation to the natural environment (Sanusi and Ojo, 2015; Chung Sing et al. 2017). The harvest of solar technologies needs information about the meteorology and solar irradiance. The later at the earth's surface is critical for the development and use of solar energy to generate electricity. It is required for designing converters for the solar photovoltaic cells dependent equipment.

The world solar radiation changes and climatic effects are most of the environmental problems bedeviling human survival. The changes in climatic variables like pressure, temperature, humidity, wind, precipitation can rapidly occur. Droughts and floods are serious climate phenomenon that percentage-wise can change more adversely than the mean climate, (Ndilemeni et al. 2013). These events are among the world's expensive natural disasters that affect a very large number of people each year (Sanusi & Ojo, 2015), it is therefore, essential to be mindful to their occurrences, understanding and, may be predict their possible variations through the studies of solar radiation data. It is important in the study of climatic changes and global warming because it is an indication of human activities on the environment. Also, it can be used in optimal design and to predict the system performance of solar system devices.

Renewable energy sources; including solar power can provide enormous electrical power supply to the grid; however, they are also highly variable sources of energy. Changes in weather conditions can cause rapid changes in power output, thus creating a challenge for utility companies to effectively use these renewable energy resources. The immediate challenge foreseen is in the area of large scale feed-in of renewable energy mix into existing utility supply structures (Aiyelabegan, 2014; Heinemann et al. 2017; Saad et al. 2014). To resolve this problem and harness the maximum output energy from the sun, there is a need to quantify the amount of energy that can be harvested in an area to ensure the cost-effective application of PV in suburban and rural areas to generate electricity. Hence, the evaluation and assessment of available solar energy resources using meteorological data obtained in a location for the effective deployment of solar photovoltaic (PV) became necessary.

This paper aims to assess and characterize solar irradiation measured at 5-minute interval for one-year duration. The solar radiation data were collected from meteorological stations at Bauchi (Lat. N10°16'48.1", Long. E 9°47'23"Alt. 627m), Jos (Lat. N9° 55'42.6", Long. E 8° 53'33"Alt. 1200m, Maiduguri (Lat. N11° 48' 35.6", Long. E13° 12' 34.9"Alt. 355m) and Yola (Lat. N 9° 17'33.88", Long. E12° 23'26.69"Alt. 260) installed by the Centre for Atmospheric Research (CAR) Ayingba, Kogi State.

Many authors have worked in this area of interest. Falaye and Rabiu, (2008) presented the clearness index evaluation of Ikeja, Ilorin, Ibadan, Port Harcourt and, Benin, using Gun-Bellani distillate. The calculations of clearness index for Sokoto was presented by Ndilemeni et al. (2013) using solar resource data estimated from sunshine hour data collected from NIMET data base. Serim et al. (2013) studied the satellite-derived cloud mask product and to determine sunshine & clearness index time series for Turkey using data from nine (9) stations. Darlington et al. (2014) studied the clearness index for Nsukka using four years (2008-2011) high resolution radiation data obtained from the Centre for Basic Space Science at the University of Nigeria, Nsukka. They found an average of 34% as clearness index. Sanusi and Ojo (2015) conducted a similar studies of the clearness index in southwestern Nigeria using data bank of NASA, particularly, global solar radiation, minimum and maximum temperature.

Chun et al. (2017) studied the clearness index profile for Kenya in East Africa and Johannesburg in South Africa, their study was based on the relationships of clearness index array around the study area using four years forecasted data and obtained a threshold of 35% for Kenya and 88.7% for Johannesburg. Yusuf, (2017) presented the clearness index of Iseyin calculated using Global solar radiation data measured by Gun-Bellani distillate during 2000 – 2007 obtained from NIMET database from their Oshodi center and reported an average of 66%. Yeboua **et al. (2019) conducted a predictive study by classification of hourly clearness index of solar radiation in the District of Yamoussoukro, Cote** d'Ivoire. They used a combination of data ranking in ascending categories and double splitting methods. **The estimation of global solar radiation, sunshine hour distribution and, clearness index in Enugu, Nigeria was studied by (**Adeniji et al. 2019). The value of the clearness index was estimated to range from 0.43 to 0.61 showing Enugu as a partly clear sky city. Olanrewaju, (2020) reported the clearness index of 39% for Ile-Ife, Nigeria.

This paper presents the clearness indices for Bauchi, Jos, Maiduguri, and Yola based on the diurnal characterization method for the computation. In addition, we have applied the diurnal characterization method proposed by (Taehong et al. 2015; Kang and Tam, 2013) to the data generated from ground stations taking into consideration remote microclimate effects specific to the locations. We used this method because it only takes spatial and temporal data which includes all the weather variability that is of interest to bring out the desire clearness index of the atmosphere at that microclimate.

Furthermore, this work is anchored on the use of real-time data generated from the individual weather stations to implement the key objective of the paper. To the best of our knowledge, no literature review, on the Nigerian milieu, has utilized the terrestrial-based technique developed in this work. Indeed, the existing literature used satellite historical data either from the NASA website or aerodrome sites from the NIMET database that did not meet both spatial and temporal resolutions required by the proposed method.

1. METHODOLOGY

2.1 MATERIALS

The materials used to successfully actualize the objectives of this paper are as presented herein. This will then lead to the use of suitable methods and methodologies available for the realization of the overall objective to get to the results of the paper. They are presented in the following order in the actualization of the work. The ground data was measured and obtained from the four meteorological stations installed at the study localities depicted in Plate. I (a, b, c & d) and the parameters measured by the stations are presented in Table 1. The key data measuring equipment installed at the stations are; Kipp & Zonen Pyranometer, Wind Monitor (05103-L) (Medugu & Ogbaka, 2017), Data Logger (CR 1000), etc. are all found at Campbellsci, (2021). Figure1 depicts the functional block diagram of the meteorological station setup.

Table 1: Meteorological Data Description

S/No.	Parameter	Unity
1.	Solar Irradiance	W/m^2
2.	Ambient Temperature	(^oC)
3.	Air Temperature	(^oC)
4.	Relative Humidity	%
5.	Wind Speed	m/s
6.	Wind Direction	Degrees
7.	Barometric Pressure	Bars
8.	Rain Rate	Mm
9.	Soil Temperature	(^oC)


(a) Bauchi (b) Jos


(c) Maiduguri (d) Yola

***Plate 1**: Meteorological Stations at The Four Locations*

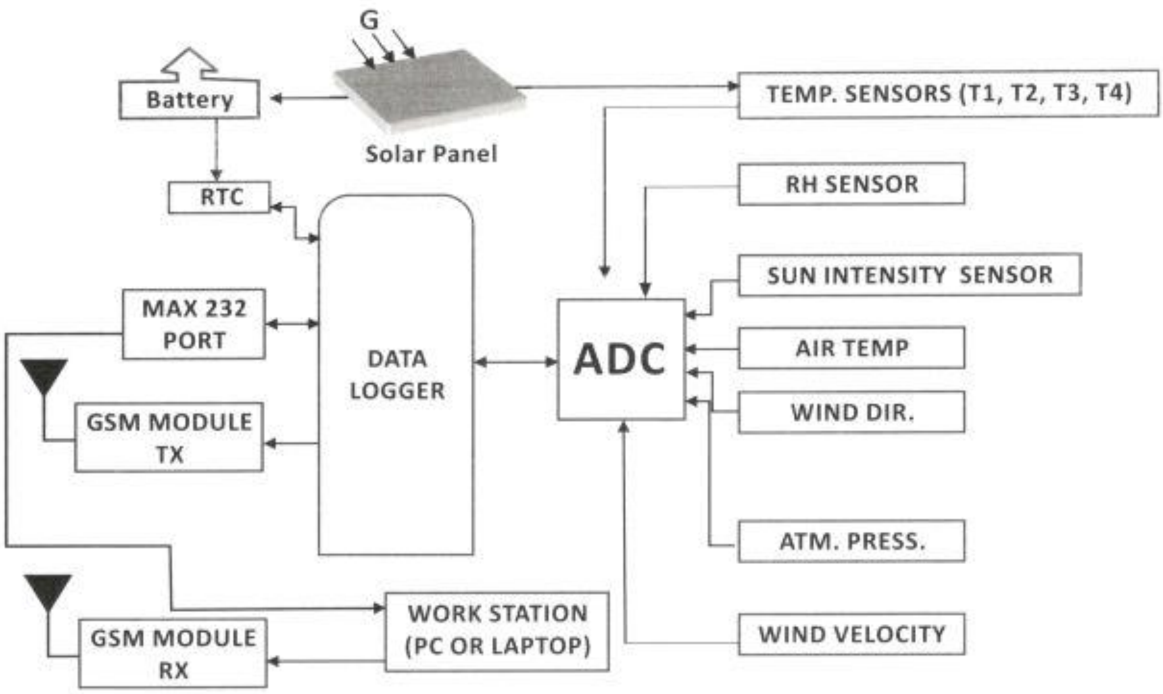

Figure 1: Functional Block Diagram of the Meteorological Stations

2.2` Methods

2.2.1 Model Equations

The abundance of photon energy and other meteorological parameters are important to solar engineers to give precise estimates of the available energy resource. In determining the performance of a system utilizing solar energy, an important parameter to consider is the extraterrestrial radiation (Ho) reaching the surface of the Earth's atmosphere from the sun, which is found to be mostly disappearing in the atmosphere due to absorption, reflection, and scattering. The magnitude of sun intensity that invariably gets to the Earth's surface is known as the global solar radiation H. The ratio of these two radiations (H/Ho) is known as the clearness index (K_T) of the atmosphere. This relation is given by *Eq. (1)*.

$$K_T = \frac{H}{H_O} \text{ ----------------- } (1)$$

Where:
H is the monthly mean daily photon energy on a horizontal plane at the Earth's surface. This is the value that can be found from meteorological station data. H_o is the monthly mean daily value of extra-terrestrial photon energy incident on the plane of the array. Clearness index values evaluated in this way are valid in the range $0.3 \leqslant K_T \leqslant 0.8$ between $v = \pm 55°$ for a tracking system. It can be used to find the ratio of diffused irradiation to total irradiation for a horizontal surface (ITACA, 2018). Table 2 presents the clearness index for the study areas adopted from (David *et al.* 2018)

Table 2: NASA Computed Clearness Index (M)

Location	Clearness Index, (K_T)
Bauchi	0.59
Maiduguri	0.60
Jos	0.56
Yola	0.58

The evaluation of the photon energy incident on a surface perpendicular to the Sun's rays outside and within the Earth's atmosphere on any day of the year can be achieved by using the relationship in Eq. (2).

$$I_o = I_{sc}\left[1 - 0.034\cos(2\pi\frac{n}{265.26})\right] \text{-------------------} (2)$$

Where:
I_0 is the extraterrestrial photon energy (W/m^2), I_{sc} is the solar constant (1367 W/m^2), n is the day of the year such that for January the 1st, n = 1.

The angle of declination (δ) which has a unit of (radians) measured on any day on the surface of the earth is given by Eq. (3): (Akif *et al.* 2015; ITACA, 2018). It is the same for the whole globe on any given day

$$\delta \cong 23.45\sin\left(2\pi\left(\frac{284+n}{36.25}\right)\right) \text{---------------------------} (3)$$

n is defined as in Eq. (2) above (Alkasim *et al.* 2017; Mahachi, 2016).

For many locations in the world, the mean daily photon energy on a plane of the array can be observed. The mean average precision towards data science indication of how much energy is incident on a solar panel tilted at an angle from the horizontal, can always be done. To find the mean irradiation on a tilted surface at the same location, the measured data is split into its beam and diffused parts. These are further found for the chosen panel angle and a reflected component is added. Because the beam irradiation is directional and the diffused radiation is not, the adjustment for these two values is not the same. Hence, the three components are added together to give the total irradiation on the tilted panel given by Eq. (4).

$$I(\beta) = I_{Bh}cos\theta_i + I_D R_D + I_{Th} R_A \text{----------------------} (4)$$

$I(\beta)$ is the terrestrial insolation intensity on a plane tilted at β degrees to the horizontal surface (W/m^2); I_{Bh} is the terrestrial beam insolation intensity on a horizontal plane(W/m^2); θ_i is the angle of incidence of the radiation on the tilted plane; I_D is diffused irradiation component on a horizontal plane (W/m^2); R_D = a conversion factor to adjust I_D to a value for a tilted plane; I_{Th} is the total terrestrial insolation intensity on a horizontal plane (W/m^2); R_A is a conversion factor used to find the reflected (or albedo) component for a tilted plane. Note that the following happens if $\theta_i > 90°$; (Louazenem *et al.* 2015)

i. The tilted plane will be shading itself. ii. θ_i changes throughout the day as do R_D and R_A.
From the foregoing therefore, I (β) can then be used to find the total irradiation incident on a tilted plane

$$H(\beta) = \int_{sunrise}^{sunset} I(\beta)dt \text{-------------------------------} (5)$$

We can use Eq. (5) for monthly average values or values for single days (ITACA, 2018).
The numerical model of the solar irradiance is then given by Eq. (6) (Kalogirou, 2014).

$$I_{ETI} = I_o E_o cos\theta_z = (1{,}366.1)\left(1 + 0.033\cos\left(\frac{2\pi d_n}{365}\right)\right) cos\theta_z \text{----------------} (6)$$

d_n is the number of the day in the year and θ_z is the zenith angle, which is calculated as a function of local time and location.

The simple sky model that is generally used in solar energy simulations that is characterized by the parameters of the peak solar irradiance (S_{max}), the sunrise time (t_{rise}), and the sunset time (t_{set}) as given by Eq. (7) (Taehong *et al.* 2015).

$$I_{simple-sky} = \begin{cases} 0, \ t \leq t_{rise} \\ S_{max} \sin\left(\frac{\pi(t-t_{rise})}{t_{set}-t_{rise}}\right), \ t_{rise} < t < t_{set} \\ 0, \ t \geq t_{set} \end{cases} \quad (7)$$

The corresponding solar radiation model for a cloudy sky on the simple sky model that is used for simulations is presented by Eq. (8) (Taehong *et al.* 2015).

$$I_{cloudy\ sky} = S_{max} sin\left(\frac{\pi(t-t_{rise})}{t_{set}-t_{rise}}\right)\left(1 - a_1 \times \left|sin\left(b_1 \times \frac{\pi(t-t_{rise})}{t_{set}-t_{rise}}\right)\right|^{C_1}\right.$$

$$\left. -a_2 \times \left|sin\left(b_2 \times \frac{\pi(t-t_{rise})}{t_{set}-t_{rise}}\right)\right|^{C_2}\right), t_{rise} < t < t_{set} \quad (8)$$

The variables in Eq. (8) are defined as; S_{max} is the peak solar irradiance; t_{rise} is the sunrise time; the amount of solar irradiance variations, frequency of weather changes and the rate of weather change are given by a_1 and a_2; b_1 and b_2 & c_1 and c_2 respectively. Their explanations are presented properly by (Edric *et al.*, 2014). Hence, the proposed model includes periods of weather variations characterized by parameters with subscripts 1 and 2, respectively (Taehong *et al.* 2015; Kang and Tam, 2013; Muhammad, 2018).

2.2.2 Data Collection and Processing

Solar irradiance data collected from the meteorological stations at the study locations were for the year 2015. The data were filtered removing the not physically consistent measurements due to monitoring problems or instrument malfunctions using Data filter Program, Origin Carl. The data was extensively investigated on daily basis plotting daily diurnal solar irradiation curves.

The extra-terrestrial irradiance (I_{ETI}) is defined as the product of the solar constant (I_0 = 1366.1), and the eccentricity correction factor (E_0) that is usually represented using a simple correlation as in Eq. (7). Equation (8) does not represent accurately the variation in the solar radiation due to weather changes, an overlap of multiple sinusoidal waves with different magnitudes and frequencies are considered in theory and are applied here to determine the changes (Taehong *et al.* 2015) as presented in Eq. (8) and simulated in MATLAB using codes based on the algorithm proposed by Taehong *et al.* (2015).

The flowchart of the pseudo-codes for the MATLAB program is presented in Figure 2. It presents the computation of the ideal irradiation value $I_{ext} = H_{SS}$ (MWh/m^2/day) which represents the term H_{0h} defined as the monthly average daily value of global or extraterrestrial energy falling on a plane of array, I_{meas} represents $\bar{H}$ (MWh/m^2/day) the monthly average daily irradiation on a horizontal plane at the Earth's surface. This is the value that can be referenced from weather station data. Arising from the foregoing definitions, the clearness index ($\check{K}_T$) is defined for this paper as in Eq. (9).

$$K_T = \left\{\frac{H_{SS}-I_{meas}}{H_{SS}}\right\} \times 100\% \quad (9)$$

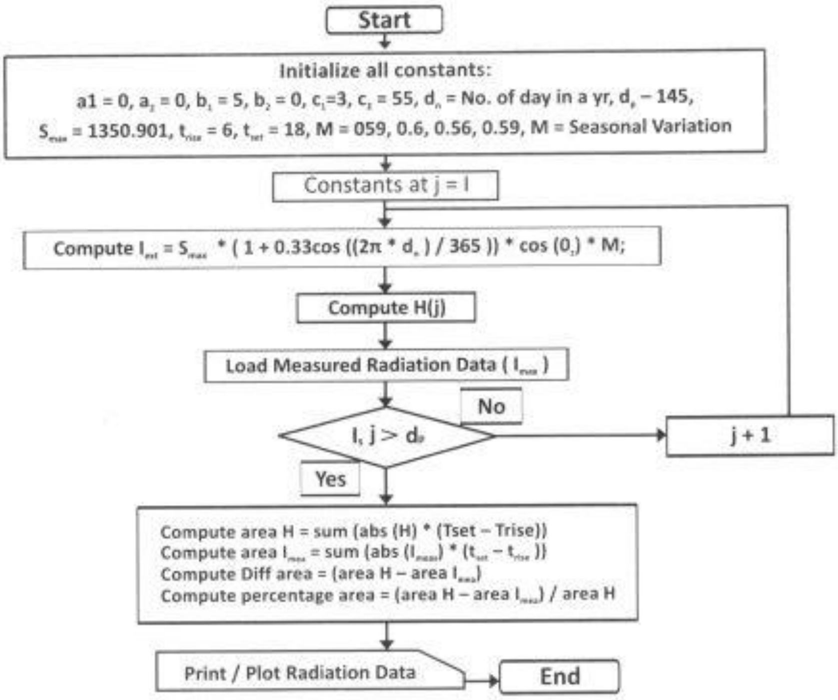

Figure 2: Flow Chart of the Pseudo Codes for the MATLAB Program

1. RESULTS AND DISCUSSION

The clearness index at a point in Bauchi, Jos, Maiduguri, and Yola was evaluated using the method described above and the data collected from ground meteorological stations at those locations. The general pattern of the characteristic shows asymmetric data values of clearness index as depicted in in Figure 3 for Bauchi, Figure 4 for Jos, Figure 5 for Maiduguri and Figure 6 for Yola. This asymmetry indicates that the data may not be normally distributed throughout the year due to obvious factors of climate variability across the study locations. *The* average annual clearness indices for the localities are evaluated to be 53, 41, 61, and 58 % respectively.

Table 3: Ppresents the average monthly clearness indices for the various study localities.

Table 3: Average Monthly Clearness Index for the Study Locations

Months	Bauchi	Jos	Maiduguri	Yola
January	0.62	0.39	0.57	0.53
February	0.60	0.33	0.61	0.72
March	0.58	0.67	0.55	0.55
April	0.43	0.12	0.60	0.55
May	0.49	0.33	0.50	0.52
June	0.49	0.39	0.68	0.56
July	0.46	0.58	0.72	0.72
August	0.48	0.35	0.59	0.58
September	0.54	0.53	0.71	0.57
October	0.53	0.33	0.54	0.54
November	0.57	0.40	0.63	0.63
December	0.57	0.51	0.59	0.53
Average	0.53	0.41	0.61	0.58

However, the results presented when compared to the values obtained from the NASA website returned disparity errors for Bauchi, Jos, and Maiduguri. More precisely, except for Yola where there is an agreement between the NASA clearness index value and computed clearness index value, the percentage deviations for Bauchi, Jos, and Maiduguri from their respective NASA declared values are 10.17%, 26.79%, and -1.89%. The foregoing variations in clearness index could lead to forecast errors of ±5% in the energy harvest from PV systems sited at those locations.

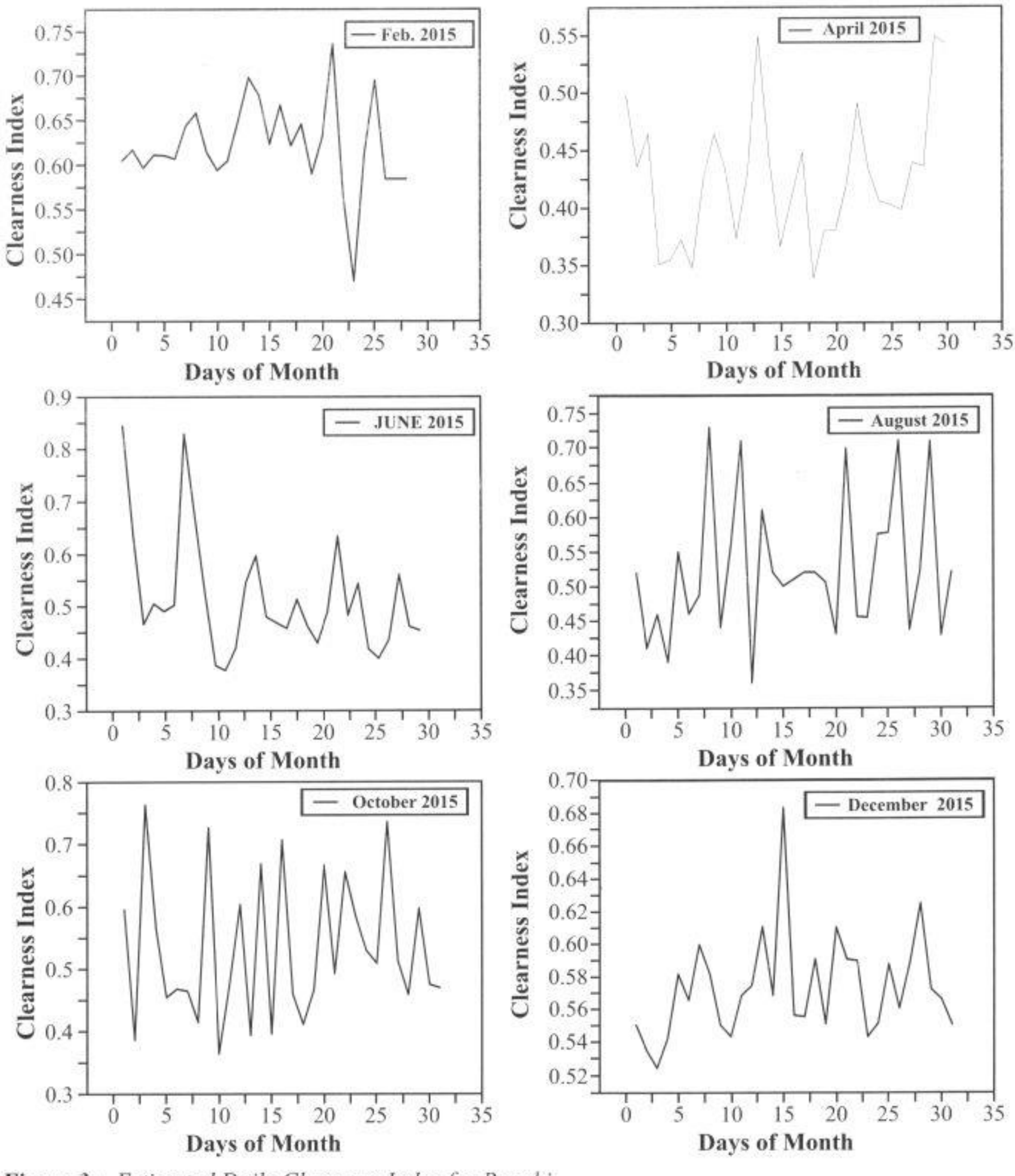

Figure 3: *Estimated Daily Clearness Index for Bauchi*

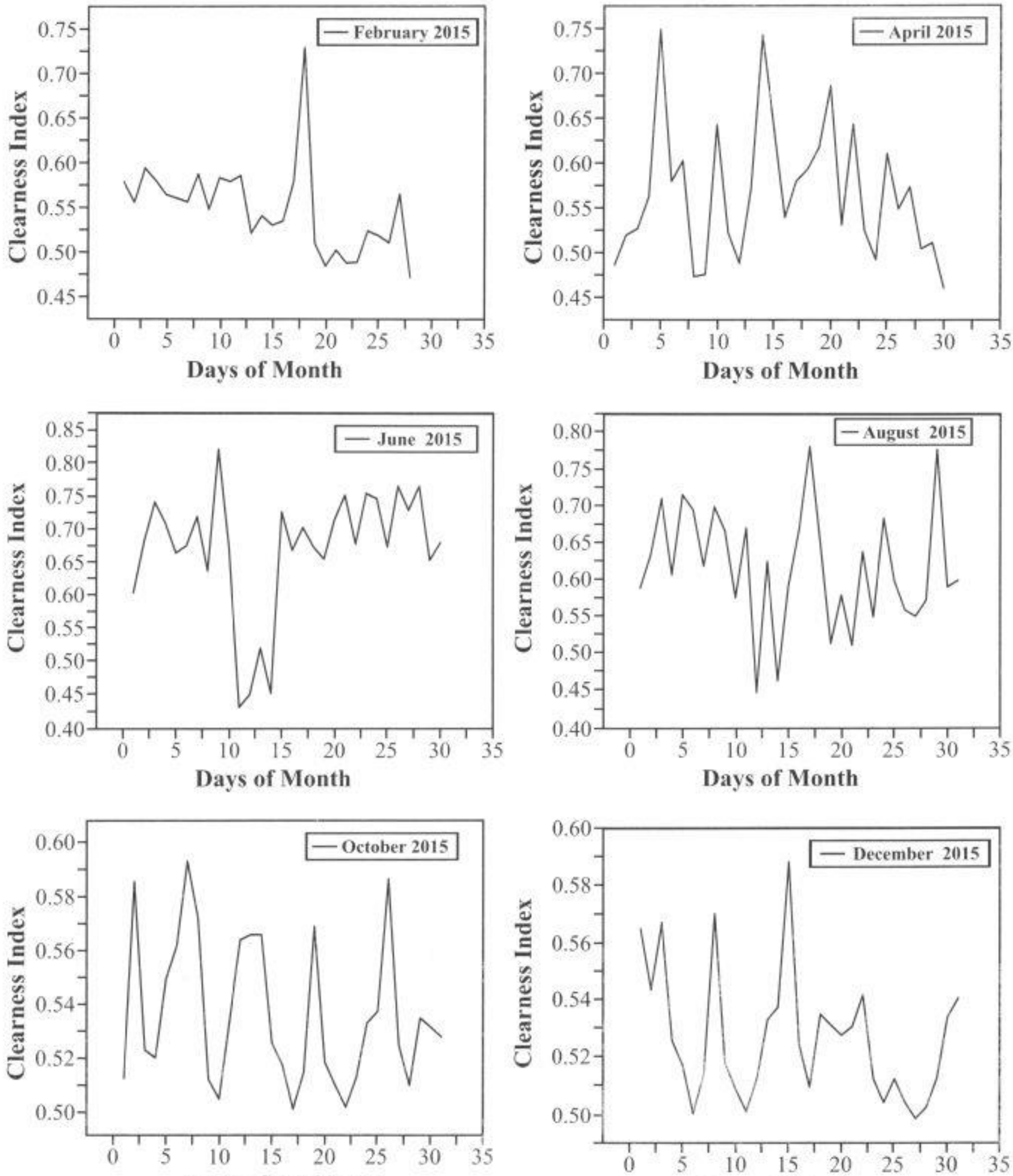

Figure 4: *Estimated Daily Clearness Index for Jos*

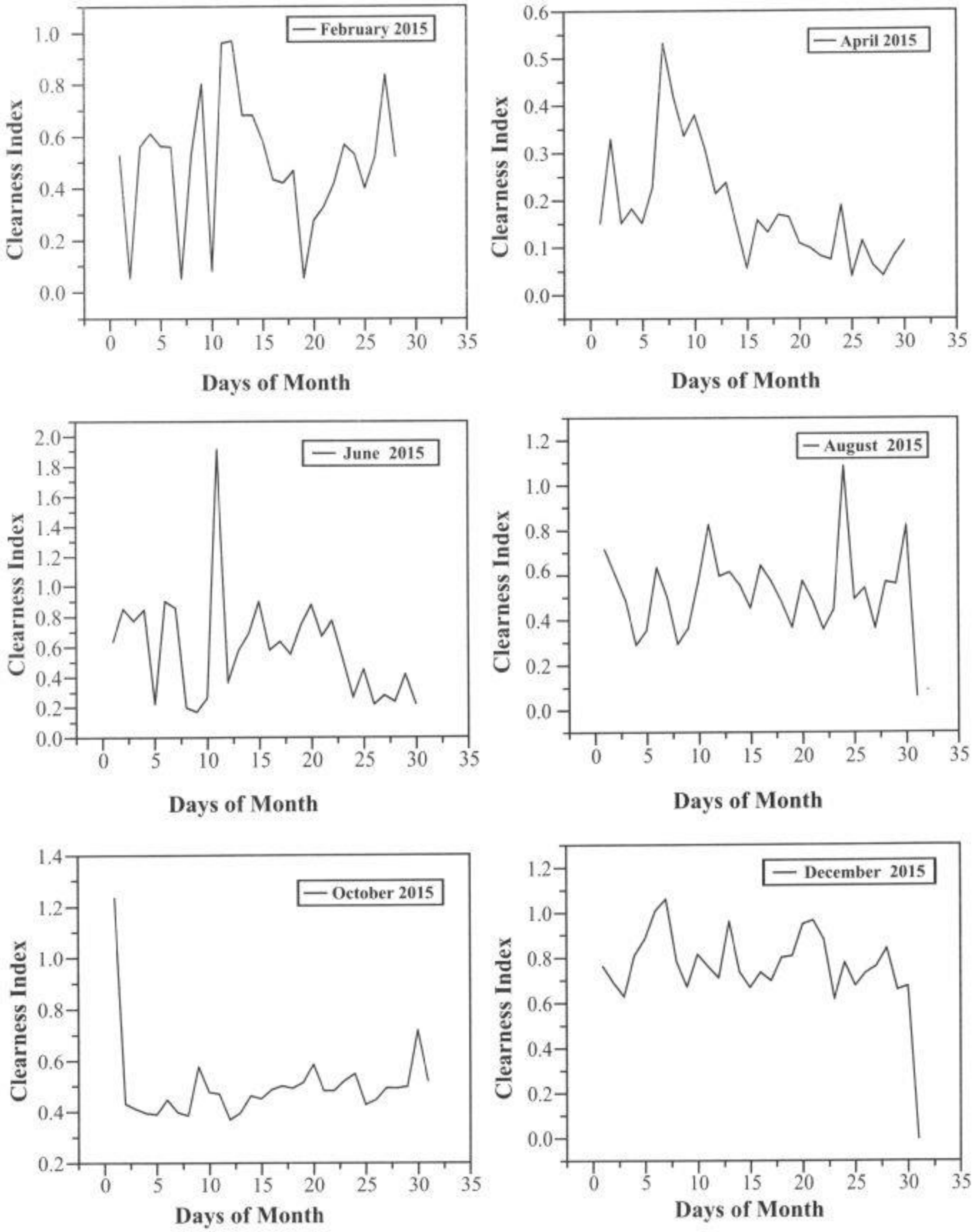

Figure 5: Estimated Daily Clearness Index for Maiduguri

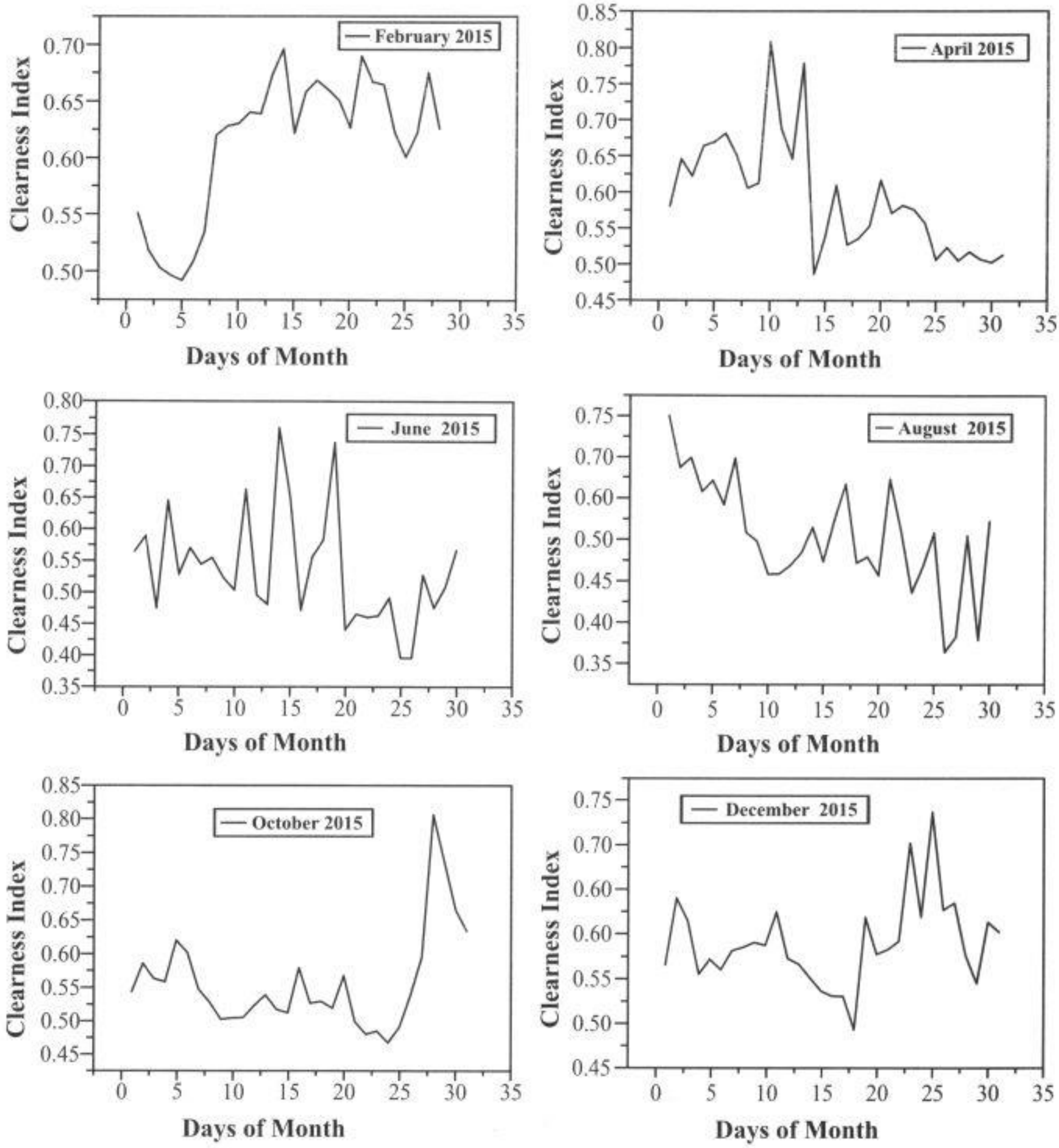

Figure 6: Estimated Daily Clearness Index for Yola

4. CONCLUSION

An assessment of daily solar radiation collected for the year 2015 from the study localities was presented and assessed using diurnal and statistical analysis methods to evaluate clearness indices for the selected study areas. The study provided benchmark values for all the study areas as to how much solar irradiation can be experienced in those individual locations. It was found that the clearness index for the study areas in Bauchi was 53%, Jos 41%, Maiduguri 61% and Yola 58%. Comparative analysis carried out with the values obtained from the NASA website for the study locations returned percentage deviations of 10.17% for Bauchi, 26.79% for Jos, and -1.89% for Maiduguri, and parity for Yola. The key results presented herein have conclusively revealed that microclimate conditions occurring at different locations, due primarily to global climate change and desert encroachment, are not uniform but should be entertained in PV design optimization for maximum energy harvest.

ACKNOWLEDGEMENT:

The authors thank the Centre for Atmospheric Research, National Space Research and Development Agency, Federal Ministry of Science and Technology, Anyigba, Nigeria for allowing us to use the data from their meteorological stations across the country. This paper relied on TRODAN data collected and managed by the Centre for Atmospheric Research and its partners for promoting high standards of atmospheric observatory practice as well as the Federal Government of Nigeria for continuous funding of the Nigerian Space program (www.carnasrda.com).

REFERENCES

Aiyelabegan, A. T. (2014). Latitudinal Dependence of Some Meteorological Parameters in Nigeria. *International Journal of Technical Research and Applications, www.ijtra.com.* , *2*(6), 07-10.

Alkasim, A., Dikko, A.B., & Eyube, E.S. (2017). An Empirical Model for the Estimation of Global and Diffuse Solar Radiation over Yola, North-Eastern Nigeria Based on Air Temperature. *IJRDO-Journal of Applied Science, 3*(9), 14 - 24.

Akif Karafil1, H. O., Metin, K. and Huseyin, P. (2015). **Calculation of Optimum Fixed Tilt Angle of PV Panels Depending on Solar Angles and Comparison of the Results with Experimental Study Conducted in Summer in Bilecik, *Turkey*** *Conference Paper* · November 2015. DOI: 10.1109/ELECO.2015.7394517 Pp.970-976

Byung O. K. and Kwa-Sur T. (2013).A new characterization and classification method for daily sky conditions based on ground-based solar irradiance measurement data. *Solar Energy 94*, 102–118. Published by www.elsevier.com/locate/solener. Available at www.sciencedirect.com

Center of Atmospheric Research (CAR). (2021). Accessed at www.carnasrda.comAyingba, Kogi State, Nigeria on 25/07/2021, 12:28pm.

Chun Sing, L., Xuedong, L., Loi Lei, L. and Malcolm, D. M. (2017). Daily clearness index profiles and weather conditions study for photovoltaic systems, *9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017,* Cardiff, UK. Energy Procedia 142, 77–82. www.s.csiceinecnecdeidreircetc.ct.ocm

Danjuma, M., Ladan, M., & Mohammed, U. (2015). Renewable Sources Of Energy For Economic Development In Nigeria. *International Journal of Sustainable Energy and Environmental Research, Vol. 4*(2), pp. 49 - 63. DOI: 10.18488/journal.13/2015.4.2/

Darlington I. E., Howard 0. N., Samuel O. E. (2014). Sky Conditions at Nsukka as Characterized

by Clearness Index and Cloudiness Index. *International Journal of Scientific Research and Innovative Technology, 1(5); December 2014.*

E. O. Falayi and A. B. Rabiu, (2008). Prediction of Clearness Index for Some Nigerian Stations using Temperature Data. ***Journal of Science and Technology, 28(2), August 2008.***

Edric, J., Cyril, V., Michel, F., Marc, M., Marie-Laure, N., & Christophe, P. (2014). Short-term solar irradiance and irradiation forecasts via different time series techniques: A preliminary study. *https://hal-polytechnique.archives-uvertes.fr/hal-01068569*. Paper presented at the 3rd International Symposium on Environment-Friendly *Energies and Applications, EFEA 2014, Nov 2014, Paris, France. 2014., Paris.*

Heinemann, D., Lorenz, E., & Girodo, M. (2017). Solar Irradiance Forecasting for The Management of Solar Energy Systems. *retrieved on 22/10/2017* 6:00 pm at *www.energiemeteorologie.de*.
https://www.campbellsci.com/cmp3-l accessed on 23/07/2021 @11:08pm
https://www.campbellsci.com/cr1000.accessed on 23/07/2021 @11:08pm
ITACA. 2018. The Sun as a source of Energy ITACA. Retrieved 30/10/2018, from *http://itaca.solutions*

Kalogirou S. A. (2014). *Solar Energy Engineering, Processes and Systems*. Second Edition, Elsevier Academic Press, New York. Pp. 49-119.

Kang, B.O.; Tam, K.-S. (2013). A new characterization and classification method for daily sky conditions based on ground-based solar irradiance measurement data. ***Solar Energy*** *2013,* ***94,*** *102–118.*

Louazenem, M. L., Korich, D., & Azoui, B. (2015). Optimization of Global Solar Radiation of Tilt Angle for Solar Panels, Location: Ouargla, Algeria. *Journal of Electrical Engineering. www.jee.ro*.

Mahachi, T. (2016). Energy yield analysis and evaluation of solar irradiance models for a utility-scale solar PV plant in South Africa. (Master of Engineering M. Eng.), *Faculty of Engineering at Stellenbosch University, Stellenbosch. https://scholar.sun.ac.za.*

Medugu, D. W., & Ogbaka, D. T. (2017). Evaluation of Global Solar Radiation for Mubi, Adamawa State, Nigeria. *Journal of Scientific and Engineering Research, 2017,4(8):6-10,4*(8), pp.6 - 8.www.jsaer.com.

Muhammad, I. (2018). Spatial Mapping of Solar Energy Potentials in Kebbi State, Nigeria. *Dutse Journal of Pure and Applied Sciences (DUJOPAS), Vol. 4*(2), 291 - 301.

Ndilemeni, C. C., Momoh, M, & Akande, J. O. (2013). Evaluation of Clearness Index of Sokoto Using Estimated Global Solar Radiation. *IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT), www.Iosrjournals.Org, 5*(3), 51 - 54.

Olanrewaju O. S. (2021). Evaluation of Clearness Index and Cloudiness Index using Measured Global Solar Radiation Data: A Case Study for a Tropical Climatic Region of Nigeria. *Published in Atmosfera, 34 (1), 25-39.*

Saad Saoud, L. , Rahmoune, F., Tourtchine, V., & Baddari, K. (2014). Prediction of the daily global solar Irradiation of the great Maghreb region using the complex-valued neural networks. *Revue des Energies Renouvelables 17*(1), 173 - 185.

Sanusi, Y. K. and Ojo, M. O. (2015).**Evaluation of Clearness Index and Diffuse Ratio of Some Locations In South Western, Nigeria using Solar Radiation Data.** *IOSR Journal of Applied Physics (IOSR-JAP) e-ISSN: 2278-4861. 7(5), 45-51 Ver. II (Sep. - Oct. 2015)*

Serim, S., İsmail, S., Bülent, A., Selahattin, İ., Ceyhan, K. (2013). **A Cloud Mask analysis with Sunshine and Clearness Index:** A **Case Study for Marmara and South-Eastern Anatolia Regions of Turkey. IX.** ***Clean Energy Symposium, UTES'13 25-28*** **December 2013, Konya**

Taehong, S., Sang, Y. Y., & Kyung, C. K. (2015). A Mathematical Model of Hourly Solar Radiation in Varying Weather Conditions for a Dynamic Simulation of the Solar Organic Rankine Cycle, www.mdpi.com/journal/energies. *Energies 2015., 8*, 7058 - 7069. DOI: 10.3390/en8077058

Thessa, B., Thomas, D., Emiel, H., Aniche, P-E., & Bolade, A. S. (2016). *Captive Power in Nigeria A Comprehensive Guide to Project Development*. In I. d. Visser (Ed.), Market Study and Project Scouting Nigeria (pp. 152). Eschborn, November 2016: African EU Renewable Energy Corporation Programme.

Yusuf, A. (2017). Characterization of Sky conditions using Clearness Index and Relative Sunshine duration for Iseyin, Nigeria. *International Journal of Physical Sciences Research 1(1), 53-60, April 2017.* Published by European Centre for Research Training and Development UK (www.eajournals.org)