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AN ASSESSMENT OF DECADAL VARIATION OF SUNSHINE DURATION IN NIGERIA

IGWE O. EWONAA, SUNDAY O. UDOB, OSANG, JONATHAN. EA.

EMAIL: steveewona2007@yahoo.com
A.DEPARTMENT OF PHYSICS, CROSS RIVER UNIVERSITY OF TECHNOLOGY CALABAR, NIGERIA
B.DEPARTMENT OF PHYSICS, UNIVERSITY OF CALABAR ,CALABAR

Abstract

An assessment of sunshine duration in 20 locations in Nigeria between 1978 and 2007 has been undertaken. The data which was provided as monthly mean daily total values was obtained from the Nigeria Meteorological Agency (NIMET), Oshodi. In addition to simple arithmetic analysis, decadal changes in the regression parameters along with trends and their latitude dependence have been studied. The results show that monthly mean daily sunshine duration has increased in the past three decades. The regression parameters which have been reported in the form of tables also show that the constant a which is a reflection of the trend of the parameter lies between -0.00 and 0.004 while b lies between 3.243 and 8.159. Sunshine duration shows marked latitudinal dependence as can be seen in the positive slopes of the graph of b against latitude and the graphs of decadal means of monthly mean daily sunshine duration against latitudes of the stations.

Keywords: Decadal variation, regression parameters, latitude dependence, sunshine duration.

Introduction

In the face of drastic changes in weather and climate, it is important to provide an up to date assessment of the state of key climatic factors that have a direct bearing on the socioeconomic well being of man. One of such strong factors is sunshine duration. Sunshine duration is a strong index in climate considerations. It is well correlated with solar radiation, average temperature, cloudiness, and evaporation especially during the day.

An analysis of measured sunshine duration in 23 selected locations in Nigeria spread across its major latitudes from north to south is presented in the form of decadal means, regression parameters and distribution of monthly mean daily sunshine duration on latitudinal basis. The data correspond to a thirty year period which is between 1978 and 2007. Because of ease of measurement over solar radiation, the practice of estimating solar radiation data from sunshine data dates back to 1924 when Angstrom developed the first empirical relationship between solar radiation and sunshine duration (Angstrom, 1924). Sunshine duration is observed at more stations and sometimes for longer periods than solar radiation (Baker,1984).

Sunshine duration is also important in agricultural productivity and food preservation. It is also important in architectural design and tourism which is the reason why most tourist sites are located within the sunny regions of the world (Thom, 1959, Okpiliya et al, 2006 and Ewona and Udo, 2008).

Solar energy systems sometimes require the time distribution of solar radiation values during the year. Such time values are often estimated from daily sunshine hours in the absence of solar radiation values. (Bendt et al, 1981, Saunier et al 1987, and Zabara and Zenginoglou, 1989, Gopinathan , 1991).

Regression parameters of monthly mean sunshine duration are important indices for studying trends and the distribution of sunshine hours. Regression parameters **a** and **b** sometimes depend on the site which gives significant scatter in the parameters as observed in most works (Bashahu and Nkundabakura, 1994) .

Geography of the area

Lying between latitude 4º-14º North and longitude 2.5º-15º South, Nigeria has virtually its climatic zones in the Northern Hemisphere arranged symmetrically from south to north. The zones are determined mainly by latitude, except where highlands greatly modify the climate. Nigeria experiences an extreme tropical climate. Apart from latitude which is most prominent, several other factors influence the climate of Nigeria, determining its climatic pattern, seasonal variations and day-to-day weather. The most important climate control is related to atmospheric conditions and wind patterns; other major controls include topography, ocean currents, and clouds and airborne materials from the Sahara desert (Newman, et al, 2006).

The Nigerian meteorological environment has a network of over forty - five data collecting stations which measure parameters such as: Minimum and maximum temperature, rainfall, relative humidity at 9.00hrs and 15.00hrs GMT, evaporation, cloud cover, wind speed and direction, and solar radiation. There are more stations in the south perhaps because there is higher population density and the climate seems to be more complex. Figure 1 shows the distribution of stations selected for the study.

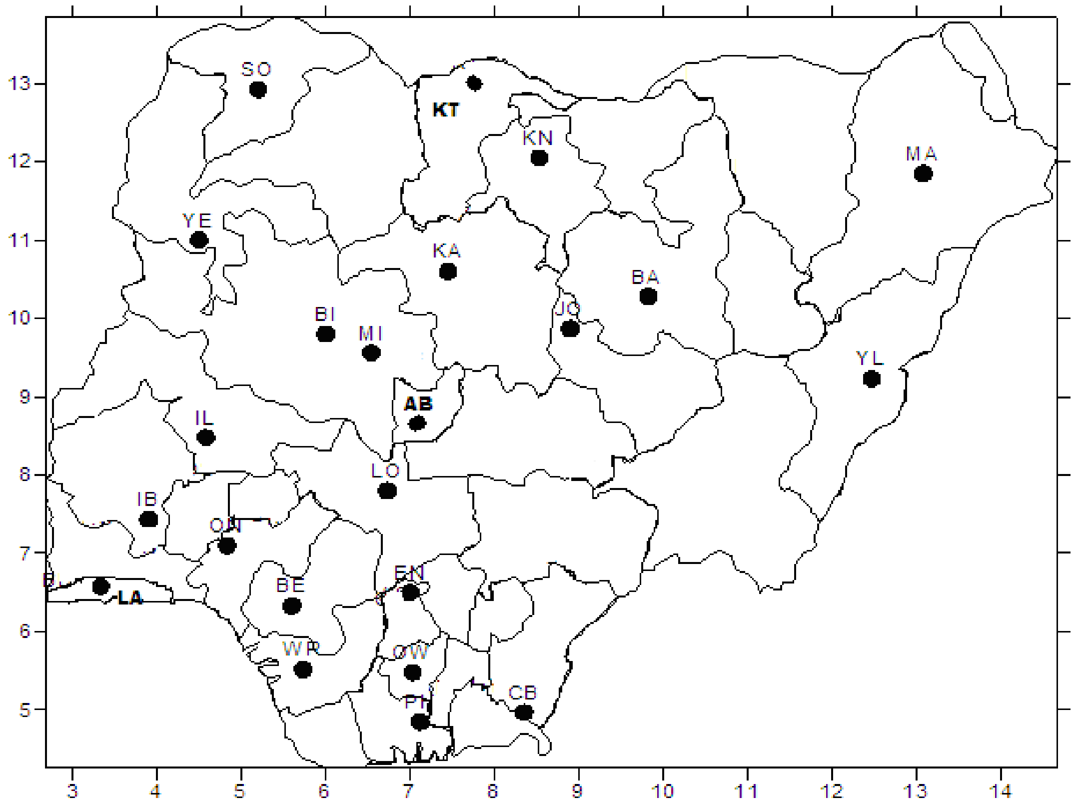


FIG.1: Map of Nigeria showing selected meteorological locations for the study.

Materials and methods

The present study is based on data provided by the Nigeria Meteorological Agency (NIMET), Oshodi. The stations were selected in a way that they reflect on the geographical zones of the country. This can be seen from figure 1.

Data preparation is in terms of detection and replacement of outliers. We define an outlier as a data point which is twice the value of the sum of the two corresponding periods lying before and or after the outlier for a periodic data set. In general, it is replaced by the mean observation of successive corresponding periods before and after and outlier. But if the outlier is in the first or last cycle of a periodic set of data, the replacement is considered in terms of two successive periods for the first cycle or two preceding periods for the last cycle. For a cycle of twelve months, which is the case for almost all meteorological data, x_i is an outlier if

$$x_i \succ (x_{i-12} + x_{i-24})$$

or $x_i \succ (x_{i+12} + x_{i+24})$

or $x_i \succ (x_{i-12} + x_{i+12})$ 1

X_i is therefore replaced by

$$x_{i'} = \frac{x_{i+12} + x_{i-12}}{2} \quad (2)$$

or $= \frac{x_{i+12} + x_{i+24}}{2}$ for an outlier in the first cycle 3

or $= \frac{x_{i-12} + x_{i-24}}{2}$ for an outlier in the last cycle. 4

A regression equation connecting monthly mean daily sunshine duration and time - given in months, was determined for the thirty year period. The equations for each location provided the regression constants for each location. Table 1 shows the distribution of regression constants with latitudes over a thirty year period.

Trend analyses were carried out for all twenty three stations to determine the regression constants **a** and **b**. The general expression for the regression equation for each location is given as

$$y_i = ax_i + b \quad (5)$$

Where y is the value of the predicted sunshine duration, x stands for the months numbered sequentially from 1 being January, 1978 to 361 being December, 2007. The constant **a,** describes the direction of the trend line while **b** is its intercept on the sunshine duration axis.

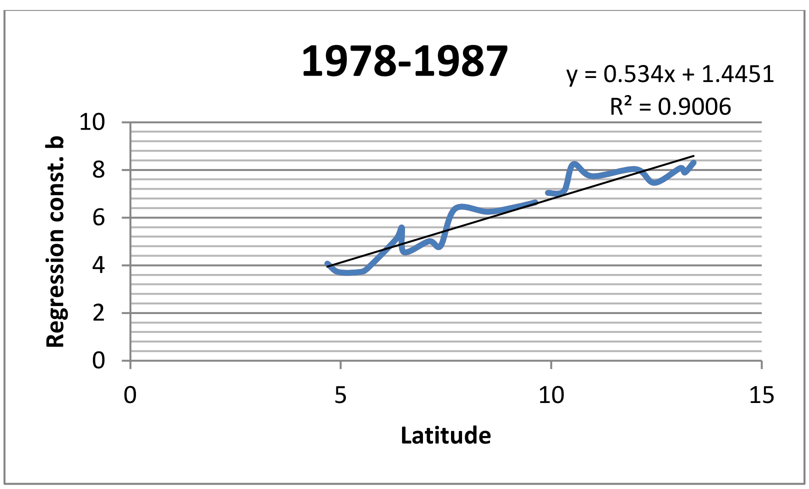
Results

The results are presented in the form of a table of regression constants against locations which have been arrange according to their latitudinal values. Also presented are trend equations indicating the direction of variation of Monthly mean daily sunshine duration in hours. The analyses and the results are also viewed in terms of their decadal responses which are reported in terms of the slope **a,** as shown in table 1. Figure 2a- d shows the variation of the regression constant **b** to latitude.

Table 1: Decadal distribution of regression constants over selected stations in Nigeria: D1=1978-1987; D2=1988-1997; D3=1998-2007.

S/N	Station	Lat.	Regression constant a for different decades			Regression constant b for different decades			1978-2007	
		Lat.	D1	D2	D3	D1	D2	D3	**a**	**b**

1	KATSINA	13.38	-0.004	0.006	-0.001	8.305	7.662	8.341	0.000	7.97
2	MAIDUGU RI	13.17	0.003	-0.002	-0.001	7.89	8.517	8.218	0.000	8.10
3	SOKOTO	13.07	-0.004	0.007	-0.004	8.080	7.196	8.644	0.001	7.59
4	YOLA	12.45	-0.001	0.003	0.008	7.460	7.392	6.954	0.000	7.33
5	KANO	12.00	-0.006	0.004	0.006	8.031	7.211	7.691	0.001	7.41
6	YELWA	10.97	-0.005	-0.008	0.012	7.735	7.062	8.169	0.000	7.26
7	KADUNA	10.52	-0.009	0.003	-0.010	8.236	7.941	7.424	-0.004	8.16
8	BAUCHI	10.30	-0.004	-0.003	0.009	7.11	6.629	6.926	0.000	7.07
9	JOS	9.92	0.002	-0.001	0.003	7.037	7.235	7.211	0.001	7.07
10	IBI		-0.003	0.002	0.000	7.029	6.739	7.267	0.001	6.69
11	MINNA	9.62	-0.001	0.002	0.005	6.637	6.429	6.531	0.001	6.37
12	ABUJA	9.18	0.003	0.016		6.452	6.799		0.004	6.36
13	ILORIN	8.50	-0.005	0.000	0.000	6.244	6.136	6.399	0.001	5.85
14	LOKOJA	7.72	-0.002	0.007	-0.001	6.380	5.734	6.375	0.000	6.19
15	IBADAN	7.37	0.000	-0.008	-0.006	4.812	5.798	6.078	0.002	4.75
16	ONDO	7.10	-0.005	0.007	0.000	5.010	5.024	4.834	0.000	4.84
17	LAGOS	6.50	0.000	-0.006	0.005	4.550	5.330	4.952	0.002	4.48
18	ENUGU	6.45	0.001	0.004	0.000	5.578	5.182	5.654	0.000	5.40
19	BENIN	6.32	-0.005	0.008	-0.001	5.112	4.093	5.049	0.000	4.65
20	WARRI	5.68	0.000	-0.005	-0.002	3.947	4.264	4.553	0.001	3.89
21	OWERRI	5.50	0.009	0.004	0.003	3.731	4.230	5.190	0.004	3.87
22	CALABAR	4.95	-0.008	0.005	0.001	3.713	3.539	3.705	0.002	3.24
23	PORT HARCOUR T	4.68	-0.007	0.003	-0.001	4.069	4.176	3.730	0.000	3.93



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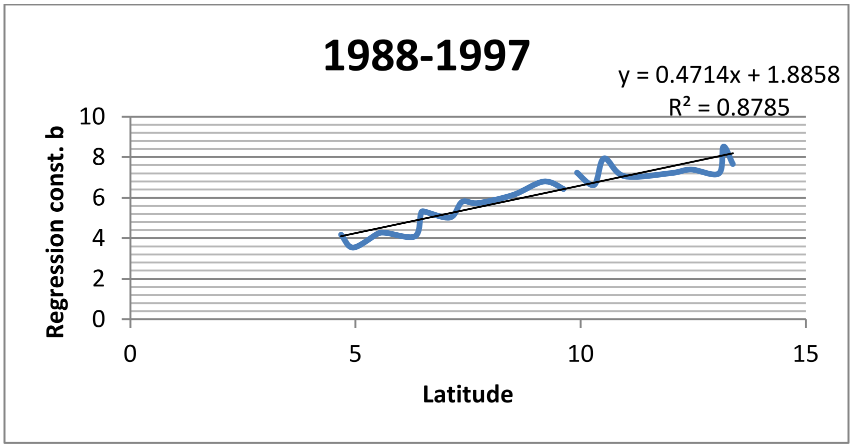

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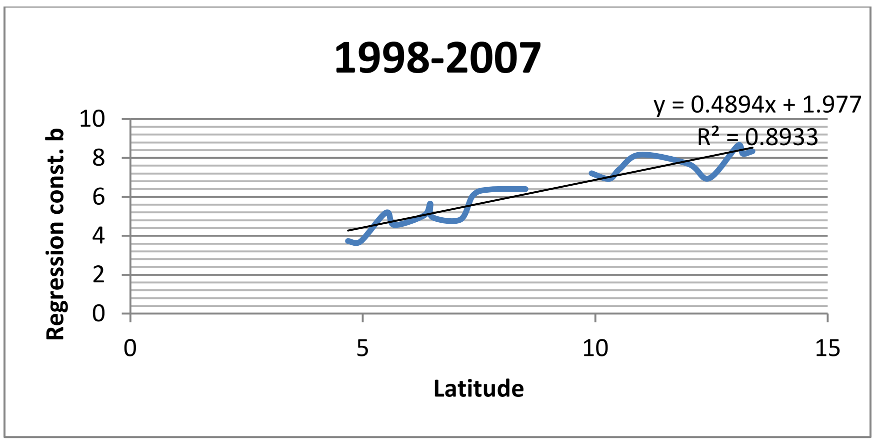

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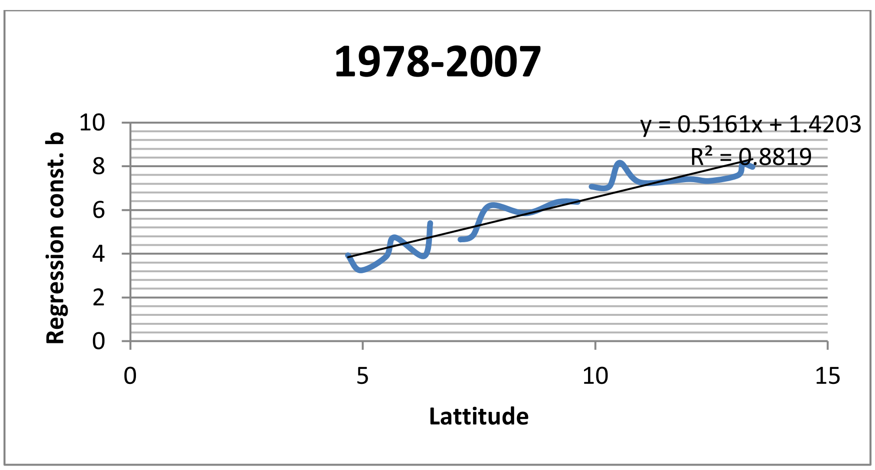

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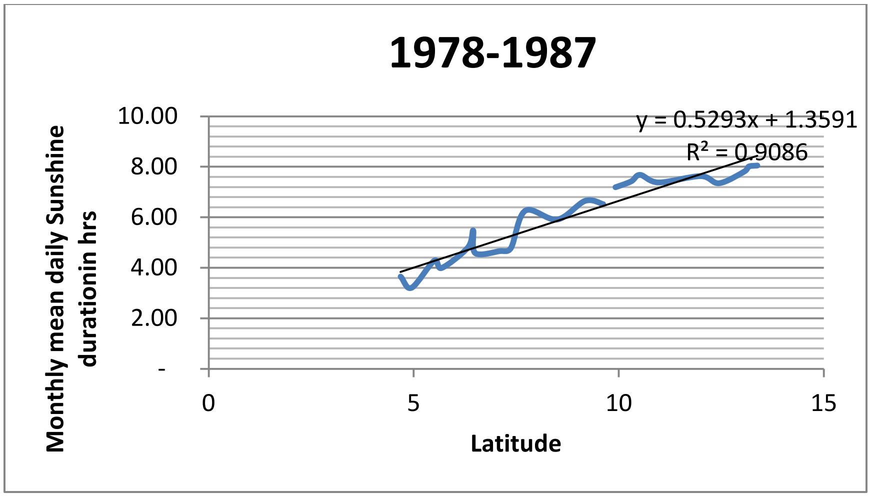
Fig. 2 a-d: Latitudinal dependence of sunshine duration as shown by regression constant b against latitude.

The following graphs in Figure 3 depict the behavior of Monthly mean sunshine duration to change in latitude. It can be used to predict the values of monthly mean daily sunshine duration for any latitude lying between these range of latitudes in each of the three decades under consideration especially for locations sharing similar climatic conditions. There is a strong correlation between regression constant b and average monthly mean daily sunshine duration within the period. This is reflected in the value of the Pearson correlation coefficient of 0.898 obtained.



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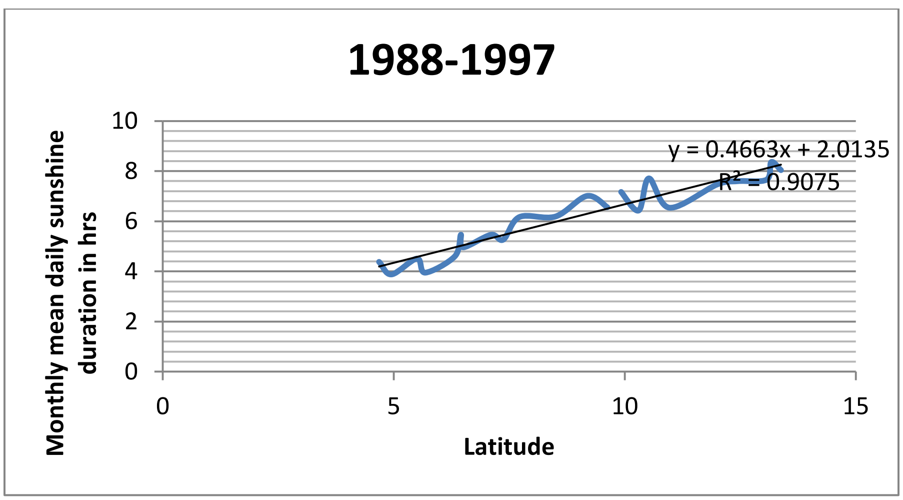

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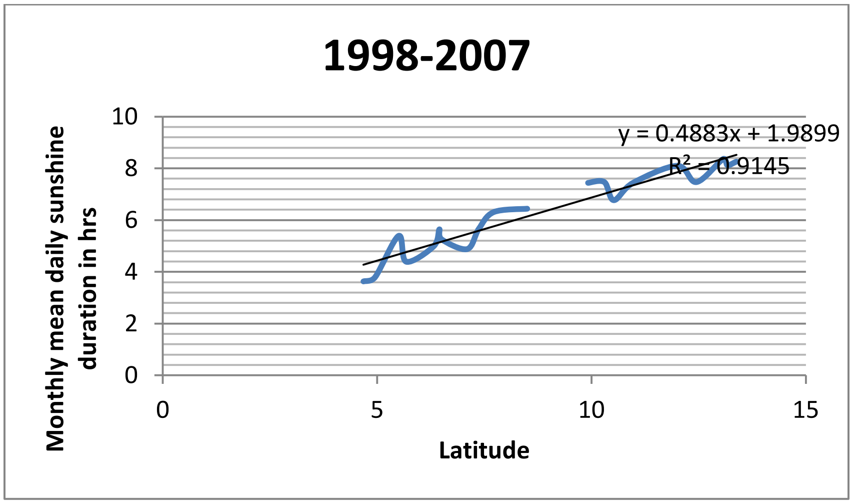

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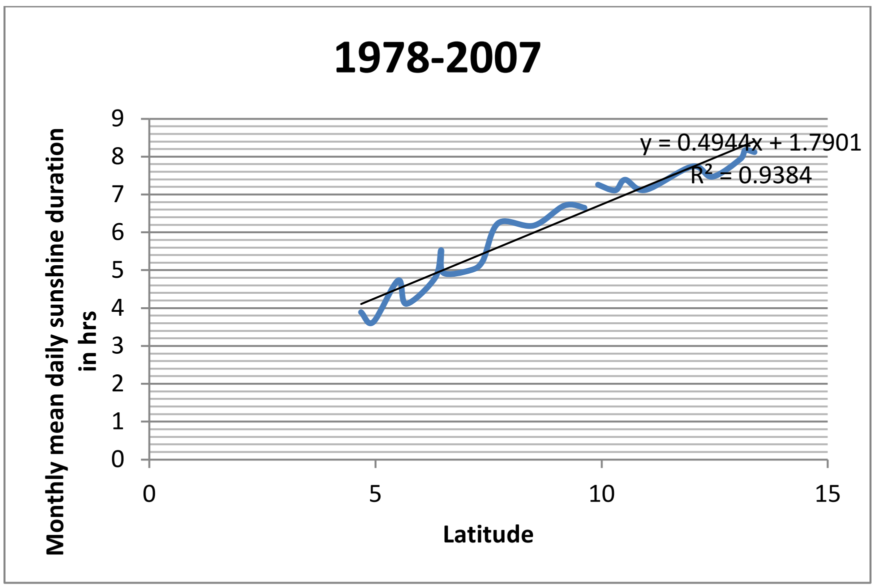

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Fig. 3: a-d Graph of decadal averages of sunshine duration against latitudes

A look at table 2 shows that:

1. In general and for the entire period i.e. 1978-2007, regression constant **a** is generally positive or zero except Kaduna which is -0.004. This is indicative of an upward trend in twelve stations while ten stations showed no significant trend. There is a general scatter in the distribution of the constant. The scatter in the values of the regression constant **a** has been attributed to the reaction of the constant to the mean values of the percent possible sunshine, S/S_o. In general **a** is related linearly while **b** is related hyperbolically (Gopinathan,1991 and Rieveld, 1978)

2. From table 1 and figure 2, we observe a clear dependence of parameter **b** on latitude. It is lowest on the south with lower latitudes and takes its highest values in the north characterized by higher latitudes. The predictive regression equations are also shown against each plot to ease estimate by calculation.
3. The strong positive slope of the graph of **b** against latitude indicates that there is a strong dependence of **b** on latitude. A Pearson correlation coefficient of about 0.948 was obtained between the two parameters.
4. In general, the high values of **b** show that Nigeria has high potentials for solar energy utilization across the country especially in the northern part. The values of **b** in any station will particularly help solar equipment designers when planning solar energy installation and characterization. From the relationships so established, it is also possible to estimate these values where sunshine measurements are not carried out which is the case with many rural areas.

The implication of these results is that most cities in Nigeria constitute good locations for solar energy harvesting. This will increase the potentials for harnessing solar energy in Nigeria and place it as one the foremost natural raw materials for electrical energy sourcing.

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