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Comparison between first and Second Order Angstrom Type Models for Solar Radiation of Yola, Nigeria

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Abstract

In this paper a set of constants for Angstrom-type correlation of the first and second order has been determined to estimate average monthly global solar radiation using sunshine hours for Yola. Solar radiation in Yola has been estimated by correlating meteorological parameters. This was achieved by applying the first and second order regression and multiple correlation analysis method. Comparison of the measured and predicted values of solar radiation based on the relative humidity, average temperature and wind speed second order equations show a close agreement, it shows that the second order model is better than the first order model, and suggest the best equations to be used in estimating solar radiation in Yola and its similar climatic condition.

Keywords: Solar radiation, temperature, relative humidity, wind speed

1.0 Introduction

The area of the study, Yola is the capital city and administrative center of Adamawa State, Nigeria. Situated along latitude $9^0$12'N and longitude12^{0}29'E on the Benue River is geographically favorably located to tap unlimited solar energy, the most dependable renewable energy source. The climate of this zone is characterized by two distinct and well-defined seasons, namely wet (or rainy) and dry seasons (also known as Harmattan). These seasons correspond to northern hemisphere summer and winter respectively. The annual onset and cessation of the dry and wet sessions follow the quasi-periodic north-south to-and fro movement of the inter-tropical convergence zone (ITCZ). The ITCZ demarcates the dry dust north-east trade wind from the moisture south-west trade wind. The dry season in the Sahel zone of Nigeria sets in about October each year and persists till next year. This is the period when the ITCZ is displaced to the south and the prevailing north-east trade wind transports large quantities of dust and smoke from biomass burning into the atmosphere over the entire region [1].

The design of a solar energy conversion system requires precise knowledge regarding the availability of global solar radiation and its components at the location of interest. Since the solar radiation reaching the earth's surface depends upon climatic conditions of the place, a study of solar radiation under local climatic conditions is essential. An accurate knowledge of solar radiation distribution at a particular geographical location is of vital importance for the development of many solar energy devices and for estimates of their performances.

While it is appreciated that a number of commonly measurable atmospheric and meteorological parameters such as turbidity, relative humidity, degree of cloudiness, temperature and sunshine duration taken severally or jointly, affect the magnitude of the global irradiation incident on a given location, the preponderance of data now clearly, perhaps incontestably, point to the fact that the greatest influence is exerted by sunshine hours [2]

The fist empirical correlation using the idea of employing sunshine hours for the estimation global solar radiation was proposed by Angstrom [3]. The Angstrom correlation was modified by Prescott [4], and Page [5]. Many researchers have employed hours of bright sunshine to estimate solar radiation [6 – 8, 2].

A maximum-likelihood quadratic fit was later employed by [9] to estimate monthly global solar radiation. This quadratic fit method has been utilized by a number of authors like [10] and [11] to estimate global solar radiation. The maximum-likelihood quadratic fit method according to [11] appears to widen the range of applicability of the one-parameter correlation to cover climatologically different zones of the same geographical region. All these empirical models have been shown severally to work reasonably well on a daily or longer-term basis.

A lot of researchers have developed a correlation involving global solar radiation and sunshine hours for different locations in Nigeria. For example [11] developed a linear and quadratic equations for Benin, Ibadan and [12] also developed a linear relation for Northern Nigeria. [13] developed the linear relation for Bauchi, [14] developed a quadratic relation for Calabar, Port Harcourt and Enugu, [2] developed a model for Ilorin, [15]and [16] developed models

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for Onne. It is observed that the regression coefficients are not universal but depends on climatic conditions and the nature of pollutants of the environments. The aim of this paper is to develop a model using global solar radiation and sunshine hours for Yola.

2.0 Materials and Methods

In this paper different empirical models were investigated to determine the best that can be used to estimate the global solar radiation from the meteorological parameters obtained from the Centre for Atmospheric Research (CAR), sited at Kogi State University Campus, Anyigba, Nigeria. The station has in its data base, for the meteorological parameters of solar radiation, relative humidity, temperature and wind speed, daily data spanning for three years (2010, 2011 and2012) for Yola. The data which was recorded at five minutes intervals was averaged monthly for sunshine hours between 07.00 and 18.00 hours local time, using Microsoft Excel spread sheet.
The centre is under the supervision of National Space Research and Development Agency (NASRDA). The data were collected from a network of automatic weather stations across Nigeria, under a project with an acronym TRODAN which means Tropospheric Data Acquisition Network, initiated to provide data to the atmospheric and earth science communities in Nigeria as well as world at large. SPSS version 16.0 for windows was used for the regression analysis.

Table 1: Average Weather Data for The Three Years (2010 – 2012)

Months	Solar Radiation (W/m^2)	Relative Humidity (%)	Temperature (^0C)	Wind Speed (m/s)
January	391.2218	15.0494	30.5438	0.9222
February	398.1696	18.2388	33.4187	1.0347
March	453.1800	10.0711	35.6040	1.0954
April	468.2693	35.9493	37.6452	1.5481
May	394.3752	52.1325	34.5526	1.3452
June	351.1577	62.8889	31.1713	1.2960
July	315.6666	71.8646	29.6610	1.1621
August	322.3049	72.0824	28.7524	1.0341
September	385.6373	67.5169	29.6316	0.9012
October	428.2899	58.4905	30.3251	0.9595
November	435.2211	15.8162	32.5450	1.0696
December	413.7788	15.7150	31.3445	0.8745

The proposed regression models are:

Linear Regression model:

The linear form of the Angstrom – Prescott one parameter formula is written as:

$$y = a + bx_i, for i = 1 \; to \; 3. \qquad (1)$$

Quadratic Regression model

The maximum likelihood Angstrom – Prescott quadraticequation to be considered as the form:

$$y = a + bx_i + cx_i^2, for i = 1 \; to \; 3. \qquad (2)$$

Where a and b are constants which will be determined. y is the same as solar radiation (S) and it is the dependent variable. x is the independent variable which can be replaced by any of the meteorological parameters such as average temperature (T), wind speed (WS) and relative humidity (RH).

3.0 Results and Discussion

Therelevant meteorological and solar radiation data used in this paper are presented inTable 1.

The Linear Model:

The regression model obtained for Yola using equation (1) is

$S = 449.6063 – 1.28678\,RH \quad R^2 = 0.454 \quad (3)$

$S = -24.0+13.098T \quad R^2 = 0.548 \quad (4)$

$S = 358.027+34.807WS \quad R^2 = 0.022 \quad (5)$

Quadratic Model:

The regression model obtained for Yola using Angstrom-Prescott Quadratic equation (2) is

$S = 369.542+4.642RH – 0.072RH^2 \quad R^2 = 0.672 \quad (6)$

$S = -911.754+67.212T – 0.819T^2 \quad R^2 = 0.562 \quad (7)$

$S = 1466 – 1859WS+778.7WS^2 \quad R^2 = 0.304 \quad (8)$

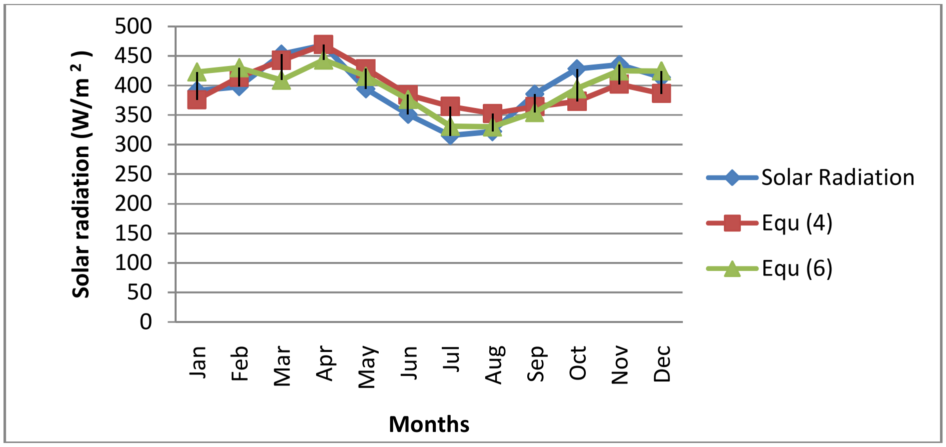

Figure 1: Comparisons between the measured and modeled values of monthly average global solar radiations using (linear and Quadratic models) for Yola.

From the months of January to April the Linear model estimates better than the quadratic model, however from the month of May to December the quadratic models on average gives better estimates of the average monthly global solar radiation for the study area Yola.

4.0 Conclusion

The empirical Angstrom-type linear model and a second degree polynomial model both based on sunshine duration have been studied in this work. The two models were compared with the meteorological data for Yola Adamawa State Nigeria, collected from the Center for Atmospheric Research (CAR) Anyigba, Kogi State Nigeria. From the comparison of R^2 of these models it was observed that the estimated average global solar radiations for Yola were in good agreement with the observed data and the two models were slightly similar. The average monthly global solar radiation and some meteorological parameters of Relative humidity, Temperature and Wind speed have been employed in this study to develop several correlation equations using SSPS computer software program. It was observed that quadratic equation model is better than linear model. This has led to choose quadratic models to be applied for the estimation of average monthly global solar radiation for Yola. The estimated data can further be used in the design and estimation of performance of solar systems in Yola.

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