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COMPARISON BETWEEN FIRST AND SECOND ORDER ANGSTRON TYPE MODELS FOR SUNSHINE HOURS OF KATSINA, 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 monthly average daily global solar radiation using sunshine hours for Katsina (Lat 12° 59′ 52″ N, Long 7° 35′ 5″ E). The predictive efficiencies of the models are compared with the actual efficiency. It is discovered that the second order model is better than the first order because R=0.702 while R=0.345 for the first order. SPSS software is used to determine the regression coefficients.

Keywords: Angstrom, correlation, monthly average Solar Radiation, Sunshine hours, Efficiencies, regression coefficients.

INTRODUCTION

The study area is located within the Sudan Savannah zone in the north-western part of Nigeria. The latitude and longitude of Katsina is 12° 59' 52" N / 7° 35' 57" E.

The climate of Katsina is tropically continental and is dominated by two opposing air masses, viz: Tropical maritime and tropical continental. The tropical maritime is moist and blows from the Atlantic Ocean, it is predominant during rainy season. The tropical continental is dry and blows from the Sahara deserts and is predominant during dry season.

Much of the rain in this state falls between June and September in the north, and April to October in the other parts. Moreover, two extreme temperatures relative to its tropical position; i.e the hot and cold seasons, characterize the state. The highest temperature during the hot season is experience in the month of March/April and there is a prevalence of Harmattan between November and February, characterized by a very cold temperature and dust-laden, which often accompanied by thick fog of alarming intensity.

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 (Udo, 2002).

The first empirical correlation using the idea of employing sunshine hours for the estimation of global solar radiation was proposed byAngstro(1924). The Angstrom correlation was modified by Prescott (1940), and Page (1961). Many researchers have employed hours of bright sunshine to estimate solar radiation Black (1956), Rietveld (1978), Togrul, Togrul and Dugyu (2000), Udo (2002).

A maximum-likelihood quadratic fit was later employed by Ogelman, Ecevit & Tasdemiroglo (1981) to estimate monthly global solar radiation. This quadratic fit method has been utilised by a number of authors like Akinoglu and Ecevit(1993) and Fagbenle (1993) to estimate global solar radiation. The maximum-likelihood quadratic fit method according to Fagbenle 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 Fagbenle (1993) developed a linear and quadratic equations for Benin, Ibadan and Samaru, Sambo (1986) also developed a linear relation for Northern Nigeria.. Burari, Sambo & Mshelia (2001) developed the linear relation for Bauchi, Augustine and Nnabuchi, (2009) developed a quadratic relation for Calabar Port Harcout and Enugu , Udo (2002) developed a model for Ilorin, Akpabio, Udo and Etuk (2005) and Akpabio and Etuk (2003) developed models 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 Katsina. SPSS software is used to determind the regression coefficients.

MATERIALS AND METHODS

The global solar radiation measured on a daily basis using Gunn-Bellani radiation integration, maximum temperature measured using casyy brand of maximum thermometer, relative humidity measured using psychometric number of hours of bright sunshine and cloud cover for Katsina within the period of five years (2005 – 2009) were collected from the meteorological department of the Federal Airport Authority of Nigeria (FAAN) Katsina Airport (Table 1).

Table 1: Data after averaging

Months	Ho(Extraterrestrial Solar Radiation) $MJm^{-2}day^{-1}$	H_m(Measured Solar Radiation) $MJm^{-2}day^{-1}$	S = n/N	$K_T = H_m/H_o$
Jan	30.24	17.38	0.68	0.5747
Feb	33.16	20.82	0.74	0.6279
Mar	36	21.26	0.65	0.5906
Apr	37.65	21.56	0.64	0.5726
May	37.79	19.74	0.64	0.5224
Jun	37.49	19.48	0.69	0.5196
Jul	37.46	16.88	0.63	0.4506
Aug	37.48	15.62	0.57	0.4168
Sep	36.41	18.68	0.63	0.5130
Oct	33.85	19.46	0.74	0.5749
Nov	36.84	18.13	0.71	0.4921
Dec	29.21	14.43	0.83	0.4940

Where n/N= SUNSHINE HOURS is the ratio of actual number of hours of sunshine received at a site to the length of the day (n is the monthly average daily sunshine hours data collected and N is the average maximum daily hours of bright sunshine for the same period). H_m represents the average measured daily global radiation The extraterrestrial solar radiation (H_0)was calculated using the formula given by (Klein, 1977) as

$$H_0 = \frac{24}{\pi} I_0 \left(1 + \frac{0.33 \cos 360n}{365}\right)\left(cos\varphi cos\delta sin\omega_s + \frac{2\pi\omega_s}{360} sin\varphi sin\delta\right) \quad (1)$$

The sunset hour angle ω_s and the solar declination δ are defined by the relations

$$\omega_s = cos^{-1}[cos(-tan\varphi tan\delta)] \quad (2)$$

and

$$\delta = 23.45 sin\left(360 \frac{284 + d}{365}\right) \quad (3)$$

Where d is the day of the year. Usually, the 15th of each month is the day of the month on which the solar declination is calculated.

Clearness index K_T ($=H_m/H_0$) gives the percentage deflection by the sky of the incoming global radiation and therefore indicates both the level of availability of solar radiation and changes in atmospheric conditions in a given locality.

linear Regression model

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

$$\frac{H_m}{H_0} = a_0 + a_1 \frac{n}{N} \text{ or } K_T = a_0 + a_1 S \quad (4)$$

for which Prescott originally proposed a_0 =0.22 and a_1 = 0.54.

Quadratic Regression model

The maximum likelihood quadratic equation to be considered is of the form:

$$K_T = a_0 + a_1 S + a_2 S^2 \quad (5)$$

RESULTS AND DISCUSSIONS

The relevant meteorological and solar radiation data used in this paper are presented in table 1.

The Linear Model

The regression models obtained for Katsina using equation (4) is

$$K_T = 0.320 + 0.308S \qquad R=0.345 \quad (6)$$

The Quadratic Models

The regression models obtained for Katsina using equation (5) is

$$K_T = -2.767 + 9.207S - 6.350S^2 \qquad R=0.703 \quad (7)$$

Table 2: The measured and modeled values of the Katsina global solar radiation.

Months	**Ho(Extraterestrial Solar Radiation) $MJm^{-2}day^{-1}$**	**Hm(Measured Solar Radiation) $MJm^{-2}day^{-1}$**	**S = n/N**	**K_T = H_m/H_o**	**Equ(6) Linear Model**	**Equ(7) Quadratic Model**
Jan	30.24	17.38	0.68	0.5747	0.5294	0.5575
Feb	33.16	20.82	0.74	0.6279	0.5479	0.5689
Mar	36	21.26	0.65	0.5906	0.5202	0.5347
Apr	37.65	21.56	0.64	0.5726	0.5171	0.5245
May	37.79	19.74	0.64	0.5224	0.5171	0.5245
Jun	37.49	19.48	0.69	0.5196	0.5325	0.5626
Jul	37.46	16.88	0.63	0.4506	0.5140	0.5131
Aug	37.48	15.62	0.57	0.4168	0.4956	0.4179
Sep	36.41	18.68	0.63	0.5130	0.5140	0.5131
Oct	33.85	19.46	0.74	0.5749	0.5479	0.5689
Nov	36.84	18.13	0.71	0.4921	0.5387	0.5689
Dec	29.21	14.43	0.83	0.4940	0.5756	0.5003

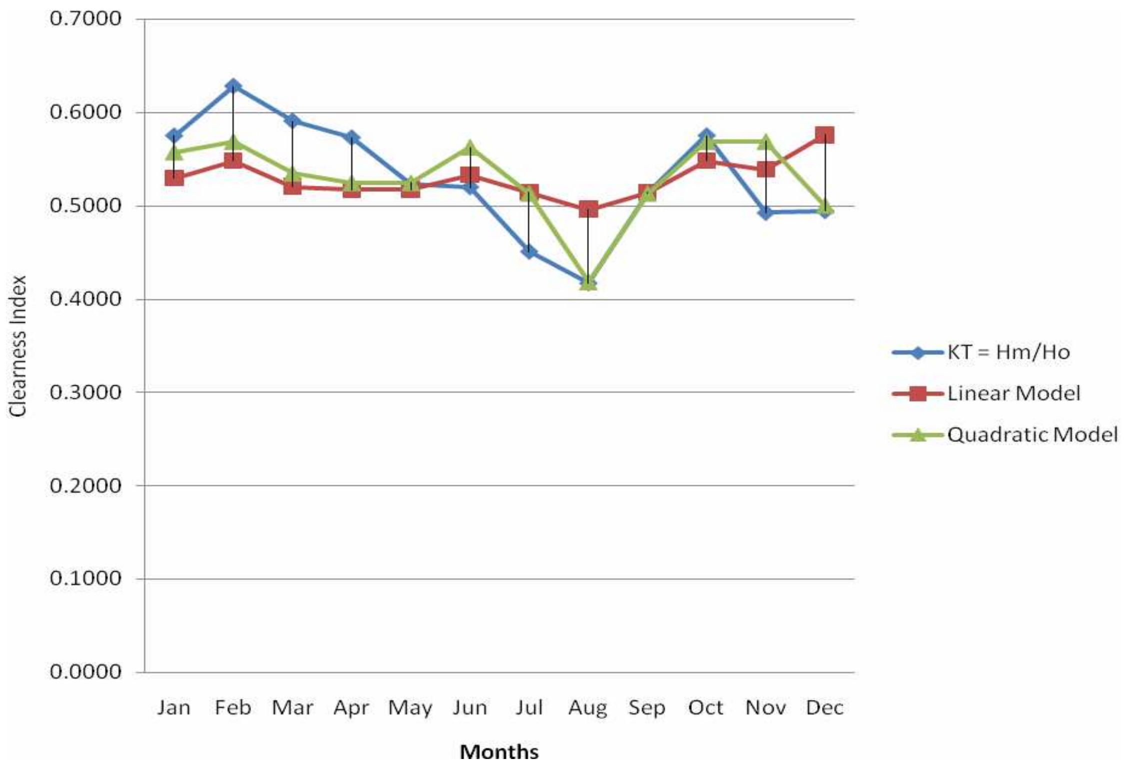

Figure 1: Comparisons between the measured and modeled values of monthly average clearness Indices of global solar radiations (linear and quadratic models)

From the months of January to April, both models under estimated the clearness index, but there is more improvement in quadratic model than linear model. At the month of May both models gave the same results. At the month of June quadratic model overestimated more than the linear. At the month of July all the models gave the same overestimation. From the month of august to October the quadratic model gave 100% of the measured clearness index while linear under estimated at the month of august gave 100% in the month of September but overestimated at the month of October. At the month of November, both the models overestimated but linear is better. Finally at the month of December quadratic becomes 100% of the measured index.

In summary, it can be said that quadratic model is better in the months of January, February, march, April, August, September, October and December. Linear is better only in the month of June. They perform correctly in the month of May, but they overestimated at the month of July.

CONCLUSION

The monthly mean daily global solar radiation and fraction of sunshine hours have been employed in this study to develop several correlation equations using SPSS computer software program. It was observed that equations quadratic model is better than linear model because it has higher correlation coefficient.

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