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EMPIRICAL MODELS FOR CORRELATION OF CLEARNESS INDEX WITH CLOUD INDEX AT ZARIA, KADUNA STATE

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***Abstract*— In this study, the monthly average daily values of global solar radiation and relative sunshine hours on a horizontal surface over a period of five years (2011-2015) using multi-linear polynomial form of the Angstrom-Prescott model have been developed to estimate global solar radiation for Zaria (northern part of Nigeria) which lies on latitude 11°04'N and longitude 7º42' E. Five different mathematical correlations models (first order, second order, exponential, powered, and logarithmic) was considered and it was found that first order, second order polynomials, exponential and powered gives a good model for estimating total solar radiation in Zaria. The agreement between the measured values (that obtained from the Nigerian Meteorological Agency) and the computed values is remarkable and the models are recommended for Zaria.**

***Keywords*— Global solar radiation, sunshine hour Zaria, Solar energy.**

I. INTRODUCTION

The sun is a very intense source of energy not only for Nigeria but also for the world. When sunlight reaches the Earth, it is distributed unevenly in different regions. Not surprisingly, the areas near the equator receive more solar radiation than anywhere else on earth. Solar radiation is the energy that comes from the sun which generate huge amount of energy through the process of nuclear fusion. Knowledge of the solar radiation is essential for many applications, including architectural design, solar energy systems, crop growth models and other applications. The global solar radiation on horizontal surface at the location of interest is the most critical input parameter employed in the design and prediction of the performance of solar energy device [6].

Several models have been proposed to estimate global solar radiation by many researchers, within and outside Nigeria, have used Angstrom type of equation to make a model for estimation of solar radiation for their location such as for Damascus in Syria, Skeiker (2006), for Onne in Nigeria, Akpabio *et al.* (2004); for Izmir in Turkey, Ulgen and Hepbasli (2002); for Minna in Nigeria, Akinbode (1992); for Kano in Nigeria, Sambo (1985). Besides the Angstrom – type one parameter model, other researchers had proposed one – parameter models based on other commonly measured meteorological terms such as temperature, rainfall, relative humidity, etc. For instance, Okpani and Nnabuchi (2008), correlated global solar radiation with maximum temperature for Enugu in Nigeria; Falayi (2008), modeled with monthly averaged daily temperature, relative humidity, and ratio of maximum temperature to daily temperature, for Iseyin in Nigeria; Sanusi and Aliyu (2005) used maximum temperature to model for Sokoto in Nigeria. Multiple regression model was proposed by some researchers; Abimbola *et al.* (2008), Falayi *et al.* (2008), Akpabio and Etuk (2002).

II. MATERIAL/METHOD

The monthly average daily data for the sunshine duration and global solar radiation for Zaria (lat. 11°04'N and long. 7º42' E) were obtained from the Nigerian meteorological Agency (NiMet) office in Zaria from 2011 – 2015.

The most convenient and widely used correlation for predicting solar radiation was developed by Angstroms – like equation [3, 4]. The formula is

$$\frac{H}{H_0} = a + b\frac{S}{S_0} - - - - - - - - - (1)$$

where:

H is the global solar radiation on the horizontal surface $(MJ/m^2 day)$

H_0 is the extraterrestrial solar radiation on the horizontal surface $(MJ/m^2 day)$

S is the number of hours measured by the sunshine recorder

S_0 is the maximum daily sunshine duration (or day length) a and b are the regression constant to be determined.

For monthly average, this formula holds:

$$\frac{\bar{H}}{\bar{H}_0} = a + b\frac{\bar{S}}{\bar{S}_0} - - - - - - - - - - - - (2)$$

Where $\overline{H}$ is th monthly average of daily global solar radiation on the horizontal surface

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$\bar{H}_0$ is the monthly average of daily extraterrestrial solar radiation on the horizontal surface

$\bar{S}$ is the monthly average daily number of hours of bright sunshine

$\bar{S}_0$ is the monthly average daily maximum number of hours of possible sunshine

$\frac{H}{H_0}$ is clearness index

$\frac{S}{S_0}$ is cloud index

The regression coefficient a and b have been obtained from the relationship given as [14]:

$$a = -0.110 + 0.235\cos\Phi + 0.323\left(\frac{H}{H_0}\right) \quad 3(a)$$

$$b = 1.449 - 0.553\cos\Phi - 0.694\left(\frac{H}{H_0}\right) \quad 3(b)$$

The extraterrestrial solar radiation on the horizontal surface can be calculated from the following equation [3, 4]:

$$H_0 = \frac{24}{\pi} x\, 3600 I_{sc}\left[1 + 0.33\cos\left(360\frac{d}{365}\right)\right]\left[\left(\frac{2\pi\omega_s}{360}\right)\sin\Phi\sin\delta + \cos\theta\cos\delta\sin\omega_s\right] \quad (4)$$

The value of solar constant I_{sc} *is* $1367\,W/m^2$.

The hour angle ω_s for horizontal surface is given as

$$\omega_s = \cos^{-1}(-\tan\theta\tan\delta)$$

Declination is calculated [3, 4] as

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

d is the day of the year.

The day length S_0 is the number of hours of sunshine or darkness within the 24hours in a given day. For horizontal surface is given by [3, 4]

$$S_0 = \frac{2}{15}\cos^{-1}(-\tan\theta\tan\delta) = \frac{2}{15}\omega_s$$

III. Experiment and Result

The various model developed for Zaria are the first and second order polynomials, exponential, power and logarithms as follow:

$$H_1 \rightarrow \quad \frac{\bar{H}}{\bar{H}_0} = 0.3758 + 0.1879\,\frac{\bar{S}}{\bar{S}_0}$$

$$H_2 \rightarrow \quad \frac{\bar{H}}{\bar{H}_0} = 0.2256 + 0.7032\left(\frac{\bar{S}}{\bar{S}_0}\right) - 0.4197\left(\frac{\bar{S}}{\bar{S}_0}\right)^2$$

$$H_3 \rightarrow \quad \frac{\bar{H}}{\bar{H}_0} = 0.380\exp\left(0.4069\left(\frac{\bar{S}}{\bar{S}_0}\right)\right)$$

$$H_4 \rightarrow \quad \frac{\bar{H}}{\bar{H}_0} = 0.5545\left(\frac{\bar{S}}{\bar{S}_0}\right)^{0.2455}$$

$$H_5 \rightarrow \quad \frac{\bar{H}}{\bar{H}_0} = 0.5494 + 0.1129 In\left(\frac{\bar{S}}{\bar{S}_0}\right)$$

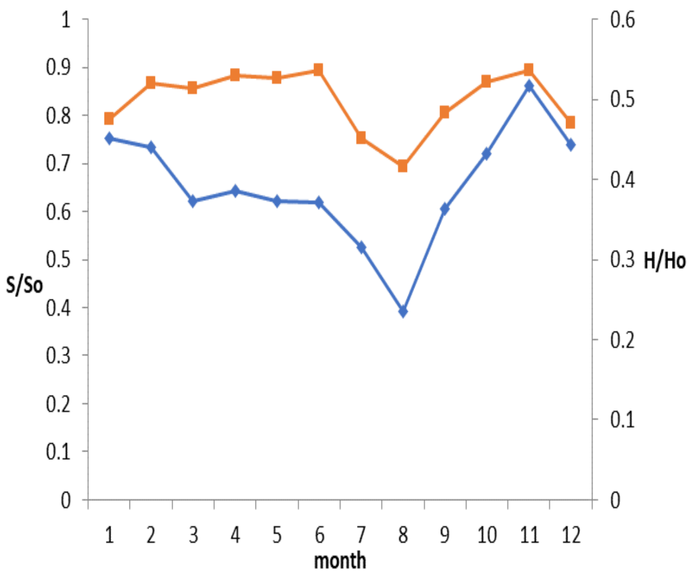

Fig 1: Variation of $\frac{H}{H_0}$ with months for different models of the year for Zaria.

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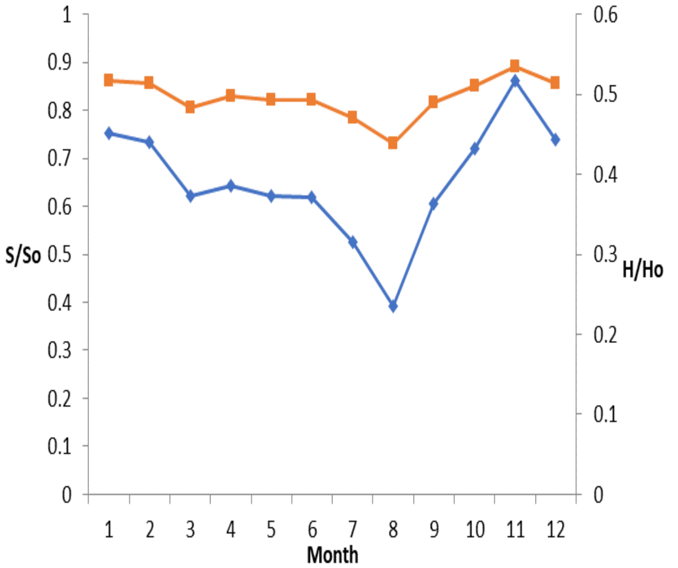

Figure 2: Variation of K_t and $S_t$estimated for months of the year for Zaria Linear model.

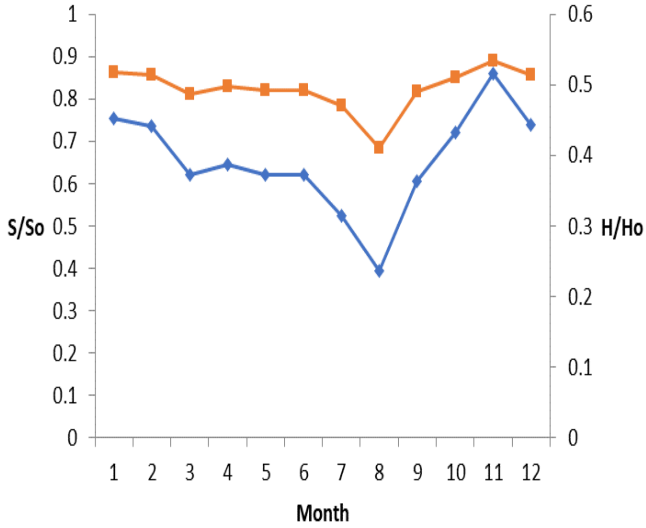

Figure 4: Variation of K_t and $S_t$estimated for months of the year for Zaria exponential model.

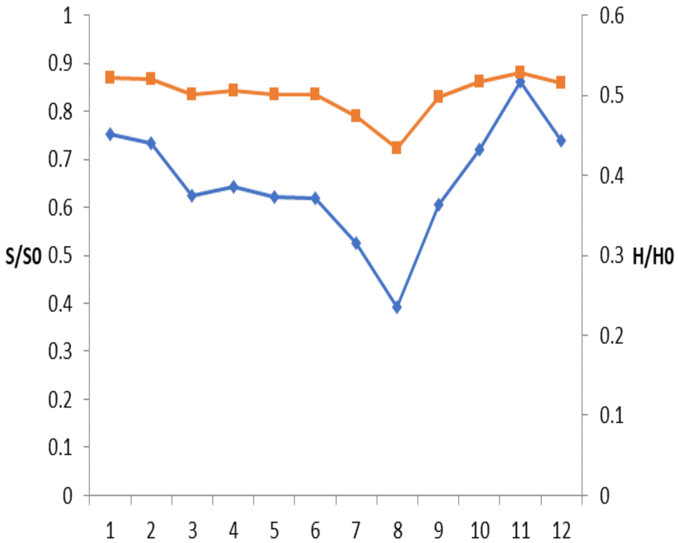

Figure 3:Variation of K_t and $S_t$estimated for months of the year for Zaria second order polynomials model.

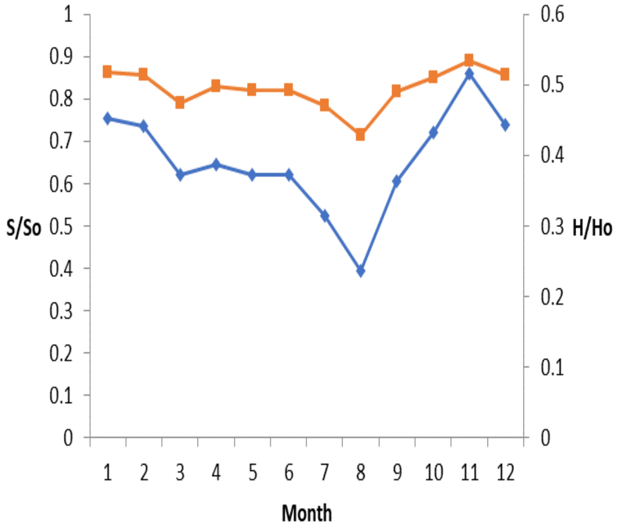

Figure 5: Variation of K_t and $S_t$estimated for months ofthe year for Zaria Power model.

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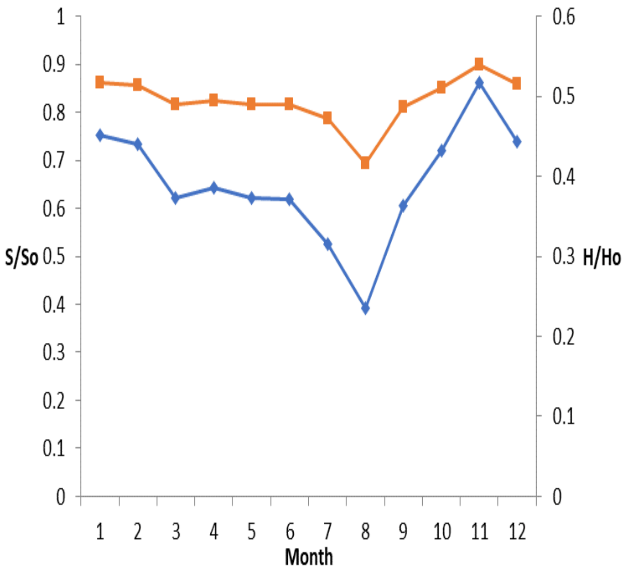

Figure 6: Variation of K_t and $S_t$estimated for months of the year for Zaria Logarithmic model.

The correlation of monthly variation of measured and calculated clearness index and sunshine index for Zaria for period of 5 years shown from fig. 1 – 6. Though there is similarity in the patterns of both plots, however, there is significance difference in the models developed. It is observed clearly that there is well defined trough in the curves in the months of July and August. This is an indication that the atmospheric condition for Zaria in which the sky was not clear. The results suggest that rainfall is at the peak during the month of July and August when the sky is cloudy and the radiation is fairly low in Zaria. However, just after the minimum in August, the clearness index and sunshine index duration increased sharply with the cloud cover crossing over the clearness index. This implies that a clear sky will be obviously felt within the dry season and hence a high solar radiation is experienced. From these figures we can shows that the estimated equations are reliable for calculated the global solar radiation on a horizontal surface for Zaria.

Figure(1) shows the relationship between clearness index and cloud index vs. months of the year that estimated using a linear model (Angstrom model). Figures (2-6) explain the relationship between clearness index and cloud index vs. months of the year from estimated equations (H_1, H_2 , H_3, H_4, and H_5). From these figures we can shows that the estimated equations are reliable for calculated the global solar radiation on a horizontal surface for Zaria. Figure (7) explain the monthly global solar radiation vs. months of the year for Zaria which can be noted the calculated value which dependent on Zaria weather condition and that of estimated values. Good agreements are obtained when comparing the clearness measured values that taken from the Nigerian Meteorological Agency for Zaria (which explained in blue color) and calculated values from various models for months (which explained un different colours as shown in figure (8).

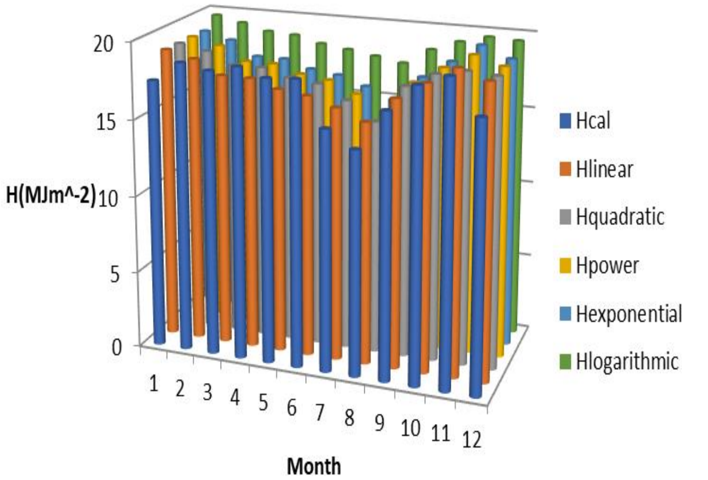

Fig. 7: Monthly Average of solar radiation vs. month for various models.

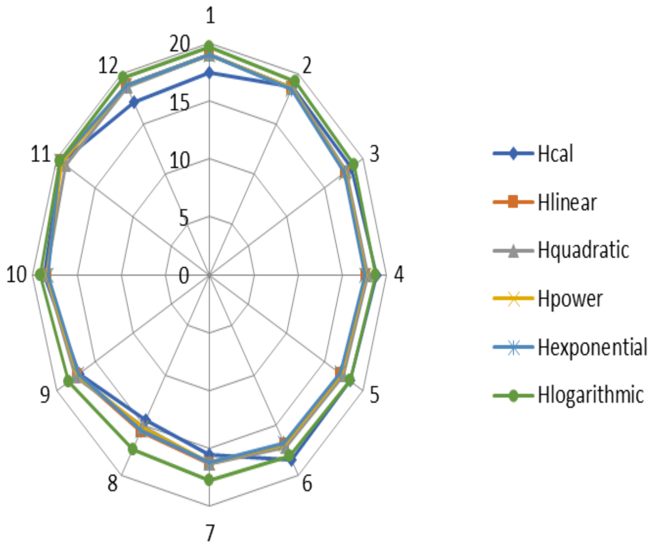

Fig. 8:The clearness index for measured values and calculated values vs. month for Zaria.

IV. CONCLUSION

The result of this study, clearly indicate the primary importance of developing empirical approaches for formulating the global solar radiation on horizontal surface reaching the earth at Zaria, Kaduna state. Good agreement between calculated and measured values of the clearness index from the above results.

V. ACKNOWLEGEMENT

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VI. REFERENCE

[1] Akpabio, L. E., Udo, S. O., & Etuk, S. E. (2004). Empirical correlations of global solar radiation with meteorological data for Onne, Nigeria. *Turkish Journal of Physics*, *28*(3), 205-212.

[2] Falayi, E. O., & Rabiu, A. B. (2005). Modeling global solar radiation using sunshine duration data. *Nigeria Journal of Physics*, *17*, 181-186.

[3] Angstrom, A. (1924). Solar and terrestrial radiation. Report to the international commission for solar research on actinometric investigations of solar and atmospheric radiation. *Quarterly Journal of the Royal Meteorological Society*, *50*(210), 121-126.

[3] Duffie, J. A., Beckman, W. A., & Worek, W. M. (1994). Solar engineering of thermal processes.

[4] Hussain, M., Rahman, L., & Rahman, M. M. (1999). Techniques to obtain improved predictions of global radiation from sunshine duration. *Renewable Energy*, *18*(2), 263-275.

[5] Skeiker, K. (2006). Correlation of global solar radiation with common geographical and meteorological parameters for Damascus province, Syria. *Energy conversion and management*, *47*(4), 331-345.

[6] DW, M., & Yakubu, D. (2011). Estimation of mean monthly global solar radiation in Yola-Nigeria using angstrom model.

[7] Majeed, A. J. (2013). Empirical models for correlation of clearness index with cloud index at Rutba, Iraq State. *Int J Eng Res Appl*, *3*, 1189-1192.

[8] Abimbola, O. J., Alkali, B., & Iorkyaa, A. (2008). Empirical models for the estimation of global solar radiation with meteorological data for Jos, Nigeria. *Ife Journal of Science*, *10*(1), 0..

[9] Udo, S. O. (2002). Contribution to the relationship between solar radiation and sunshine duration in the tropics: a case study of experimental data at Ilorin, Nigeria. *Turkish Journal of Physics*, *26*(3), 229-236.

[10] Sanusi, Y. A., & Aliyu, M. (2005). Estimation of Global Solar Radiation in Sokoto and its Environs Using Maximum Temperature Data. *Niger. Journey Solar Energy*, *15*, 193-198.

[11] Okpani, P. E., & Nnabuchi, M. N. (2008). Developing a model for predicting the global solar radiation in Enugu using maximum temperature data. *Nigerian journal of physics*, *20*(1), 112-117.

[12] Ulgen, K., & Hepbasli, A. (2002). Prediction of solar radiation parameters through clearness index for Izmir, Turkey. *Energy Sources*, *24*(8), 773-785.

[13] Akinbode, F. O. (1992). Solar radiation in Minna: correlation with meteorological data. *Nigeria Journal of Renewable Energy*, *3*(1), 9-17.

[14] Tiwari, R. F & Sangeeta, T.H (1997) Solar Energy, 24(6), 1997, 89 – 95.