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Comparison of Artificial Neural Network (ANN) and Angstrom-Prescott models in correlation between sunshine hours and global solar radiation of Uyo city, Nigeria

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ABSTRACT

In this study, the prediction of global solar radiation at Uyo- Nigeria latitude 5.020N was carried out. The daily mean sunshine hour for seventeen years (1991 to 2007) from Nigerian Meteorological Agency, Federal Ministry of Aviation, Oshodi, Lagos, Nigeria were used. The global solar radiation data were collected courtesy of Renewable Energy for Rural Industrialization and Development in Nigeria. The value of correlation coefficient and coefficient of determination using ANN model and Angstrom-Prescott model were determined to be 0.993 and 0.985 for ANN, 0.870 and 0.757 for Angstrom-Prescott model. This result indicates better correlation of ANN which is 97.4% compared to Angstrom-Prescott model which is 75.77%. Thus ANN model is recommended as a better model for Global Solar Radiation prediction.

Key-Words: Solar Radiation, Meteorology, sunshine hours, Neural Network, correlation

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INTRODUCTION

Solar radiation received at a particular station on the Earth's surface must be known in order to evaluate the performance of any solar system at a given station. The data depends on two main factors, the extraterrestrial solar irradiance and the state of the atmosphere.

The extraterrestrial solar irradiance is the rate at which solar energy arrives on a horizontal surface at the top of the atmosphere (Augustine and Nnabuchi, 2009). It varies according to the latitude of the station, the distance of the Earth from the Sun, and the time of the year. On any particular day, it varies from zero at sunrise to a maximum at noon and back to zero at sunset (Liou, 1980).

Solar radiation while passing through the earth's atmosphere is subjected to the mechanisms of atmospheric absorption and scattering. A fraction of the radiation reaching the earth's surface is reflected back into the atmosphere and is subjected to these atmospheric phenomenon's again; the remainder is absorbed by earth's surface. The absorption of solar radiation is mainly by ozone, water vapor, oxygen, nitrogen, carbon (IV) oxide, as well as clouds and scattering is due to air molecules, dust and water droplets. The interaction of solar radiation with clouds leads to the variation in intensity of sunshine and the number of sunshine hours at the ground surface (Augustine and

Nnabuchi, 2009). The variation, however, is not due only to the clouds but also to the angle of incidence of the Sun's rays with the ground surface and its azimuth (Babatunde, 1988). These in turn, are due to the rotation of the Earth around the Sun and the inclination of its axis with the plane of its orbit round the Sun. This results in the variation of the number of hours of sunshine and its intensity on the Earth's surface. The variation is from latitude to latitude. Thus, solar radiation measurement parameter is obtained and defined as the ratio of the actual number of hours of sunshine received at a site to the number possible in the day i.e. the length of the day. The ratio is known as fraction of sunshine hours, it is found to vary daily and seasonally (Shears et al., 1981).

The most appropriate way of getting solar radiation data in any location is to install pyranometer at that location, and day to day reading gives the value of solar radiation data. But because of high cost of solar radiation measuring devices, efforts are made to develop various models as alternative ways for the prediction of solar radiation at any location of interest.

Several researchers have used one or more meteorological data to estimate global solar radiation on horizontal surface. Medugu and Yakubu (2011) Estimated the mean monthly global solar radiation in Yola – Nigeria using Angstrom model, Augustine Nnabuchi (2009), develop the correlation between sunshine hours and global solar radiation of Warri-Nigeria using Angstrom-Prescott model, AbdulAzeez (2011), Estimated the global solar radiation using meteorological parameters in Gusau, Nigeria using Artificial Neural Network(ANN).

In this work, a comparison between the prediction of global solar radiation of Uyo-Nigeria using the Angstrom-Prescott and ANN model is studied based on the available climatic parameters of sunshine hour and computed values of the extraterrestrial solar radiation.

Artificial Neural Network

A neural network is a massively parallel distributed processor made up of simple processing units that have a natural propensity for storing experiential knowledge and making it available for us. Artificial neural network (ANN) is a type of Artificial Intelligence technique that mimics the behavior of the human brain. ANNs have ability to model linear and non-linear systems without the need to make assumptions implicitly as in most traditional statistical approaches, applied in various aspects of science and engineering. The network usually consists of an input layer, some hidden layers and an output layer. In its simple form, each single neuron is connected to other neurons of a previous layer through adaptable synaptic weights. Knowledge is stored as a set of connection weights. During training process the connection weights are modified in certain way by using a suitable learning method. The network uses a learning mode, in which an input is presented to the network along with the desired output and the weights are adjusted so that the network attempts to produce the desired output. Therefore, the weights, after training contain meaningful information.

MATERIALS AND METHODS

The monthly mean daily data for sunshine hours were collected from the Nigerian Meteorological Agency, Federal Ministry of Aviation, Oshodi, Lagos, Nigeria. The global solar radiation data were collected courtesy of Renewable Energy for Rural Industrialization and Development in Nigeria. The data obtained covered a period of seventeen years (1991 – 2007) for Uyo, Nigeria (latitude 5^o 1', N and longitude 7^o 53' E). The monthly averages data processed in preparation for the correlations are presented in Table 1.

This study was based on Multi Layer Perceptron (MLP) neural network which were trained and tested using past seventeen years (1991-2007) meteorological data. The chosen weather data were divided into three randomly selected groups, the training group, corresponding to 66.7% of the patterns, and the test group, corresponding to 8.3% of patterns; so that the generalization capacity of network could be checked after training phase and the holdout group corresponding to 25.0% which is used for validation.

The following is an outline of the procedure used in the development of the ANN model:
i) Input and target values were normalized, in the range -1 to 1.
ii) Matrix size of the dataset was defined.
iii) Partition and create training, testing and validation sub-datasets.
iv) The MLP neural network was created
v) The MLP neural network was trained

vi) Automatic Architecture selected
vi) Output values were generated.
vii) Un-normalize the output values.
viii) The performance of the neural network was checked by comparing the output values with measured values.

Angstrom-Prescott Model
There are several types of empirical formulae for predicting the monthly mean daily global solar radiation as a function of readily measured climatic data (Iqbal, 1977; and Klien, 1977). Among the existing correlations, the one used in this paper is the Angstrom–Prescott regression equation, which relates the monthly mean daily global solar radiation to the number of hours of bright sunshine as follows

$$\frac{\bar{H}_M}{\bar{H}_O} = a + b\frac{\bar{n}}{\bar{N}} \text{-------------------------------} (1)$$

Where,
$\bar{H}_M$= measured monthly mean daily global solar radiation on a horizontal sunshine
$\bar{n}$ =monthly mean daily bright sunshine hour,
$\bar{N}$ = Maximum possible monthly mean daily sunshine,
a and b = regression constant.

The monthly mean daily extraterrestrial radiation $\bar{H}_o$ and monthly mean day length $\bar{N}$ was derived from the formulae:

$$\bar{H}_O = \frac{24}{\pi} I_{SC}\, E_O\, [W_S \sin\Phi \sin\Phi + \cos\Phi \cos\delta \cos W_S] ------(2)$$

$$\bar{N} = \frac{2}{25} \text{COS-1} (- \tan \Phi \tan \delta) \text{------------- --} (3)$$

$$\delta = 23.45 \sin [\frac{N+284}{365}] \text{-------------------------} (4)$$

$$W_S = \text{COS -1} (- \tan \Phi \tan \delta) \text{----------------} (5)$$

I_{SC}= solar constant (4.921 MJM-2 day -1)
N= characteristic day number
Φ = latitude angle
δ = angle of declination

a = - 0.110 + 0.235 cosΦ + 0.323 (n/N) --- (6)

b =1.449 -0.553 cos Φ -0.694 (n/N) ----- --(7)

RESULTS AND DISCUSSIONS

Table 1, shows the calculated values of measured monthly mean daily sunshine hours $\bar{n}$,possible sunshine fraction hours $\frac{\bar{n}}{\bar{N}}$, measured monthly mean daily maximum temperature Tm, measured monthly mean daily relative humidity R, calculated measured monthly mean daily cloudiness $\frac{\bar{c}}{\bar{c}}$, extraterrestrial solar radiation on a horizontal surface $\bar{H}_O$, measured global solar radiation on a horizontal surface $\bar{H}_m$, the clearness index $\bar{K}_T = \frac{\bar{H}_M}{\bar{H}_O}$, empirical predicted global solar radiation, as well as the result of the artificial neural network of global solar radiation on horizontal surface. A close examination of Table 1, as well as Figures 1 to 3 shows that the minimum values of the monthly mean daily sunshine hours and monthly mean daily global solar radiation on a horizontal surface both for Angstrom-Prescott, measured, and ANN values are 1.79 sunshine hours and 6.43, 11.39 and 12.01 solar radiation ($MJm^{-2}day^{-1}$), respectively, occur in the month of August. This value is within what is expected of a tropical site (Exell, 2000 and Okogbue and Adedokun, 2005).

Figures 4-5 shows the comparison between measured and predicted monthly average daily global solar radiation for the two models, figure 6 shows the comparison between the two models and the measured values of global solar radiation. It is clear that there is a good agreement between the measured and ANN predicted data.

Table 1 also shows the variation of the clearness index, which is a measure of the attenuation of the extraterrestrial global radiation passing through the turbulent atmosphere before reaching the ground surface (Augustine and Nnabuchi, 2009). It indicates that the Maximum attenuation occurred in February and minimum in August. The month of highest occur is characterized as heavy rain falls, therefore is well expected. It is important to state here that from the records of temperature made during the seventeen year period, August has the lowest monthly mean daily average temperature of 28.99 0C.

Figure 4 shows the variation of measured and ANN of global solar radiation during the year. Figure 5 shows the variation of measure and Angstrom-Prescott of global solar radiation, and figure 6 compared the variation between the two models and the measured solar radiation. From the three figures, it is clear that August have the minimum value of solar radiation. Thus, the comparison makes it clearer that ANN has strong relationship and has long term correlation.

Regression analysis of two models were also carried out, ANN correlation coefficient R, coefficient of determination and Adjusted R square are 0.987, 0.974 and 0.965 respectively, indicating that 97.4 % of the variation in the monthly mean daily solar radiation on a horizontal surface can be explained by the model. The high percentage indicates high performance.

The value of R, R2 and Adjusted R square of Angstrom-Prescott model is 0.870, 0.757 and 0.733 respectively, indicating that 75.7% of the variation in the monthly mean daily solar radiation on a horizontal surface can be explained by the model. The low value and low percentage indicates lower performance of prediction compare to ANN model.

Table 1: Meteorological Data, Measured Global Solar Radiation, Empirical Solar Radiation and ANN Predicted Solar (SR) For Uyo

Month	$\bar{n}$ **hours**	$\frac{\bar{n}}{\bar{N}}$	$\bar{H}_0$ **($MJm^{-2}day^{-1}$)**	**Measured SR ($MJm^{-2}day^{-1}$)**	**Empirical SR ($MJm^{-2}day^{-1}$)**	$\bar{K}_T = \frac{\bar{H}_M}{\bar{H}_0}$	**ANN predicted SR ($MJm^{-2}day^{-1}$)**
Jan.	4.06	0.34	34.21	14.27	14.56	0.34	15.04
Feb.	4.29	0.36	35.06	14.85	15.71	0.36	15.17
Mar.	3.56	0.30	37.72	16.11	14.29	0.30	14.81
Apr.	3.89	0.33	36.48	15.75	15.11	0.33	15.01
May.	3.84	0.33	36.22	15.07	15.00	0.33	15.03
Jun.	2.86	0.24	34.13	13.57	10.39	0.24	13.75
Jul.	1.91	0.16	35.81	12.47	7.07	0.16	12.29
Aug.	1.79	0.15	35.05	11.39	6.43	0.15	12.01
Sept.	2.59	0.22	36.26	14.01	10.09	0.22	13.61
Oct.	2.84	0.24	36.68	14.75	11.16	0.24	14.01
Nov.	3.79	0.32	34.58	14.37	13.92	0.32	14.91
Dec.	3.73	0.32	32.49	15.25	13.45	0.33	14.86

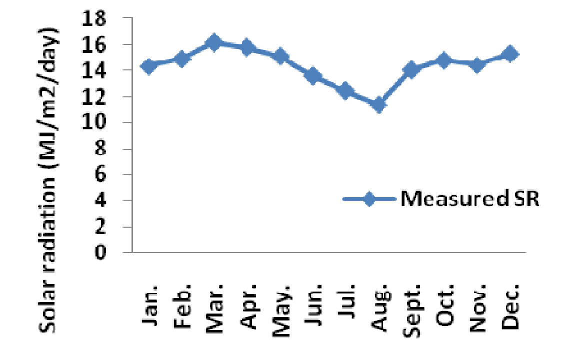

Figure 1: Graph of measure Global Solar Radiation

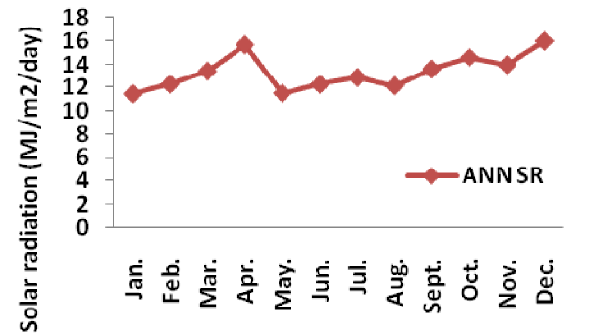

Figure 2: Graph of ANN solar Radiation

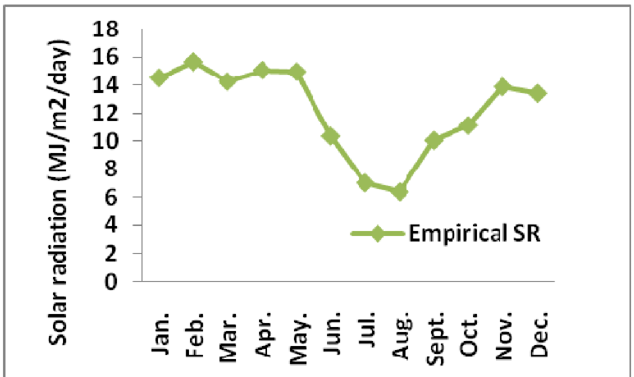

figure 3: Graph of Empirical Global Solar Radiation

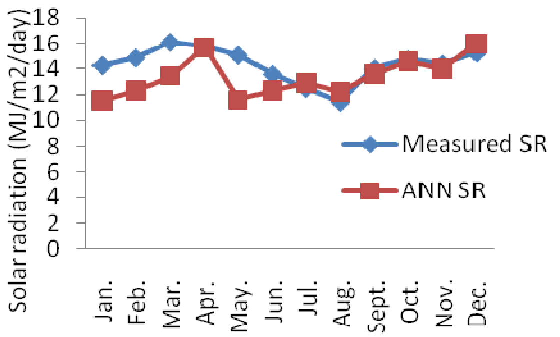

Figure 4: Graph of measured and ANN solar Radiation

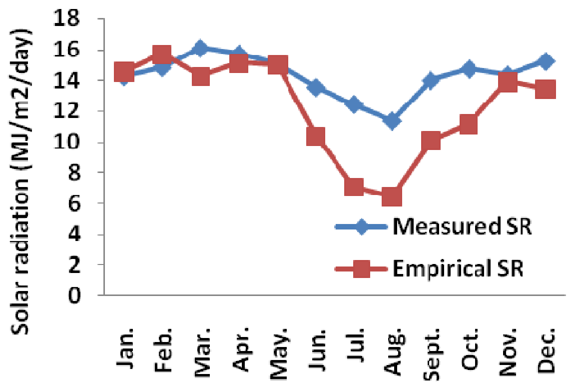

Figure 5: Graph of measured and Empirical solar Radiation

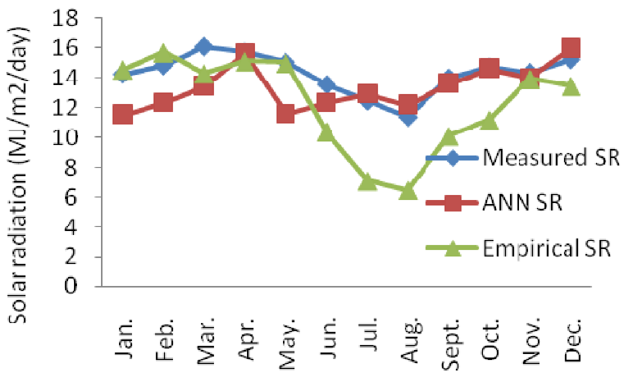

Figure 6: comparison Between Measured, ANN and Empirical solar Radiation

CONCLUSION

In this paper, ANN and Angstrom-Prescott model were use to predict the monthly average daily global solar radiation on a horizontal surface for Uyo city in Nigeria. Atmospheric parameters between 1991 and 2007 were used. Table 1 show the atmospheric parameters use for the prediction. Figure 4 and 5 show the correlation between the measured and ANN, and measured and Angstrom-Prescott model. Figure 6 shows the comparison between measured, ANN and Angstrom-Prescott value of the monthly mean daily global solar radiation on a horizontal surface. From the figures it is clear that ANN model has strong agreement and relationship with the measured monthly mean daily global solar radiation on a horizontal surface, thus the better model and should be use for prediction of monthly mean daily global solar radiation on a horizontal surface.

Regression analysis of the two models were also carried out, ANN correlation coefficient R, coefficient of determination and Adjusted R square are 0.987, 0.974 and 0.965 respectively, indicating that 97.4 % of the variation in the monthly mean daily solar radiation on a horizontal surface can be explained by the model. The high percentage indicates high performance.

The value of R, R2 and Adjusted R square of Angstrom-Prescott model is 0.870, 0.757 and 0.733 respectively, indicating that 75.7% of the variation in the monthly mean daily solar radiation on a horizontal surface can be explained by the model. The low value and low percentage indicates lower performance of prediction compare to ANN model. Therefore, ANN model is a better model for solar radiation prediction.

REFERENCES

[1] M.A AbdulAzeez, *Scholars Research Library* **2011**
[2] L.E Akpabio, and S.E Etuk ,S.E *Turkish J. Physics*. **2002 27** 161 – 167.
[3] A.S Angstrom, *Meteorological Society*. **1924**, 50 pg 21- 126.
[4] C Augustine, and M.N Nnabuchi, *Pacific Journal of Science and Technology*. **2009**, 10(2) 574-579.
[5] R.H.B Exell, *King Mongkut's University of Technology Press* **2000**.
[6] M Igbal, *Academy Press* **1983** New York, NY
[7] K.N. Liou, *Academy Press New* **1980**, York, NY.
[8] Klein, S.A (1977), *Solar Energy*.19 (**1977**) 19: pg 307-311.
[9] Medugu, D.M and D. Yakubu, D (**2011**). *Advances in Applied Science Research*, 2 (2) pg 414-421
[10] Okogbue, E.C and Adedokun, J.A (**2005**). Nigeria". Conference paper. 28th Annual conference of NIP, lle-lfe, August 17 – 20.
[11] R. D Shears, R. G, Flocchini and J. L., Hatfield, *Solar Energy*. **1981,** 27 (4).
[12] R. Hile, *Bull. U.S. Bur. Fish*., **1936**, 48 (19), 311- 317.
[13] V.R. Martin, *Pub. Ont.Fish. Res. Lab*. **1949**, 63, 1-91.
[14] K.R. Allen, *J. Anim.Ecol*., **1938**, 7, 333- 349.
[15] M.A. Jr. Moe, Biology of the red grouper *E.morio* (Valenciennes) from the eastern Gulf of Mexico. Florida Dept. (Natural Resources Mar. Res. Lab. Professional Papers Series, **1969**)10.
[16] S.M Tan and K.S Tan, *J. Primary Ind* , **1974**, 2,123-133.
[17] R. Thompsonand and J.L. Munro, *J.Fish Biol*, **1978**, 12, 115-146.
[18] M.K. Baddar, Length - weight relationship and age determination of hamoor (*Epinephelus tauvina*). In: Annual research report for 1982 Kuwait Inst. for Scientific Research, Safat (Kuwait), **1983**. 76-77.