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Full Length Research Paper

Comparison of empirical and artificial neural network models for the correlation of monthly average global solar radiation with sunshine hours in Minna, Niger State, Nigeria

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Monthly average daily values of global solar radiation and sunshine hours over a period of five years (1987-1991) using artificial neural network were developed to predict global solar radiation at Minna which lies on latitude 09.37°N, longitude 06.32° and 265.4 m above sea level. The results were used to compare results from other researchers of different models in the same area. The correlation coefficient of our model was found to be 0.997. These values were found to be higher than the correlation coefficient of other models. The values from our model and other models were tested in terms of mean percentage error (MPE), mean bias error (MBE) and root mean square error (RMSE) and our model was found to have low error values when compared with other models. From the results of these studies, it was found out that all the models have predicting capacity, but our model has better results. This is being recommended for the prediction of global solar radiation for Minna and areas that have similar climate with Minna.

Key words: Global solar radiation, artificial neural network, prediction, measured values, models.

INTRODUCTION

Energy plays an important role in determining the conditions in which living matter can exist. Renewable energy is considered as the key source for the future, as it is the vital and essential ingredient to human activities of all kind, and can only be acquired through measurement or prediction. 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. The prediction is done using some meteorological parameters. One of such meteorological parameters used is the sunshine hours (Agbo et al., 2010).

Several researchers have used one or more meteorological parameters 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 and Nnabuchi (2009) developed 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 study, we employ the ANN correlation of monthly average global solar radiation with sunshine hours and compared it with other researcher’s results of the correlation between monthly average global solar radiation with sunshine hours with different empirical models.

DATA AND METHOD OF ANALYSIS

The monthly average daily data for the sunshine duration and global solar radiation were obtained from the monthly meteorological observations at the Nigeria Meteorological Agency

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Table 1. Geographical location of the station.

Station	Latitude	Longitude	Altitude (m)
Minna	09.37°N	06.30°E	256.4

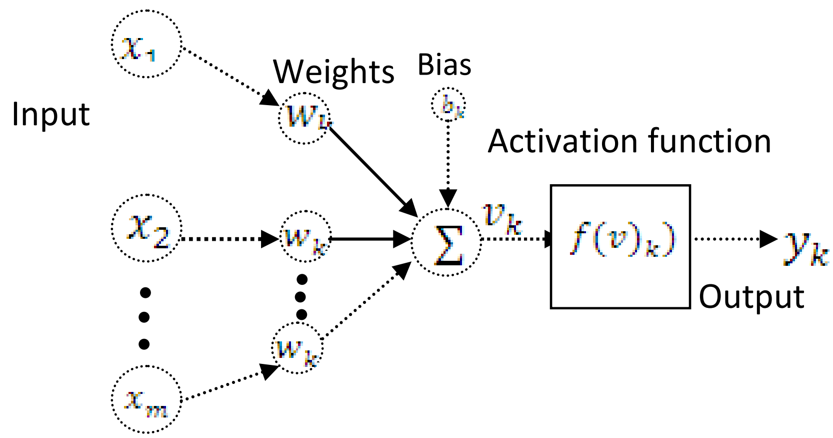

Figure 1. Mathematical structure of ANN.

(NIMET), Oshodi, Lagos, Nigeria. The geographical location of the station is presented in Table 1. The duration of the record is from 1987 to 1991.

The basis of the ANN model used is of neuron structure as shown in Figure 1. These neurons act like parallel processing units. An artificial neuron is a unit that performs a simple mathematical operation on its inputs and imitates the functions of biological neurons and their unique process of learning. The weighed sum of the inputs,

$$v_k = \sum_{k=1}^{N} x_j w_{kj} + b_k \quad (1)$$

is calculated at kth hidden node, where w_{kj} is the weight on connection from the *jth* to the *kth* node; x_j is an input data from input node; N is the total number of input (N = 5) and b_k denotes a bias on the *kth* hidden node.

Each hidden node then uses a sigmoid transfer function to generate an output of the form:

$$z_k = [1+e^{(-v_k)}]^{-1} = f(v_k) \quad (2)$$

between -1 and 1.

We then set the output from each of the hidden nodes, along with the bias b_0 on the output node, and then calculated a weighted sum,

$$y_k = \sum_{k=1}^{N} v_k z_k + b_k \quad (3)$$

where N is the total number of hidden nodes and v_k is the weight from the *kth* hidden node to the sigmoid transfer function of the output node.

In this work, multilayer perceptron (MLP) neural networks were used, with meteorological data as input variables. In the process, meteorological data of sunshine hours were the independent variables, while measured solar radiation is the dependent factor. Both the independent and dependent factor were used for the prediction.

RESULTS AND DISCUSSION

The input parameters used in the analysis is as shown in Table 2. A set of inputs is applied to a neuron; which were done through links. The inputs are multiplied by the weights associated with the corresponding links through which they are applied. The summation of the weighted inputs is passed through an activation function. The output is then distributed to other neurons as inputs. The summation of inputs is then passed through another activation function, which leads to the desired output.

Table 3 shows the measured global solar radiation, the results of predicted global solar radiation of different models and predicted global solar radiation of our model (ANN). H_1, H_2, H_3, H_4 and H_5, respectively is the result of Agbo et al. (2010), using Angstrom model prediction of global solar radiation up to fifth order polynomials.

It is pertinent to note from Table 3, that there is a close agreement between the measured values and the prediction made from our model. This is an indication that our model significantly improved the accuracy of the prediction of the radiation in Minna as earlier estimated by Agbo et al. (2010). Figure 2 shows the graph of measured values and our model values of global solar

Table 2. Input parameters for the estimation of monthly average daily global solar radiation at Minna, Nigeria.

Month	H	n/N
January	16.22	0.522
February	17.66	0.614
March	18.22	0.560
April	18.08	0.599
May	17.28	0.574
June	16.16	0.452
July	14.70	0.358
August	14.18	0.310
September	16.62	0.511
October	17.88	0.625
November	18.36	0.757
December	16.42	0.577

Table 3. Monthly values of measured global solar radiation and the estimated values from others models and model of this study (ANN).

Month	$H_{measured}$	H_{GM}	$H_{Bahel\ et\ al}$	$H_{Reitveld}$	$H_{Allen\ et\ al}$	H_1	H_2	H_3	H_4	H_5	H_{ANN}
January	16.22	17.85	26.58	11.15	12.35	14.86	15.11	15.19	15.24	15.24	16.23
February	17.66	20.95	29.25	13.08	14.18	17.37	17.61	17.59	17.40	17.40	17.66
March	18.22	21.29	27.27	13.30	14.59	17.69	17.97	18.01	18.03	18.03	18.22
April	18.08	22.65	30.91	14.14	15.38	18.79	19.06	19.05	18.92	18.92	18.10
May	17.28	21.89	28.69	13.67	14.95	18.18	18.46	18.48	18.46	18.46	17.27
June	16.16	19.19	20.28	12.00	13.54	16.04	16.28	16.45	16.34	16.34	16.17
July	14.70	17.45	15.00	10.92	12.68	14.66	14.79	14.88	14.57	14.57	14.74
August	14.18	16.76	12.70	10.49	12.39	14.13	14.17	14.09	14.23	14.57	14.17
September	16.62	20.46	24.14	12.79	14.20	17.04	17.33	17.43	17.49	14.23	16.61
October	17.88	21.49	30.50	13.42	14.51	17.81	18.04	18.02	17.77	17.77	17.88
November	18.36	22.12	37.74	13.81	14.55	18.24	18.29	18.42	18.36	18.36	18.31
December	16.42	18.26	24.06	11.41	12.47	15.17	15.40	15.42	15.39	15.39	16.41

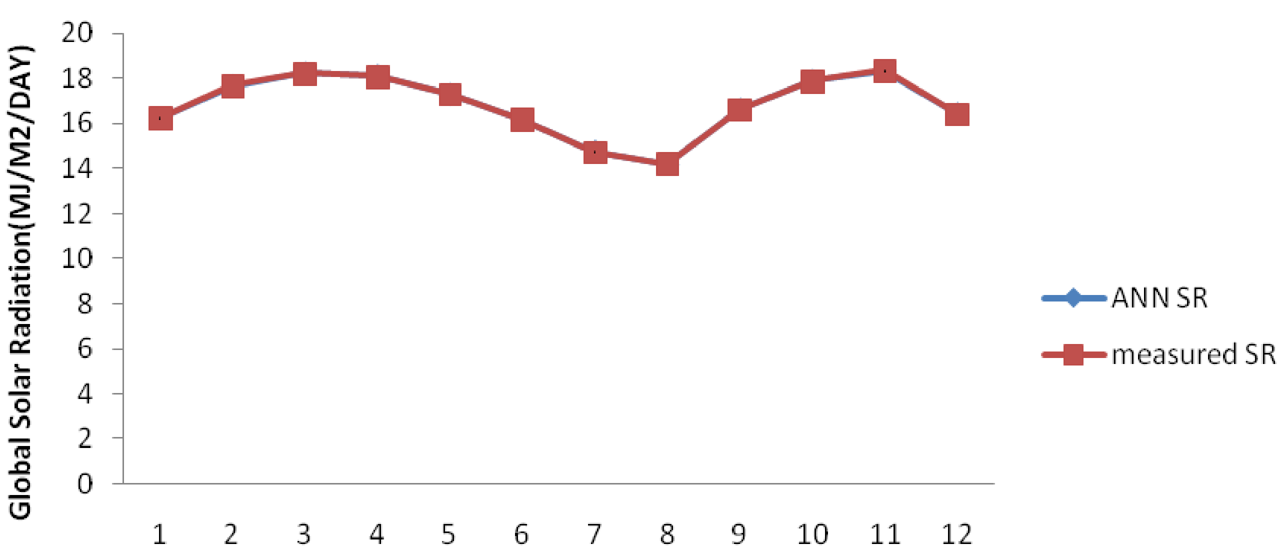

Figure 2. graph of measured and ANN of global solar radiation.

Table 4. Error estimation of various models from the measured values of the monthly global solar radiation.

Error	H_{GM}	$H_{Bahel\ et\ al}$	$H_{Reitveld}$	$H_{Allen\ et\ al}$	H_1	H_2	H_3	H_4	H_5	H_{ANN}
MBE	3.21	8.87	-4.30	-3.00	-0.15	0.06	0.10	0.03	0.03	-0.00083
MPE	19.01	50.09	25.63	17.72	0.94	0.30	0.55	0.15	0.15	1.7708E-05
RMSE	3.338	10.357	4.330	3.088	0.665	0.661	0.656	0.648	0.648	0.001294
CC	0.794	0.826	0.791	0.633	0.927	0.928	0.929	0.932	0.932	0.997

radiation of Minna. Table 4 shows the mean bias error, mean percentage errors and root mean square error, correlation coefficient (CC) from our model and that of the other models The mean percentage errors from the models of Glover et al. (1958) (H_{GM}), Bahel et al. (1887) ($H_{Bahel\ et\ al}$), Rietveld (1978) ($H_{Reitveld}$), Allen et al. (1998) ($H_{Allen\ et\ al}$,), H_1, H_2, H_3, H_4, and H_5 are, respectively 19.01, 50.09. 25.63, 17.72, 0.94, 0.30, 0.55, 0.15 and 0.15, while in our model, the corresponding mean percentage errors is 1.7708E-05. Close examination of Table 4 shows that the values of Agbo et al. (2010) and our model for mean percentage error is less than 1%, but our model has smaller mean percentage error which is 0.000017708, almost zero percent compared to the smallest value of Agbo et al. (2010) which is 0.15, respectively. The smallest value of RMSE for other models is 0.648, while our model is 0.001294, respectively.

Conclusion

The predicting ability of the models was accessed using mean bias error (MBE), mean percentage error (MPE) and root mean square error (RMSE). The results clearly show that other models have predicting capacity, but our model can better predict the global solar radiation. It is therefore, recommended by this result that the prediction of global solar radiation of Minna and areas that have similar climate conditions with Minna should be estimated using ANN.

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REFERENCES

AbdulAzeez MA (20011). Artificial neural network estimation of global solar radiation using meteorological parameters in Gusau, Nigeria. Scholars Res. Library, 3(2): 586-595.

Agbo GA, Baba A, Obiekezie TN (2010). Empirical models for the correlation of monthly average global solar radiation with sunshine hours at Minna, Niger State, Nigeria, J. Basic Phys. Res., 1(1): 41-47.

Allen RG, Pereira LS, Raes D, Smith M (1998). Crop evaporate transpiration Guideline for computing crop water requirement. FAO Irrigation and Drainage Paper 56. Rome, Italy, p. 290.

Augustine C, Nnabuchi MN (2009). Correlation between sunshine hours and Global solar radiation in Warri, Nigeria. Pac. J. Sci. Technol., 10(2): 574-579.

Bahel V, Bakhsh H, Srinivasah R (1887). A correlation for estimation global solar radiation. Energy, 12: 131-135.

Glover, McCulloh GJ, McCulloh F (1958). The empirical relationship between solar radiation and hours of sunshine. QJR Met. Soc., 84(359): 56-60.

Medugu DW, Yakubu D (2011). Estimation of mean monthly global solar radiation in Yola – Nigeria using angstrom model. Adv. Appl. Sci. Res., 2: 414- 421.

Rietveld MR (1978). A new method for estimating the regression coefficients in the formulae relating solar radiation to sunshine. Agric. Meteorol., 19(3): 243-252.