Comparison of Angstrom-Prescott, Multiple Regression and Artificial Neural Network Models for the Estimation of Global Solar Radiation in Warri, Nigeria

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Abstract

In this paper, the application of artificial neural network, Angstrom-Prescott and multiple regressions models to study the estimation of global solar radiation in Warri, Nigeria for a time period of seventeen years were carried out. Our study based on Multi-Layer Perceptron (MLP) of artificial neural network was trained and tested using seventeen years (1991-2007) meteorological data. The error results and statistical analysis shows that MLP network has the minimum forecasting error and can be considered as a better model to estimate global solar radiation in Warri compare to the estimation from multiple regressions and Angstrom-Prescott models.

Index terms— Artificial neural networks, multiple regression, Angstrom-Prescott, prediction, troposphere, Multi-layer perceptron.7

1 Introduction

he troposphere is the lower layer of the Earth's atmosphere. Most of the weather phenomena, systems, convection, turbulence and clouds occur in this layer, although some may extend into the lower portion of the stratosphere. The troposphere contains almost all the atmospheric water vapour. It contains about 70 to 80 percent of the total mass of the earth's atmosphere and 99 per cent of the water vapour.

Temperature and water vapour content in the troposphere decrease rapidly with altitude and thus most of the water vapour in the troposphere is concentrated in the lower, warmer zone. Water vapor concentrations vary with latitude. The condition of the atmosphere as dictated by the sun is very dynamic both in space and time scales. The resulting solar interactions on the atmosphere leads to changes in weather as well as the so called climate change.

2 Year

The objective of this study is to model the relevant data provided by the Nigerian Meteorological Agency, Federal Ministry of Aviation, Oshodi, Lagos, Nigeria as shown in Table 1 and the global solar radiation data collected from Renewable Energy for Rural Industrialization and Development in Nigeria using the Angstrom-Prescott, statistical technique (multiple regression model) and the artificial neural networks (ANN), and then comparing the results of these three models along with the measured solar radiation data. The table below (Table1) shows the atmospheric parameters in preparation of the prediction.Ibeh G.F ? , Agbo G.A ? , Oboma D.N ? , Ekpe J.E ? , & Odoh S II.

3 Methods and procedures Multiple regressions

Regression method is one of the most widely used statistical techniques Mendenhall and Beaver (1994) and Sharda, and Patil (1990). Multiple regression analysis is a multivariate statistical technique used to examine the

relationship between a single dependent variable and a set of independent variables. The objective of the multiple regression analysis is to use independent variables whose values are known to predict the single dependent variable (Olaniyi, 2011). The effect of independent variables on the response is expressed mathematically by the regression or response function f:y = f (x 1 , x 2 , ?, x n ; ?? 1 , ?? 2 , ?, ?? n) (1)

where y is the dependent variable.

? 1 , ? 2 , ?, ? n in the regression parameters which will be determined

The regression model for the observed response variable is written as?? = ?? + ?? = ð ??"ð ??" ??? 1, ?? 2, ? , ?? ?? ; ?? 1, ?? 2 , ? ?? ?? ? + ?? (**2**)

Where ?? is the error in observed value z (Olaniyi, 2011).

To find unknown regression parameters {?? 1, ?? 2 , ? ?? ?? }, the method of least squares **??** Beenstock, 1992) can be applied:E (?? 1, ?? 2 , ? ?? ??) = ? (?? ?? ? ?? ??) 2 = ? (?? ?? ? ð ??"ð ??" (?? 1 ?? 2 , ? , ?? ?? ; ?? 1, ?? 2 , ? ?? ??)) 2**(3)**

Where E (?? 1, ?? 2 , ? ?? ??) is the error function or sum of squares of the deviations.

To estimate ?? 1, ?? 2 , ? ?? we minimize, E, by solving the system of equations:???? ???? 1 = o, ?? = 1,2, ? , ??**(4)**

4 a) Model Specification and Analysis

The regression model to consider in this study takes the maximum temperature (Tm) and sunshine hour (?? ?) as the explanatory variables and measured values (?? ??) as dependent variable. This is used to obtain a reliable parameter estimates in the regression. The model to be used can be specified as?? ?? = f (?? ?? , ?? ?) (5)

More precisely;?? ?? = ?? 0 + ?? 1 ?? ?? + ?? 2 ?? ? (6) ? 0 , ? 1 , ? 2 > 0 III.

5 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; **??**nd 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 The monthly mean daily extraterrestrial radiation ?? ? ?? and monthly mean day length ?? ? was derived from the formulae: ?? ? ?? = 24 ?? ?? ???? ?? ?? [?? ?? sin ?? sin ?? + cos ?? cos ?? cos ?? ??] ?? ??? = 2 25 COS-1 (-tan ? tan ?)**(9)**? = 23.45 sin [??+284 365]**(10)**?? ?? = COS -1 (-tan ? tan ?)**(11)**

IV.

6 Artificial neural network model

Artificial neural network models are based on the neural structure of the brain . The brain learns from experience and so do artificial neural networks. Previous research has shown that artificial neural networks are suitable for pattern recognition, prediction and pattern classification tasks due to their nonlinear nonparametric adaptive-learning properties. As a useful analytical tool, ANN is widely applied in analyzing the data stored in database or data warehouse nowadays (Massie, 2001). One critical step in neural network application is network training. Generally, meteorological data is selected and refined to form training data sets. Artificial Neural Network is widely used in various branches of engineering and science and their unique proper of being able to approximate complex and nonlinear equations makes it a useful tool in quantitative analysis (Olaniyi, 2011).

The true power and advantage of neural networks lies in their ability to represent both linear and Traditional linear models are simply inadequate when it comes to modeling data that contains non-linear characteristics. In this paper, one model of neural network is selected among the main network architectures used. The basis of the model is neural structure as shown in Fig. 1. These neurons act like parallel processing units.

7 a) Multi-Layer Perception

The most popular network architecture in use today is perhaps the Multilayer Perceptron network and it uses supervised network (Hair and Tatham, 1998). This type of neural network is known as a supervised network because it requires a desired output in order to learn. The goal of this type of network is to create a model that correctly maps the input to the output using historical data so that the model can then be used to produce the output when the desired output is unknown. Figure 1 show the block diagram of a double hidden layer multiplayer perceptron (MLP). The inputs are fed into the input layer and get multiplied by interconnection weights as they are passed from the input layer to the hidden layer. Within the hidden layer, they get summed then processed by a nonlinear function (usually the hyperbolic tangent).

If more than a single hidden layer exists then, as the processed data leaves the first hidden layer, again it gets multiplied by interconnection weights, then summed and processed by the second hidden layer and so on. Finally the data is multiplied by interconnection weights then processed one last time within the output layer to produce the neural network output.

An artificial neuron is a unit that performs a simple mathematical operation on its inputs and imitates the function of biological neurons and their unique process of learning . The weighted sum of the inputs are calculate

using the following equation, (7) Where v k is the weight sum from the kth hidden node, ?? ???? is the weight on connection from the jth to the kth node; x j is an input data from input node; m is the total number of input (N=17); and b k denotes a bias on the kth hidden node.

The mathematical structure of the normal method is as shown in fig. 2 Output layer Hidden layer Input layer V.? ? ? ? ? ? (D D D D) D

8 Results and discussions

Table 2 is obtained from the SPSS output for the analysis of the multiple linear regressions relating the measured values of global solar radiation as a function of the maximum temperature (Tm) and the sunshine hour (n). The standard error for each of the variables is indicated in the table 3. From figure 1, the highest value of solar radiation is 18.16 and 18.11MJ/M 2 /Day respectively. These results suggest that there is peak dry season in Warri during December and April when the solar radiation is high. Again, the low values of solar radiation occur from May to August, which indicates peak rainfall Warri when the sky is cloudy and solar radiation is low.

9 Conclusion

In this paper, three techniques for modeling and forecasting the solar radiation of Warri Nigeria: Neural Network, Angstrom-Prescott and Statistical Technique. The forecasting ability of these models is accessed on the basis of MBE, RMSE and MPE. We have discovered the fact that Neural Networks output perform better in forecasting from table 2 and 3 compare to other two models. Thus, ANN should be used for prediction of global solar radiation of the location and other location that has similar condition.

10 ERROR ANN REGRESSION

11 ANGSTROM-PRESCOTT

Figure 1:

$$v_k = \sum_{j=1}^{m} x_j w_{kj} + b_k$$

Figure 2:

1

T Month	?? ? Hour	T m ?	(D D D D) D ?? ? ?? (MJm 2 day -1)
JAN	4.72	33.00	12.52
FEB	4.80	33.68	14.26
MAR	4.61	33.45	15.64.
APR	4.92	32.86	18.11
MAY	4.89	31.93	12.84
JUN	3.86	30.53	13.99
JUL	2.27	28.77	14.67
AUG	2.31	28.89	13.85
SEPT	2.57	29.99	15.40
OCT	4.15	31.28	16.55
NOV	5.23	32.74	15.81
DEC	5.66	32.66	18.16

Figure 3: Table 1 :

2

Variable Coefficient	Std.	Std. Error	t-statistic Prob.	
Tm	-0.362	0.656	-0.461	0.785
?? ?	0.966	0.428	0.830	0.617
Constant	22.591	0.301	1.098	0.000

Figure 4: Table 2 :

3

Figure 5: Table 3 :

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