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# Comparative Study of Multiple Regression Model with Curvefit Model for The Prediction of Solar Radiation in Mubi Town Adamawa State, Nigeria

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**ABSTRACT**

The sun emits solar radiation, which is critical for researchers working on renewable energy technology that provides ecologically favorable power systems. This research created a new model to forecast DHSR for the Mubi metropolitan area in Adamawa State, Nigeria. Data for this study were obtained from the National Aeronautics and Space Administration (NASA) over a 22-year period (2000 – 2021). When DHSR was employed as an output, the requested values were air temperature (Tai) and relative humidity (Rhi). The MATHLAB curve fitting program was used to create the new DHSR mathematical model. The model was validated using five statistical methods in this study: MSE (mean square error); SSE (sum of square errors); RMSE, Chi-square error (X2), and the absolute fraction of variance (R2) are 0.0005, 0.0064, 0.0231, 0.0011kWh/m2/day, and 0.9998, respectively.

**KEYWORDS**

Solar radiation
Curvefit model
Air temperature
Relative humidity
Mubi town and NASA

## INTRODUCTION

The sun provides infinite solar energy (electromagnetic power); however, the world receives only a part of what the sun produces as it emits 38 x 107EW energy, and the Earth receives 0.17EW, which is beneficial to life. According to [1], the sustenance of life on Earth primarily depends on the sun's temperature. The sun has 60M/m2 of solar power. However, the Earth only receives 1325MW/m2 to 1418MW/M2 power with an average value of 1367MW/M2, which is referred to as the solar constant [2]. According to Shahsavari and Akbari and Soonmin et al. [3], [4], Australia receives the most solar radiation (4-6kwh/m2) of any continent, and it is further explained that in terms of everlasting energy resources that are environmentally friendly, solar radiation (energy) offers the best possible solution. Solar energy has received much attention. Not only is it sustainable, but it is also abundant and environmentally beneficial [5], [6].

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According to Raji et al. [6], the sun's heat and light produce solar energy, which is very clean, inexpensive, and widely available. They also claimed that these two elements are the building blocks of fossil fuels. Renewable energy is widely available, and its use is essential, particularly at the moment when fossil fuel prices are rising. Global warming has emerged as a problem that affects everyone on Earth. The solar radiation in northern Nigeria is higher than the levels advised for concentrating solar power technology, ranging from 6 to 7.5 kWh/m2/day [7]. From Nigeria's coastline region to its northern region, the average solar energy intercepted ranges from 3.4 to 7.0 kWh/m2/day [8]. Similarly, solar energy incident to the Nigerian surface Earth fluctuates at coastal Zones (12.6MJ/m2/day and 25.2MJ/m2/day in the northernmost parts). The northern portions of Nigeria have higher solar radiation on the horizontal surface whenever the sun is incident on them, according to Owolabi et al. [9], and this study concluded that these regions have the higher feasible (viable) potential for solar power plants [9], [10].

Kumar et al. [11] performed a techno-economic analysis of Malaysia's 1MWP grid-connected solar power plant. The authors used two separate solar radiation databases for their modeling: PVWatt and PVGIS. Olatomiwa et al. [12] predicted the potential of solar radiation in Nigeria using support vector regression (SVR). This project developed the model with observed meteorological data from the Iseyin meteorological station. Based on the coefficient of determination values, they determined that SVR predicted better than radial basis function (RBF). Raji et al. [13] developed a preliminary assessment model of global solar radiation in the Maiduguri meteorological station. The authors tested multiple models in micro-Excel 2013 using statistical tools such as standard deviation, variation, and coefficient of determination (R2). They concluded that the logarithmic model predicted better than other models with the highest R2 and the lowest values of deviation.

Feed Back Propagation Neutral Network (FBPNN) for estimating monthly average solar radiation in northern Nigeria (Gusau). Sunshine hours, ambient temperature, and relative humidity were employed as inputs, and the entire result was solar radiation. After employing statistical methods such as mean percentage error, root mean square error, and statistical analysis of regression, their results indicated good agreement between the predicted and observed values [13]. Multiple regression (MR) and artificial Neutral Network (ANN) capacity were reported in recent machine learning studies and construct equation among data set, making them adequate for swift estimation and more appealing for many engineering applications. However, little study has been conducted on curve-fit models, which offer the best ability to handle large amounts of data in linear and complicated non-linear formats and find plausible relationships between dependent and independent variables. As a result, this research aims to create a new model to estimate daily horizontal solar radiation using two parameters: temperature and relative humidity, and to compare it to the MR model provided in 2020.

## MATERIALS AND METHOD

### Study Area

The majority of the towns and cities in Nigeria's Northeast with substantial population densities lack access to metrological stations or are too far away from them. Mubi is a settlement in the

Northeast, between latitude 10.27°N and longitude 13.28°E. It has a land area of 4728.77km2, a population of 759045 in 2003, and an elevation of 580m above sea level on average [14]–[16].

## Weather Data Resources

The data used in this study were secondary data obtained from the NASA website, and any relevant non-climate data were obtained from any relevant online or print publications. These data were collected and compiled in tabular form from January to December, as shown in Figure 1. The values received as input for the new model include air temperature (oC) and relative humidity (%), while the DHSR (kWh/m2/day) functioned as output. Figure 1 displays the data from which the new model was created using curvefit (CF) in Mathlab 2019. Input and output pairs are submitted to the CF, and the weights are automatically changed to minimize the difference between the output and the actual NASA numbers. Once training is complete, a new set of data can be predicted using the previously trained network.

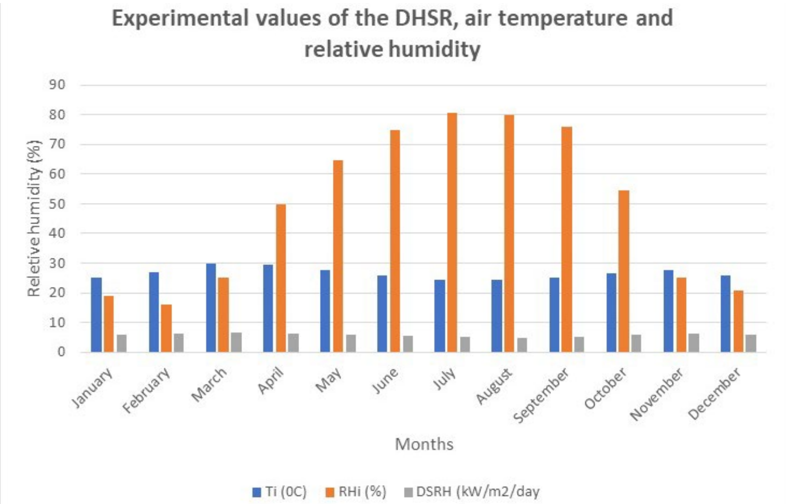


Figure 1. Experimental values of the DHSR, Tai and Rhi

## Curvefit modelling

Curve fitting is a tool that allows to fit a curve interactively. Using a best fit model, Mathlab curve fitting is used to build a mathematical relationship between dependent and independent data. According to Ciu et al. [17], the cubic smoothing spline estimate of the function is defined as the error minimizer, as shown in equation 1.

$$P_s \sum_{i=1}^{n} (y_i - \hat{s})^2 + (1 - P) \int \lambda(x)/d^2\hat{s}(x)/^2 dx \tag{1}$$

This numerical technique is used to replace a limited amount of lost DHSR data with their equivalent approximation, where Ps is a smoothing value that is data dependent. Equation 2 expresses the expected value of $Y_i$ as an nth-degree polynomial.

$$Y_i = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + \cdots + a_n x^n \tag{2}$$

An equation of the sum of the square of the residuals Ri is expressed in equation 3.

$$R_i = [S(x_1) - Y_1]^2 + [S(x_2) - Y_2]^2 + [S(x_3) - Y_3]^2 + \cdots + [S(x_i) - Y_i]^2 \tag{3}$$

The minimum value of $R_i$ can be determined by taking the partial derivatives of $R_i$ concerning $a_1, a_2, a_3, \cdots\ a_n$ and equating them to zero given in equations 4–7.

$$\frac{dR_1}{dA_1} = 0 \tag{4}$$

$$\frac{dR_2}{dA_2} = 0 \tag{5}$$

$$\frac{dR_3}{dA_3} = 0 \tag{6}$$

$$\frac{dR_i}{dA_i} = 0 \tag{7}$$

This yields a system of equations with unknowns $a_1, a_2, a_3, \cdots\ a_n$. The solutions to the aforementioned equations provide the values of the polynomial coefficients that best fit the DHSR profiles. Equation 8 is the non-linear least squares problem for determining coefficients (Cb, Cv, Ca and Co) by data fitting.

$$\min_x \parallel S(x, x_{data}) - Y_{data} \parallel_2^2 = \min_x \sum_i^n \left(S(x, x_{data,i}) - Y_{data,i}\right)^2 \tag{8}$$

Where $x_{data}$ and $Y_{data}$ are vectors $DHSR, data$ and $S(x, x_{data})$ is a matrix valued of the same size as $y_{data}$ (model data).

The curve fit approach is utilized for training the network in this study because it can successfully predict any non-linear relationship with a high level of accuracy [18], [19].

## Validation of the model

The experimental value and the newly generated model of DHSR produced by curve fitting will be compared with Raji et al. [6] paper presented. To validate error, five statistical methods were used: mean square error (MSE), the sum of square error (SSE), roots mean square error (RMSE), chi-square error (x2), and the absolute percentage of variance (R2). The equations were provided in the order 9 -13.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(a_i - p_i)^2 \tag{9}$$

$$SSE = \sum_{i=1}^{n}(p_i - a_i)^2 \tag{10}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(p_i - a_i)^2}{n}} \tag{11}$$

$$chi\ square\ error, x^2 = \frac{\sum_{i=1}^{n}(p_i - a_i)^2}{p_i} \tag{12}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(p_i - a_i)^2}{\sum_{i}^{n} p_i} \tag{13}$$

Where ai (kWh/m2/day) is the actual/experimental value, pi (kWh/m2/day) is the predicted values (CF output values), and n is the number of the data.

## RESULTS AND DISCUSSION

In this prediction investigation, Mubi town data was obtained from Raji et al. [6] and utilized to predict a new model. In this work, the physical characterization of the DHSR (output) contains two inputs: air temperature ($T_{ai}$) and relative humidity ($R_{hi}$). These two parameters serve as the fundamental for this empirical model. Thus, the expression in equation 14 represents a CF mathematical model that utilizes the physical components of Mubi town's weather condition data.

$$\begin{gathered} DHSR = P_0 + P_1 T_{ai} + P_2 R_{hi} + P_3 {T_{ai}}^2 + P_4 (T_{ai})(R_{hi}) + P_5 (R_{hi})^2 + P_6 (T_{ai})^3 \\ + P_7 (T_{ai})^2 (R_{hi}) + P_8 (T_{ai})(R_{hi})^2 + P_9 {R_{hi}}^3 \end{gathered} \tag{14}$$

Figure 2 compares the previously predicted DHSR model values multiple linear regression (MLR) model values by Raji et al. [6] with measured data values. To compare these models and justify the applicability of the fitted model, as well as to determine the adequacy of the field data, which established high model reliabilities for accurate prediction of Mubi town's DHSR [20]. Five statistical methods were employed in this investigation, as shown in equations 9-13. The results of this study region demonstrated that the field data curve between the upper and lower bound curves trended at 95% confidence bound, which further enhanced the validity of the model reliabilities and adequate justification of the field data. In terms of MSE (1.61) and R2 (0.95), equations 9-14 revealed 0.00056, 0.1064, 0.0231, 0.0011, and 0.9998 correspondingly. The result obtained in this study is slightly better than the result reported by Raji et al. [6].

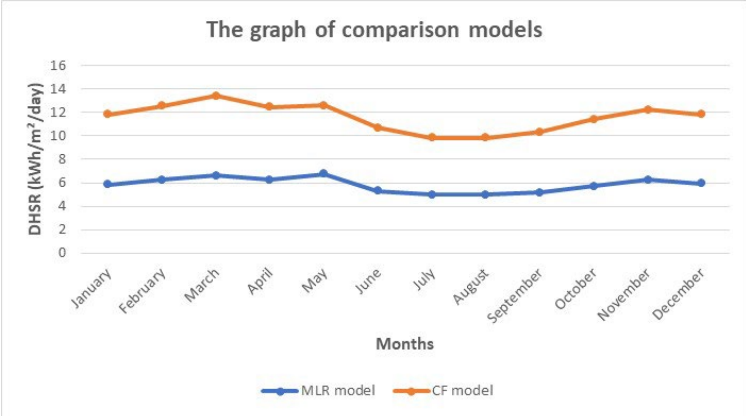


Figure 2. Comparison of predicted MLR Model and new model (CF model)

According to Azad et al. [21], the best results are produced when the error(s) values are close to zero, which agrees with the new model's results. R2 determines the linear relationship between predicted values and experimental/measured data values. These result values indicate that the model has strong predictive power, as evidenced by a tendency of very low errors as the value of R2 approaches one [6], [21], [22]. The level of any region is fundamental to its economic growth, transforming a community from an agrarian to an industrial one. Therefore, the implication of DHSR is her industrial development. The DSRH of this Mubi town can help to raise the level of industrialization of the town if used liberally to produce the stability of power generation through photovoltaic systems both in stand-alone and grid configurations.

## CONCLUSION AND RECOMMENDATION

In this study, the new DHSR model was developed and presented using Mubi town weather data using a curve fitting approach and compared to existing models [6]. Five statistical tools were utilized to compare the model to meet the primary goals of this study. It should be recommended that any of these statistical techniques can be used namely: SSE, MSE, RMSE, chi-square error, and R2, is adequate for ranking models; however, analysis utilizing all of these methods for ranking models is more precisely recommended. The results revealed that the CF technique is more efficient for determining the values of DHSR to fit the measured data curve. The results also demonstrated that, in terms of capacity prediction, the CF model predicted better results than the MLR result [6]. One alternative and useful way for determining the true DHSR value of Mubi town is the CF model. For the engineering and socio-economic development of the town, this novel prediction model of the DHSR of the study area (Mubi town) is a helpful tool. In this study, we recommended any further investigation of this new model's (DHSR) prediction, and only Mubi town weather data was considered. Other researchers can take the challenges to look at the behaviors of this model at any other location in Northeast Nigeria to look at capacity and boost its confidence in predicting DHSR models.

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