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Validation of Global Solar Radiation (GSR) Data Using Artificial Neural Networks (ANN) for Estimation of GSR in Nigeria for Solar Energy Applications

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Abstract

The potential use of ANN in this study is to validate the collected Global Solar Radiation (GSR) data with results obtained from ANN for prediction of solar global radiation for our stations and any other locations where solar energy is required. The written computer codes were used to carry out the analysis and the simulation carried out using MATLAB software. The ANN model indicates good training performance with RMSE value of 0.0371 MJ/m^2/day and standard deviation of 1.955 x 10^{-4}MJ /m^2/day and R^2 greater than 0.7.

Keywords: Neural Network; Global Solar Radiation; MATLAB software.

1. Introduction

The ANN model is a 3-layer network consisting of two hidden layers. The transfer function (t_f) used are sigmoid and purelin. The sigmoid is a non-layer t_f that transfers data from the input layer to the next hidden layer, while the purelin is a linear t_f that connects the ANN outputs to the preceding hidden layers. It is a branch of artificial intelligence (AI), which belongs to the group of computational algorithms called connectionist models [11]. ANN modeling technique offers a better solution for developing a more generalized model for prediction of solar radiation data using climatological parameters. It is a modeling and prediction tool, widely accepted as a technique offering an alternative way to tackle complex and ill-defined problems [9].

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Technique of ANN has been applied to solving meteorological global solar radiation problems by a number of researchers [6,9,8,13]. The potential use of ANN in this study is to validate the collected Global Solar Radiation (GSR) data with results obtained from ANN for prediction of solar global radiation for our stations and any other locations where solar energy is required.

2. Methodology

The written computer codes were used to carry out the analysis . GSR data were divided into two sets (Training and Testing) for each of the stations according to years of data as shown in Table 1. For these stations, both the training and testing data is a 365×7 matrix, where 365 represents the days of the year and 7 stand for the number of years. The training set was used to train an artificial neural network object while the testing set was used to project the data for the future years. The simulation was carried out using MATLAB software. The properties of the created ANN object are outlined in Table 2. The testing stages of the simulation comprise the Load the testing data, Normalize the data, Simulate the data with the ANN object created in the training stage, Denomalized the predicted ANN output to get back the real data format, Compare the predicted data with the actual data, Compute the mean square error (MSE), standard deviation (SD), and forecast error (the difference between the exact value and predicted value).

Table 1: Training and Testing Data Set

Station	Training data set	Testing data set
Maiduguri	1985 – 1991	1992 – 1998
Kano	1985 – 1991	1992- 1998
Lagos	1985 – 1991	1992 – 1998
Ibadan	1985 – 1991	1992 – 1998

Table 2: The ANN Simulation Parameters

Parameter	Value
Architecture	3-layer (2 hidden layers and 1 input)
Transfer function	{tansig, purelin}
Training function	Levenberg-Marquardt (trainlm)
Training epoch	500
Performance function	Mean-Squared Error (MSE)
Performance goal	1.0E-6

3. Results and Discussions

The result of the ANN training process presents the plot of the regression, which shows the degree of fitness of

the input data to the target output. The regression value of 0.94915 shown on reveals a very good fitting. Figure 1 show the results of ANN analysis for Lagos station. The predicted GSR data matches the actual data for nearly all the days of the year. Figure 2 indicates that the percentage forecast error is within ± 5%, except for few days of the year.

The results obtained for Ibadan station are shown in Figure 3. The predicted values are in excellent agreement with the data for almost all of the days of the year. The percentage forecast errors are also relatively low (Figure 4). The results for Maiduguri station are presented in Figure 5. The simulation results shows higher percentage forecast errors shown in Figure 6 indicates the error margin is between -10 and 5% .Similarly for Kano daily GSR prediction for January to June is shown in Figure 4.23 and the forecast error lies between -15 and 15 % (Figure 7).

The RMSE values and standard deviations (STD) obtained from the testing of the ANN models for all the stations were presented in Tables 1.3a and 1.3b, respectively.

The mean RMSE value for all the stations is 0.0371 $MJ/m^2/day$; while the mean STD is 1.955×10^{-4}. $MJ/m^2/day$ while the errors were presented in Tables 4a and 4b, respectively.

The low values of the mean RMSE and STD indicated a good ANN training performance.

The ANN model was used to simulate the month-by-month global solar radiation also. The picture is bit difference from what is obtained on daily timescale.

The behavior of simulated results and observational data together with the forecast error are presented in Figure 5 for Lagos, Ibadan, Maiduguri, and Kano, respectively.

The forecast errors are within $\pm$5% for all stations. The RMSE values and standard deviations (STD) obtained were presented in Table 5.and Table 6.

The comparison between the observed and ANN GSR model were presented in Figure 6.Figure 10 presented variability of ANN Generated and Observed GSR Values (Left Plots) and Percentage error between the ANN Model Generated and the Observed values (Right Plots) in Selected Stations over Nigeria, over an Annual Cycle.

Table 3a: Root Mean Squared Error (RMSE) Performance of the ANN Model

Station	Training data set	Testing data set
Maiduguri	0.0224	0.1405
Kano	0.0171	0.0487
Lagos	0.0203	0.0234
Ibadan	0.0000	0.0093

Table 3b: Standard Deviation (SD) Performance of the ANN Model

Station	Training data set	Testing data set
Maiduguri	2.4994e-004	3.0800e-004
Kano	1.6250e-004	2.0136e-004
Lagos	2.8691e-004	5.9212e-004
Ibadan	0.2657	1.2443

Table 4a: Root Mean Squared Error (RMSE) Performance of the ANN Model

Station	Training data set	Testing data set
Lagos	0.1409	0.2817
Ibadan	0.1782	0.3054
Maiduguri	0.0945	0.1667
Kano	0.1136	0.1667

Table 4b: Standard Deviation (SD) Performance of the ANN Model

Station	Training data set	Testing data set
Lagos	0.0000	0.0004
Ibadan	0.0528	0.1406
Maiduguri	0.0639	0.1278
Kano	0.0370	0.1561

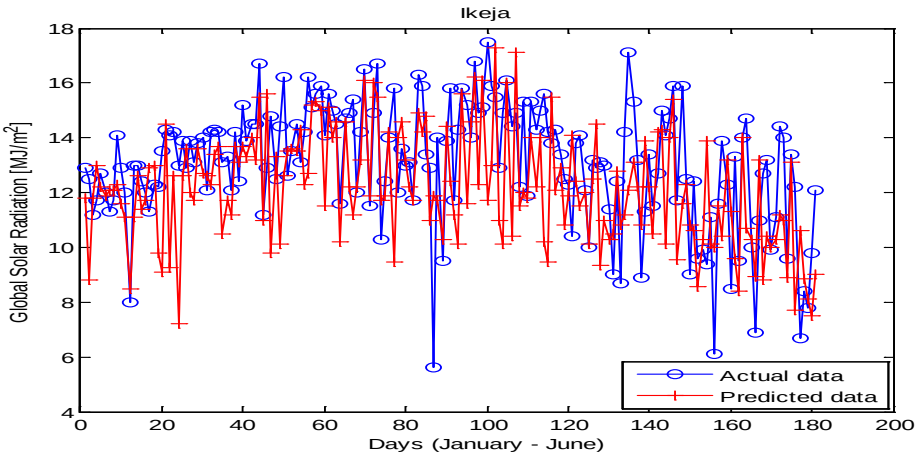


Figure 1: ANN analysis for Lagos station

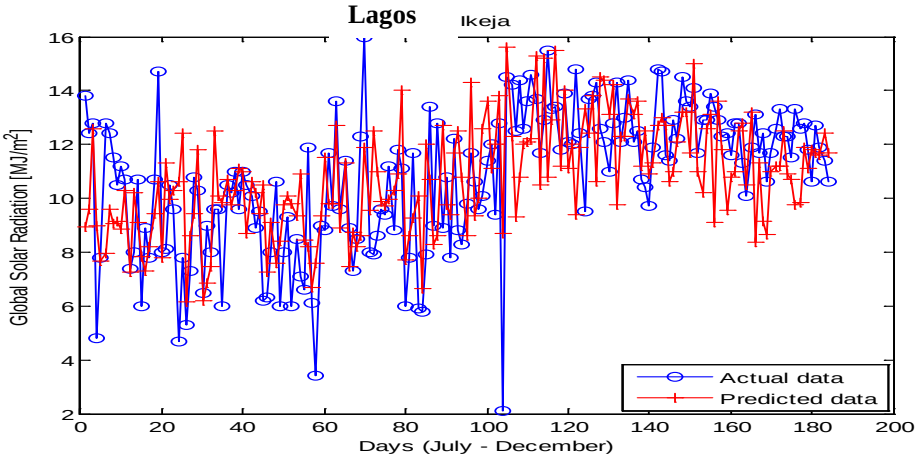


Figure 2: Comparison of GSR ANN Predicted and Observed GSR Data for Lagos

Lagos

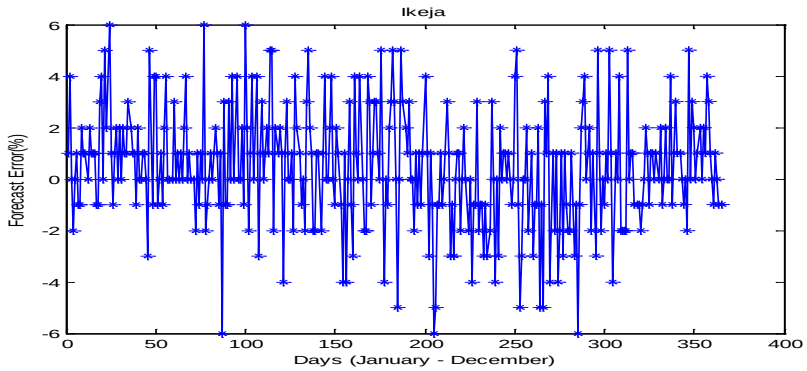


Figure 3: Percentage error between the ANN Model Generated and the Observed values in Lagos

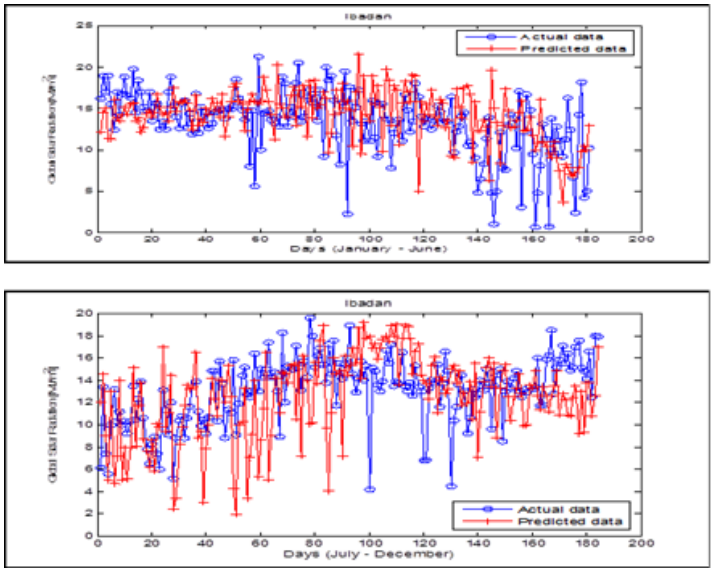


Figure 4: Comparison of GSR ANN Predicted and Observed GSR Data for Ibadan

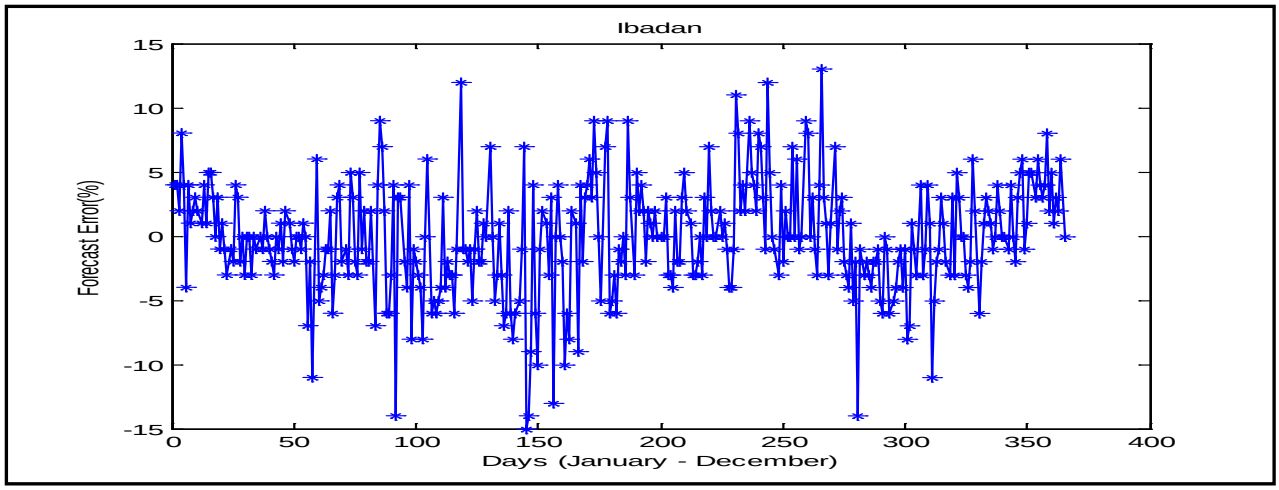
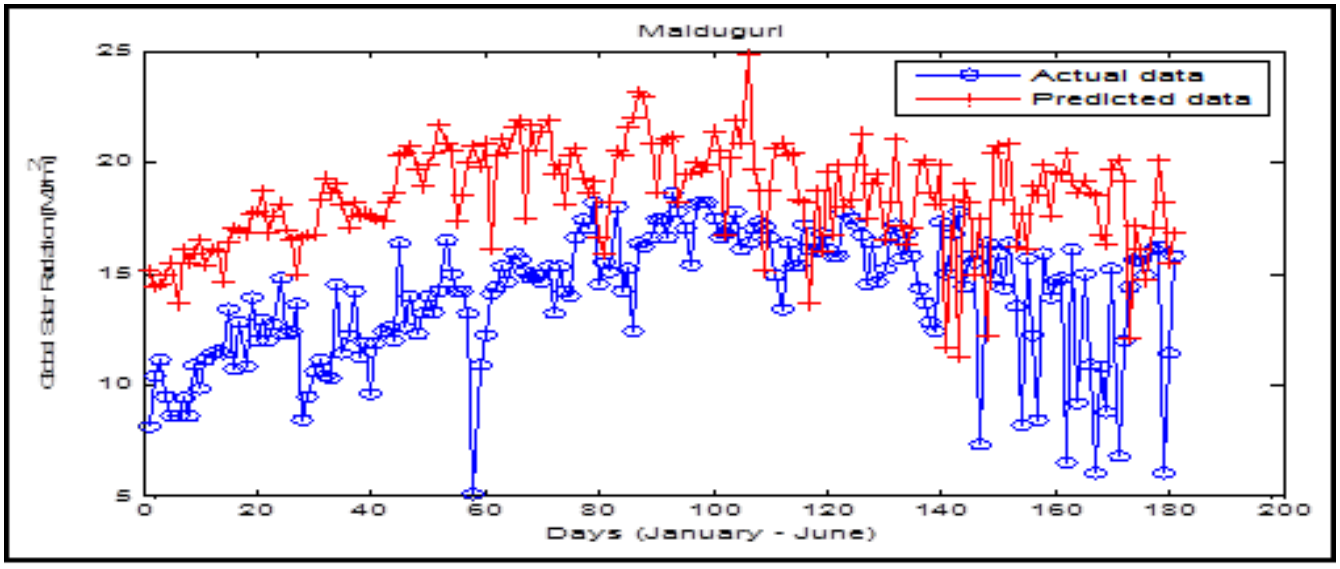


Figure 5: Percentage error between the ANN Model Generated and the Observed values in Ibadan



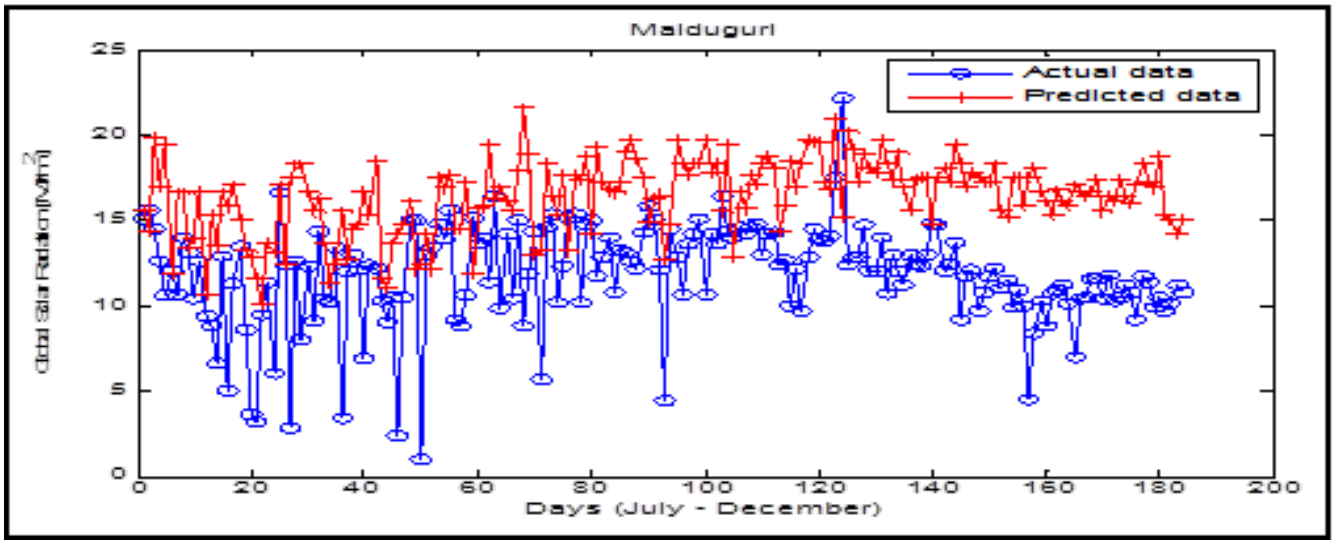


Figure 6: Comparison of GSR ANN Predicted and Observed GSR Data for Maiduguri

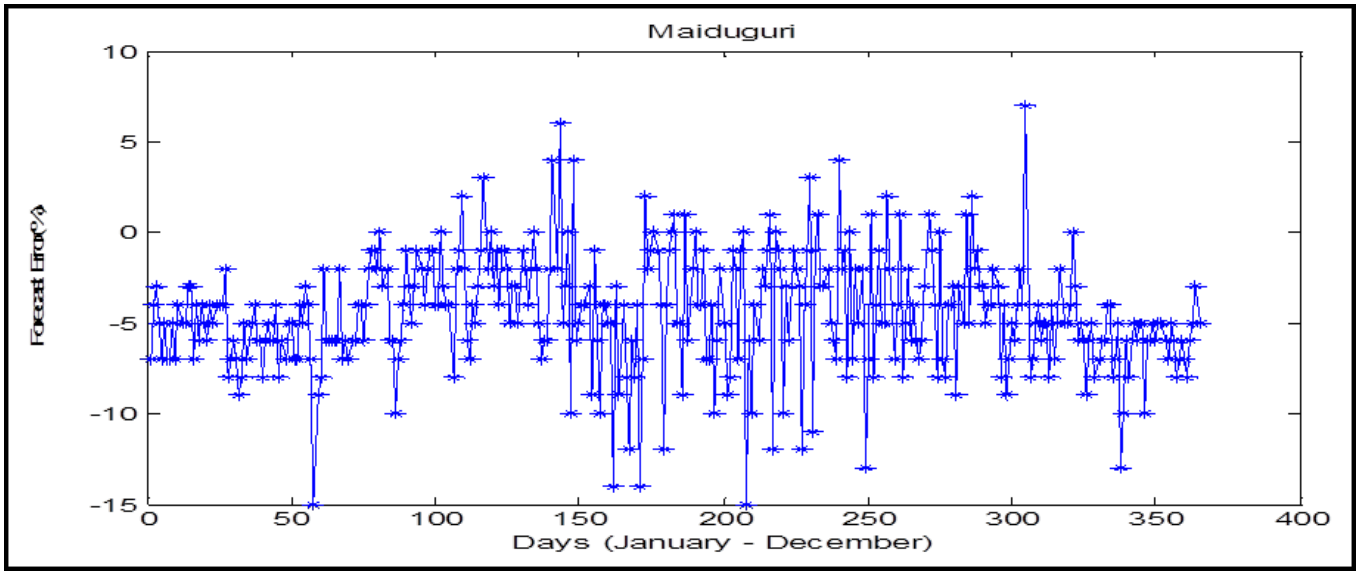


Figure 7: Percentage error between the ANN Model Generated and the Observed values in Maiduguri

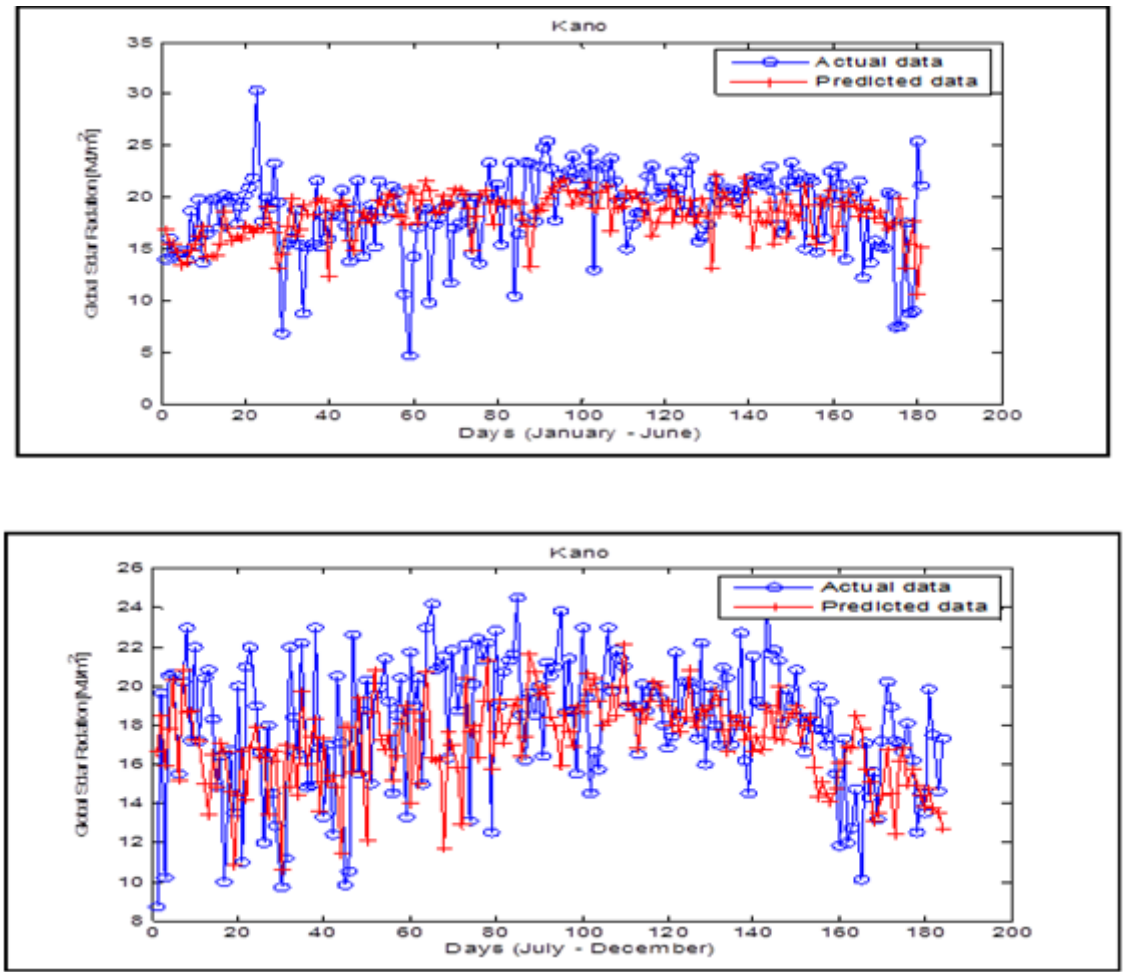


Figure 8: Comparison of GSR ANN Predicted and Observed GSR Data for Kano

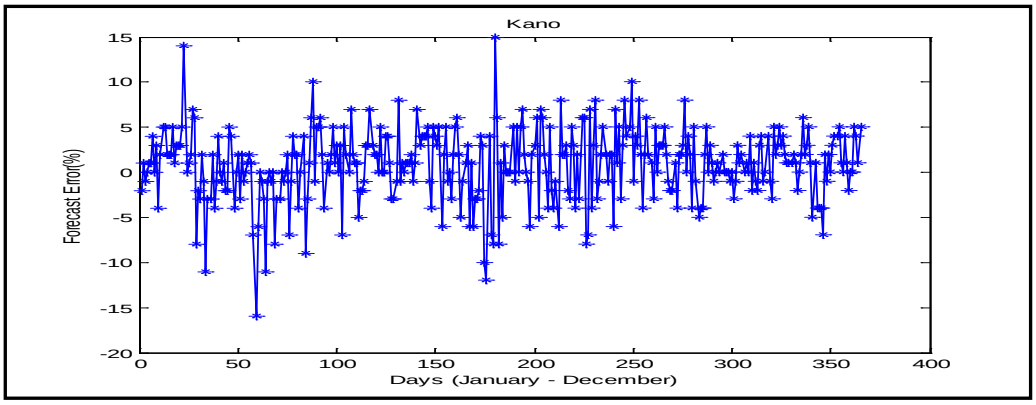


Figure 9: Percentage error between the ANN Model Generated and the Observed values in Kano

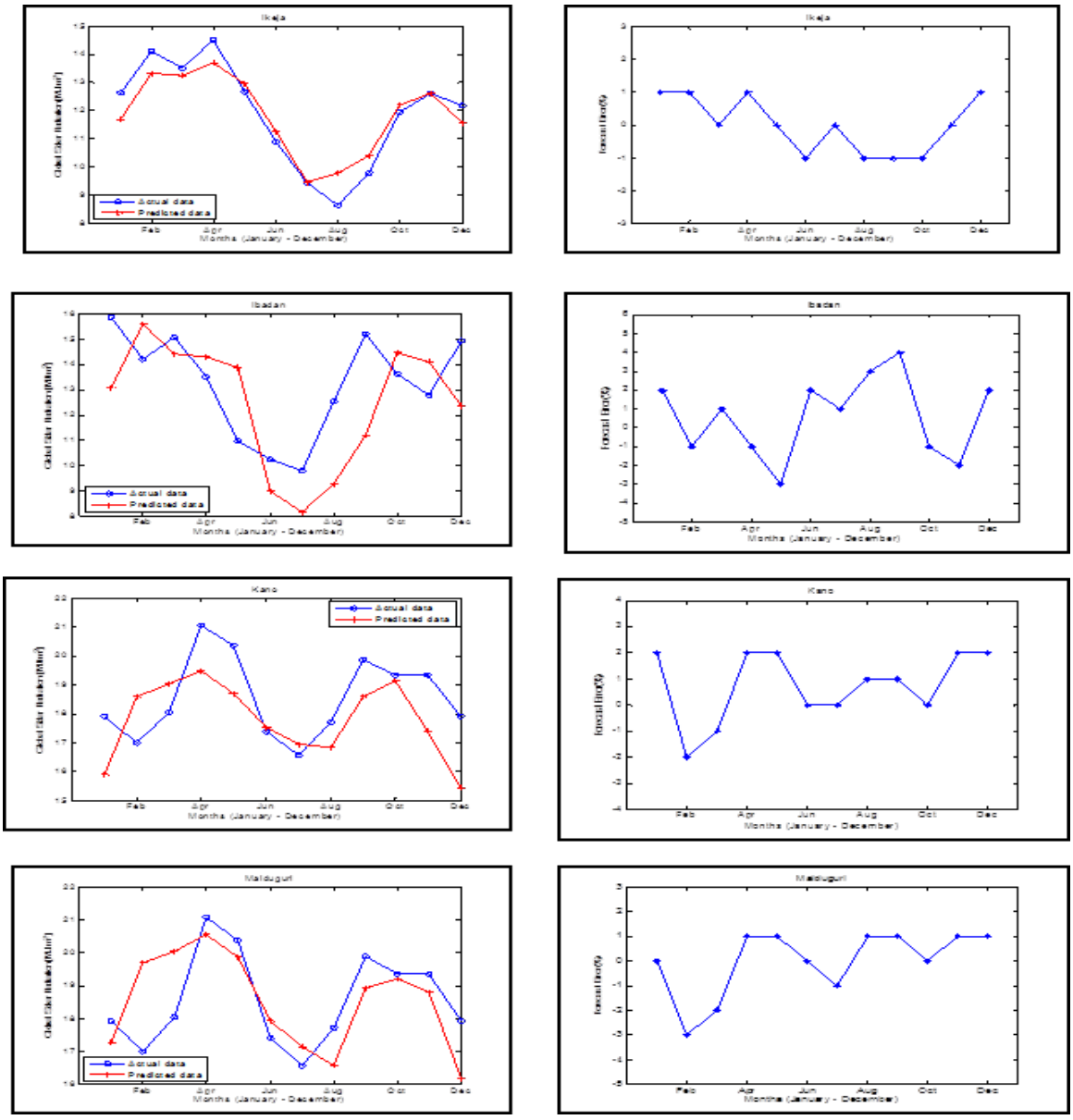


Figure 10: Variability of ANN Generated and Observed GSR Values (Left Plots) and Percentage error between the ANN Model Generated and the Observed values (Right Plots)in Selected Stations over Nigeria, over an Annual Cycle.

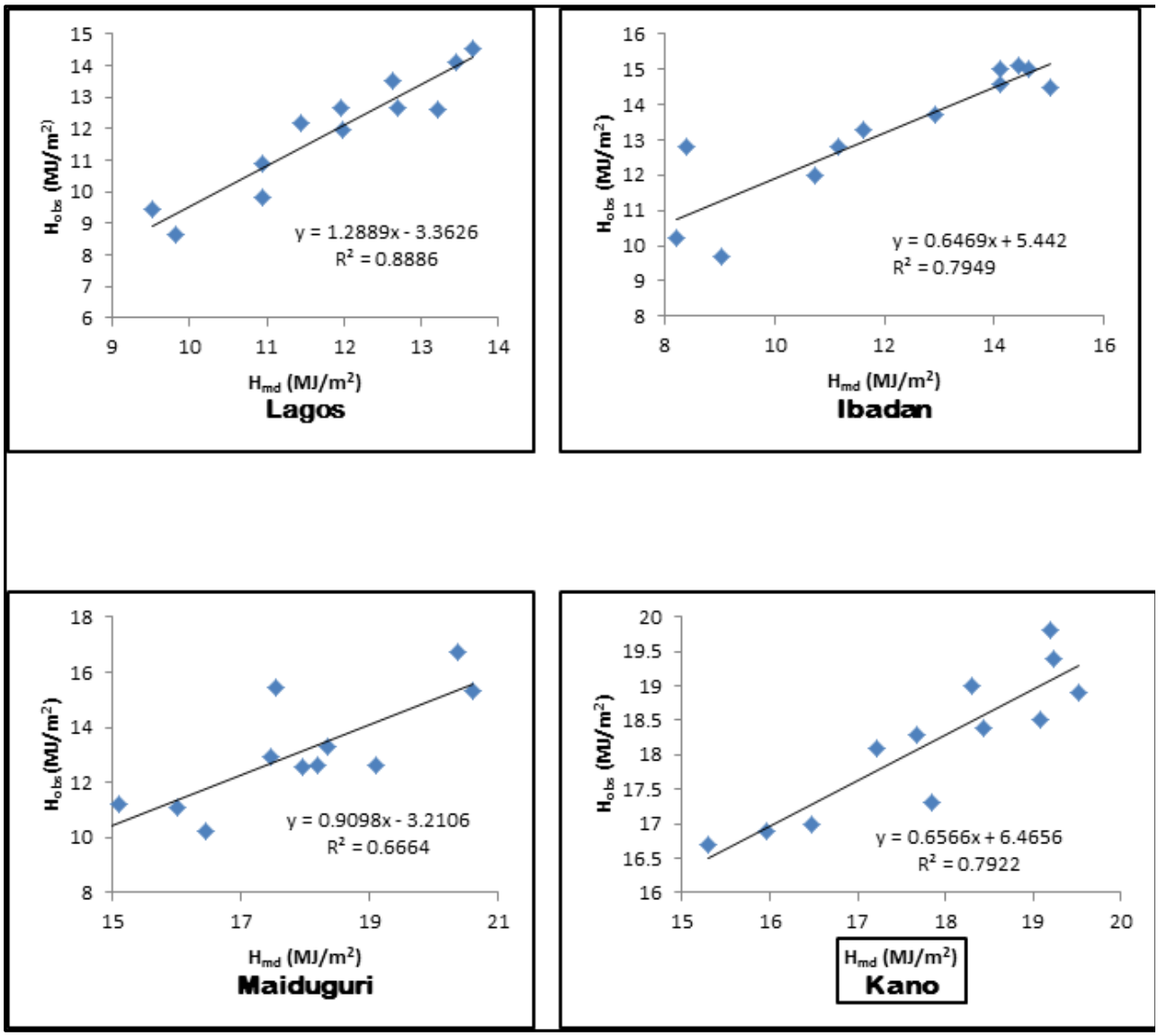


Figure 11: Comparison between observed and ANN Generated GSR Data for Lagos, Ibadan, Maiduguri and Kano

4. Conclusion

The ANN model indicates good training performance with the mean small RMSE value of 0.0371 MJ/m^2/day and standard deviation of 1.955 x 10^{-4}MJ /m^2/day and R^2 approximately greater than 0.7. The model could be used to determine the Global Solar Radiation of any location under study.

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