Temperature Prediction based on Artificial Neural Network and its Impact on Rice Production, Case Study: Bangladesh

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ABSTRACT
Potential rise of global temperature due to climate change has huge impact on rice productivity and above all on food security. The variation of temperature along with diverse climatic phenomena like cyclone, drought and changing rainfall patterns cause significant loss in food grain production every year. Although weather prediction and meteorology is a very complex and imprecise science, recent research activities with Artificial Neural Network (ANN) have shown that it has powerful pattern classification and pattern recognition capabilities which can be used as a tool to get a reasonable accurate prediction of weather patterns. In this paper, an ANN model based on Multilayer Perceptron concept has been developed and trained using backpropagation learning algorithm to estimate the Daily Mean, Maximum and Minimum temperature of Dhaka, capital of Bangladesh..The result shows that Neural Network can be used for temperature prediction successfully.

Keywords: Artificial neural network, Temperature prediction, Backpropagation learning

1. INTRODUCTION
From geographical viewpoint, Bangladesh is an agro based country located in the tropical monsoon region and the climate of Bangladesh can be characterized by high temperature, heavy rainfall, often excessive humidity, and fairly marked seasonal variations.[1] Rice is the staple food of Bangladesh and its production is highly influenced by different seasonal climatic variables such as high fluctuations of day and night temperatures, changing rainfall patterns, high carbon dioxide concentrations, humidity and day-length.[2]

The objective of this study is to develop an ANN based model for temperature prediction for Dhaka, Bangladesh which will be trained and tested using data for the last ten years (January, 2001 to July, 2010).

2. NECESSITY OF FORECASTING IN RICE PRODUCTION
In Bangladesh, about 70% of the cultivable land is used to grow rice which is about 94% of the total crop production. Crop losses can be cut down considerably through timely and precise forecasting of temperature. Temperature forecasting may provide effective guidelines for seasonal planning and choice of best suited crops to the anticipated climatic conditions. It may also be helpful to predict natural calamities like flood and cyclone which may cause serious damage in crop production. [3]

3. EFFECT OF TEMPERATURE IN RICE PRODUCTION
In addition to growth duration, temperature greatly influences the growth pattern and the productivity of rice crops. Grain yields may be highly correlated with the mean temperature, the temperature sum, range, distribution pattern, and diurnal changes, or a combination of these. It has been identified that rice plant has nine growth stages with its three distinct growth phases and every stage has an optimum temperature range for its proper development. The critical temperatures for the development of the rice plant at different growth stages (vegetative, reproductive and ripening) are shown in Table 1.

Table 1: Critical temperature for the development of rice plants in different growth stage [4]

Growth Stages	Critical Temperatures		
	Low	High	Optimum
Germination	16-19	45	18-40
Seedling Emergence	12	35	25-30
Rooting	16	35	25-28
Leaf elongation	7-12	45	31
Tillering	9-16	33	25-31
Initiation of panicle primortdia	15	-	-
Panicle differentiation	15-20	30	-
Anthesis	22	35-36	30-33
Ripening	12-18	>30	19-20

These values may differ according to variety, duration of the critical temperature, diurnal changes and physiological status of the plant. Extreme temperatures, whether low or high, cause injury to the rice plant and a significant yield reduction. When temperatures exceed the optimal for biological processes, crops often respond negatively with a steep decline in net growth and yield. [5]

IPCC fourth assessment report depicts the adverse effect of increasing CO_2 concentration in the atmosphere which results in temperature increase (as shown in fig 1). Estimated shortage in rice production of Bangladesh in the upcoming decades due to deviation from optimum temperature is shown in Table 2

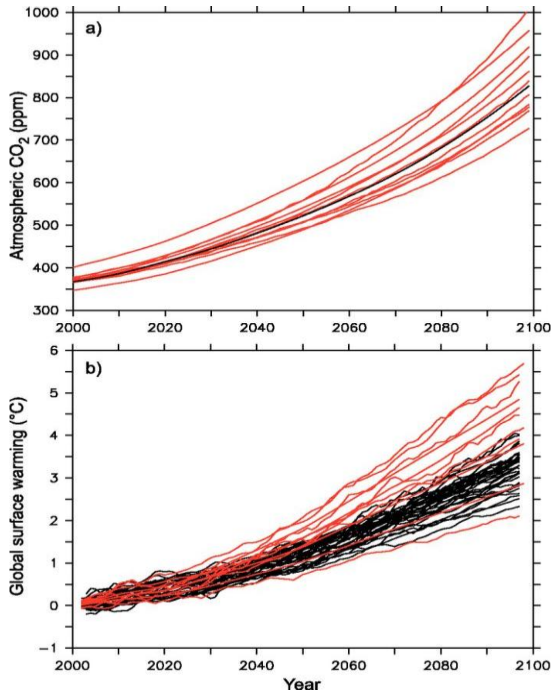


Fig 1: (a) Atmospheric CO_2 concentration of 21st-century (red) compared with the standard atmospheric CO_2 concentration (black). (b) Globally averaged surface temperature change (relative to 2000) (red) compared to global warming forced by CO_2 concentration (black). [6]

Table 2: The scenario of rice production of Bangladesh in upcoming decades due to deviation from optimum temperature [2]

Year	Total Rice Production (million tons)		
	Demand	**Production**	**Shortage**
2020	36.73	29.85	6.88
2030	42.25	34.00	8.25
2040	48.60	38.20	10.4
2050	55.90	41.97	13.93

4. TREND OF DAILY MAXIMUM, MINIMUM AND MEAN TEMPERATURE

The maximum, minimum and mean temperature of the country has been studied using historic available data of Bangladesh. Figure 2 shows month-wise distribution of the average of maximum, minimum and mean temperature. Data within last 60 years period (1948-2007) from all the 34 stations of BMD are studied all over Bangladesh. [7]

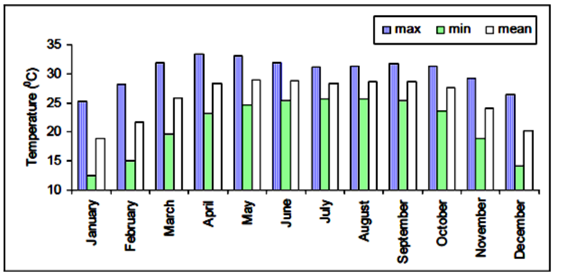


Fig 2: Monthly Average of Daily Maximum, Minimum & Mean temperature (°C) during the last sixty years (1948-2007)[6]

5. BASIC CONCEPTS OF NEURAL NETWORK

An Artificial Neural Network is defined as a data processing system consisting of a large no of simple highly interconnected processing elements (artificial neurons) inspired by the structure of the cerebral cortex of the brain (Tsoukalas and Uhrig, 1997).[8]

5.1 FEATURES OF ANN

- Can learn from cases and adjusts to situations based on its findings.
- Flexible enough to be adjusted to various input patterns and acclimatize to a diverse array of unknowns.
- Is capable of representing both linear and non linear relationships[9]

5.2 FEATURES OF MULTILAYER PERCEPTRON MODEL

- Is a feedforward artificial neural network model that maps sets of input data onto a set of appropriate outputs.
- Consists of three layers: Input layers, hidden layers and output layers.
- Performs better than single layer perceptron in cases of nonlinear function approximation, learning, generalization etc [9].

5.3 BACKPROPAGATION LEARNING

- It is a popular method of learning in multilayer feedforward networks.
- At first, the weights of the network are randomly initialized.
- The error at the output layer is calculated by comparison of actual output and the desired value to update the weights of the output and hidden layers.
- The network error is also propagated backward and used to update the weights of previous layers. [9]

6. METHODOLOGY

6.1 Backpropagation algorithm

The backpropagation algorithm consists of the following steps:

Initialization of the weights

Repeat: Comparing the calculated output and actual output
Update the linking weights
Until: Error < acceptable limit
Using Visual C++, a computer program has been developed to run the training session and to draw inferences.

6.2 Data collection and processing

1. Meteorological data are collected from Bangladesh Meteorological Department during the tenure January, 2001 to July, 2010 for Dhaka station.

1. Data from January 2001 to June, 2009 were used to train the model and data from July, 2009 to June, 2010 were chosen for testing purpose.
2. Activation function chosen: Sigmoidal
3. Normalization formula:

(Actual Value – Minimum value) / (Maximum Value - Minimum value)

6.3 System modeling

The network receives the following inputs shown in Table 3. Using these input variables, one day prediction of maximum, minimum and mean temperature is done. As described earlier, total data set is divided into two classes, training class to train the model and test class to justify the prediction.

Table 3: Set of input variables and their units

Input Variables	Unit
Mean Temperature (MnT)	*ºC*
Maximum Temperature(MaxT)	*ºC*
Minimum Temperature(MinT)	*ºC*
Mean Humidity (Rh%)	*%*
Precipitation Amount (PP)	*mm*
Average Wind Speed (WS)	*Km/h*
Sunshine (SSH)	*Hours*
Radiation (R)	*Cal/cm^2/min*

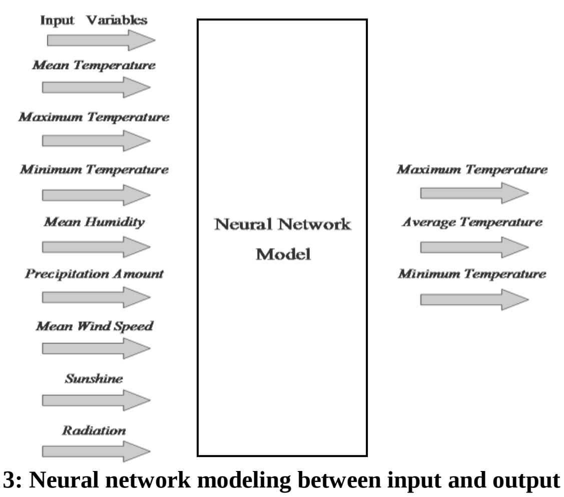


Fig 3: Neural network modeling between input and output

Without biasing condition, the predicted output is a simple function of all the input variables

$F_{WB} = f\,(MnT, MaxT, MinT, Rh\%, PP, WS, SSH, R)$

During the training of neural network, it has been observed that if an extra input bias node is added in the input layer, the error decreases during training session. The bias node, which has a unity input, is set to improve the learning speed in the training process. Thus with this extra unity input variables, the following system model has been considered for the prediction of Maximum, Minimum and Mean Temperature:

$F_{UB} = f\,(MnT, MaxT, MinT, Rh\%, PP, WS, SSH, R, 1)$

6.4 Network parameter issues

Artificial Neural Network (ANN) model relies on the values of many parameters. Among them, we studied the variation of the following parameters:

1. No. of hidden layer neurons
2. Momentum factor
3. Learning Rate coefficient
4. No. of Iterations

Here, the effect of network parameters is shown for mean temperature. The process is repeated for maximum and minimum temperature.

6.5 Effect of no. of hidden layer neurons

Hidden nodes in the hidden layers enable neural network to detect the feature, to unveil the pattern in the data, and to perform complicated nonlinear mapping between input and output variables. Our developed program allows us to vary the number of layers from 1 to 14.

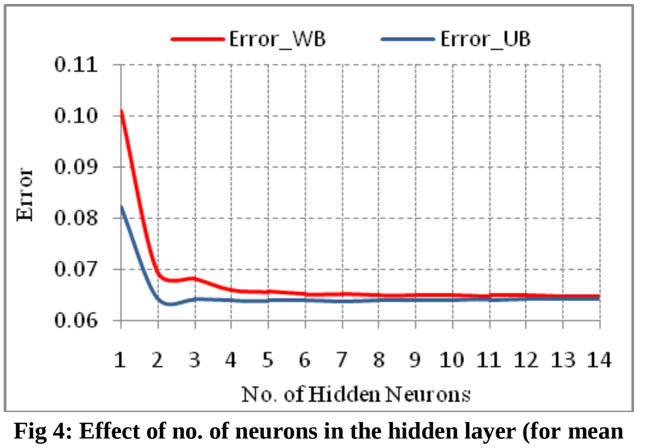


Fig 4: Effect of no. of neurons in the hidden layer (for mean temperature)

6.6 Effect of adding momentum term

A momentum parameter is added to make faster convergence and to minimize the tendency to oscillate. Typical values of momentum factor lie within 0.5-0.9.

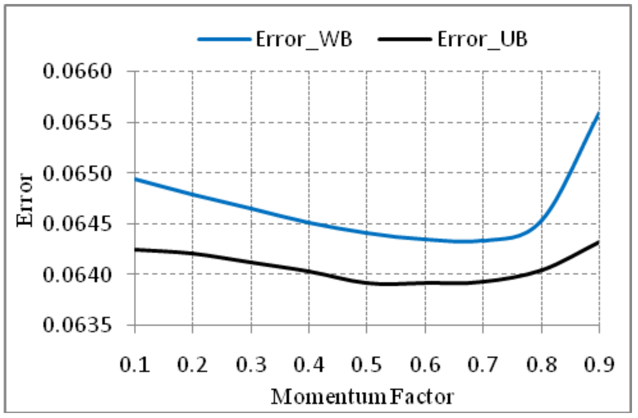


Fig 5: Effect of momentum factor (for mean temperature)

6.7 Effect of learning rate coefficient

The weight adjustment at each iteration can be regulated by learning rate coefficient and hence it can influence the rate of convergence. It is varied here from the value 0.1 to 0.9.

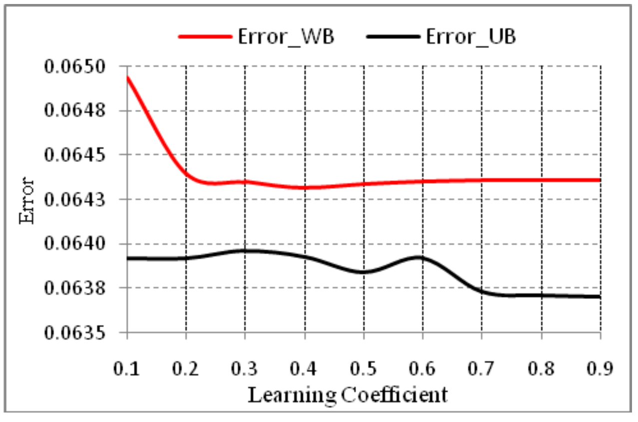


Fig 6: Effect of learning rate coefficient (for mean temperature)

6.8 Convergence of error with Iterations

The prediction error tends to reduce in accordance with the times of iteration. Here we have varied the number of iterations in between 100 to 1000 and observed the effect.

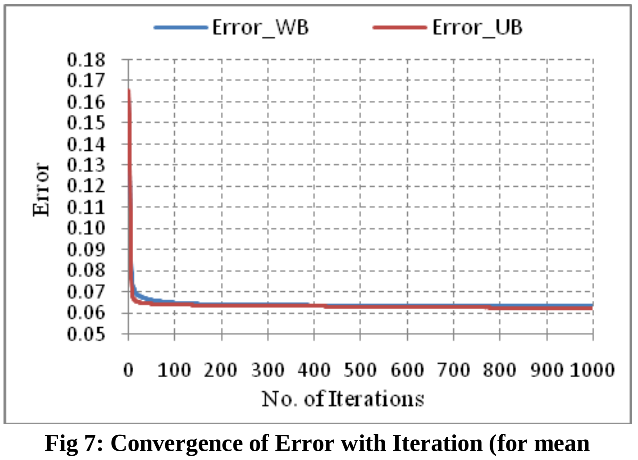


Fig 7: Convergence of Error with Iteration (for mean temperature)

6.9 Choice of best model for prediction

The model for prediction has been build up after choosing optimum parameters from the training session.

Table 3: Parameters of the neural network model without Bias node

Model	NN Structure	Learning Rate Coefficient	Momentum Factor	Iteration
Mean Temp	8-2-1	0.4	0.6	1000
Max Temp	8-2-1	0.7	0.8	1000
Min Temp	8-2-1	0.5	0.6	1000

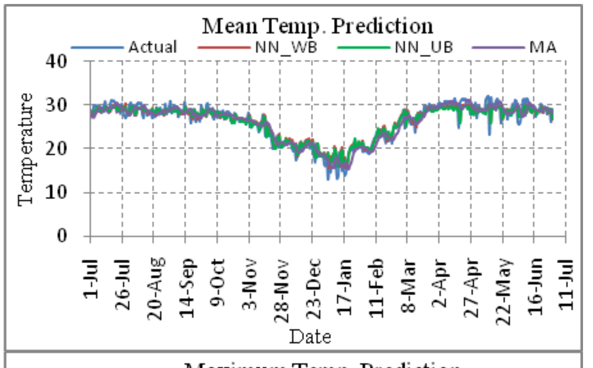
Table 4: Parameters of the neural network model using a Bias node

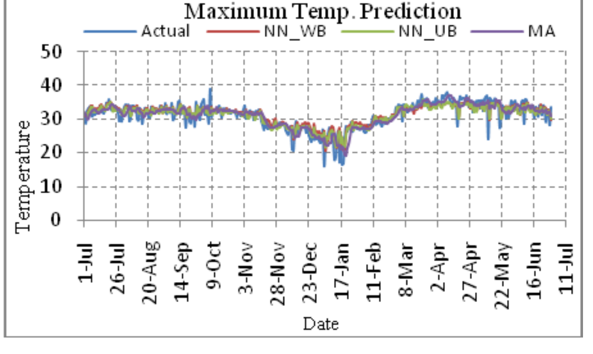
Model	NN Structure	Learning Rate Coefficient	Momentum Factor	Iteration
Mean Temp	9-2-1	0.7	0.6	1000
Max Temp	9-2-1	0.3	0.8	1000
Min Temp	9-2-1	0.5	0.8	1000

7. PREDICTED OUTCOME

After selecting the optimum model with adjusted parameters, the Mean, Maximum and Minimum error have been predicted throughout the testing period.

The Neural network modeling (both without bias (NN_WB) and using bias (NN_UB)) here is compared with Moving Average (MA) based prediction method.





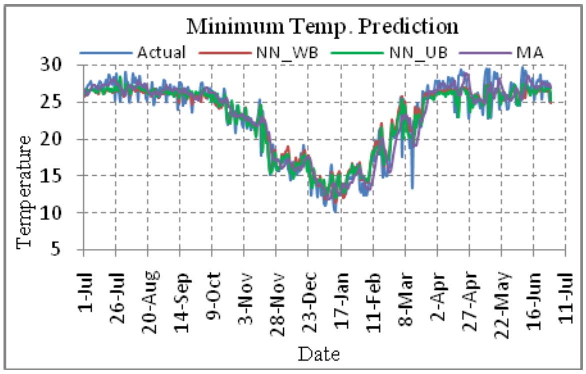


Figure 8: Prediction of (a) Mean, (b)Maximum & (c) Minimum Temperature by various methods

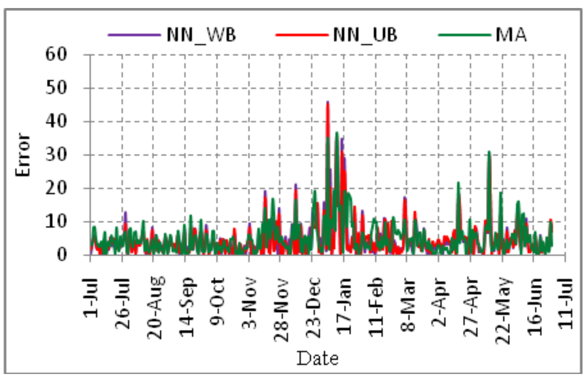
8. RESULT

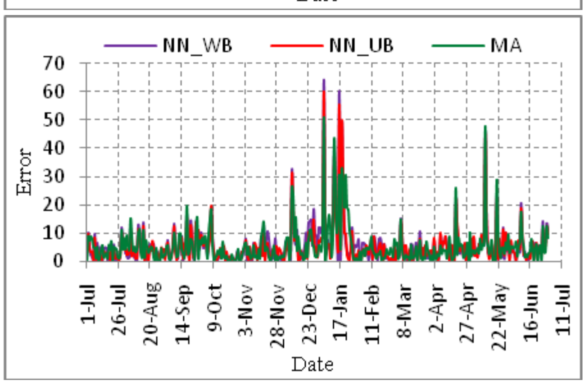
Table 5 shows the outcome errors with Neural Network prediction method with and without bias situation and the Moving Average method.

Table 5: Error comparison among different methods

Model	Mean Average Error			Root Mean Squared Error			Mean Absolute Percentage Error		
	NN_WB	NN_UB	MA	NN_WB	NN_UB	MA	NN_WB	NN_UB	MA
Avg Temp	1.12	1.09	1.20	1.52	1.48	2.46	4.62	4.47	4.96
Max Temp	1.53	1.52	1.57	2.15	2.11	2.19	5.36	5.25	5.43
Min Temp	1.19	1.18	1.33	1.61	1.59	3.20	5.60	5.59	6.49

The following graphs depicts Absolute Percentage Error (for their better acceptibility in forecasting) among different prediction methods.





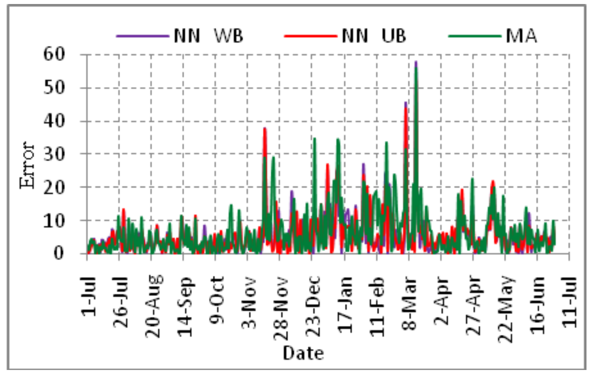


Figure 9: Absolute prediction error of Mean, Maximum & Minimum Temperature by various methods

Two random days have been picked up from the test period and the predicted temperature and actual temperature is compared.

Table 6: The forecasted temperature by different models for 01/04/2010

Date	Model	Actual Temp	Forecasted by			Absolute % Error		
			NN_WB	NN_UB	MA	NN_WB	NN_UB	MA
1/4/2010	Avg Temp	30.40	29.12	29.06	29.52	4.21	4.40	2.89
	Max Temp	36.10	33.22	33.12	34.30	7.98	8.25	4.99
	Min Temp	27.80	26.23	26.11	26.22	5.65	6.06	5.68

Table 7: The forecasted temperature by different models for 15/11/2009

Date	Model	Actual Temp	Forecasted by			Absolute % Error		
			NN_WB	NN_UB	MA	NN_WB	NN_UB	MA
15/11/09	Avg Temp	27.70	27.75	27.44	25.70	0.20	0.95	7.22
	Max Temp	31.30	32.59	32.53	31.64	4.11	3.95	1.09
	Min Temp	25.20	24.26	23.90	22.30	3.71	5.17	11.51

9. CONCLUSION

This paper presents one day temperature predictation with good accuracy which may be used as a first hand prediction tool for short term temperature prediction. Seasonal variation of temperature can be predicted using this model which may be more useful to predict the effect on rice production as rice being a seasonal crop. But foresighted planning of crop production requires long range forecasting which demands long term historical data along with further advancement of this study.

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