Weather Forecasting for the North-Western region of Bangladesh: A Machine Learning Approach

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***Abstract* - Weather forecasting has several effects in our everyday life from farming to event planning. In the northwestern part of Bangladesh, various natural calamities cause the tragic death of many people and economic loss which impacts the total economic growth in Bangladesh. However, the nonlinear relationship between the input parameters and output data in the weather forecasting system makes it more complex. This study investigates the machine learning-based weather forecasting model for the north-western part of Bangladesh to enhance the accuracy of forecasting results in short periods. Artificial neural networks and extreme learning machine algorithms were used for a strong weather prediction purpose. In this experiment, thirty years of historical weather data of temperature, rain, wind, and humidity from seven weather stations in the northwestern part were collected from the Bangladesh Meteorological Department (BMD). The Extreme Machine Learning (ELM) model performs better than Artificial Neural Network and the accuracy rate is 95%.**

Keywords— Weather Forecasting, Machine Learning, Weather parameters, Extreme learning machine (ELM), Artificial intelligence

I. Introduction

Farming is the most prominent sector in Bangladesh. The growth of this sector overwhelmingly affects the major macroeconomic targets like business condition, people's age, improvement of their lifestyle, sustenance security, and so on. A majority of people of Bangladesh procure their living directly or indirectly from the agribusiness. The population density of Bangladesh is very low in the North-Western part. Moreover, the North-Western part of Bangladesh has huge cultivated land, which produces various crops and vegetables. So the North-Western part of Bangladesh has a great impact on Bangladesh's agriculture and economy. Thakurgaon, Rangpur, Panchagarh Nilphamari, Lalmonirhat, Kurigram, Gaibandha, Dinajpur, Bogra, Chapainawabganj, Joypurhat, Naogaon, Natore, Pabna, Rajshahi, Sirajganj are total 15 districts on that area of Bangladesh. Total area is 34,359 square kilometer and the total population is 3,42, 72,616[1][2]. The climate of the north-western part of Bangladesh is varied. In the summer season, the weather is too hot, the temperature rises so high that it is difficult to take relief; the temperature is almost 40°-42° celsius. The duration of the rainy season is also very short. The rainfall rate in these regions is decreasing day by day. There is a diverse situation that exists in the winter season. Sometimes it is seen that temperature falls into 5°-8° degrees celsius. Irregular characteristics of weather are causing drought, water, and food shortage and long term effects on the environment [3][4]. It's also creating long term socio-economic and health impacts on the population. Drought is one of the effects of bad weather, mainly low rainfall and high temperature. Drought is affecting crop production, food cultivation; the water level is reducing day by day so people are suffering from pure drinking water. It's also affecting the lifestyle of people in that area adversely, they have a shortage of jobs, an acute food crisis, and a reduction of livestock; so many problems force them to migrate from their land [5]. Low rainfall is causing deforestation; rivers are drying day by day [6]. Fig 1 represents the losses in different sectors due to weather changes.

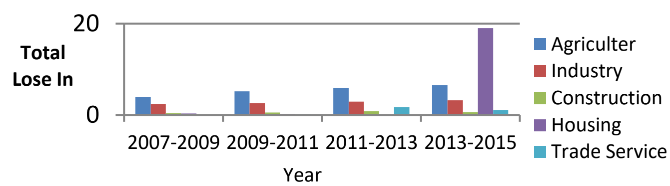

Fig 1. Total loss calculation in different years in Bangladesh Economy for changing weather in North-Wester Part

This paper is categorized into different sections. In the second section, the existing weather-related works have been discussed; the dataset collected from the metrological department of Dhaka has been discussed in the third section Machine learning methods used in this research are well explained in section III. The result and discussion explained in the fourth section. And finally, the conclusion is drawn in section V.

II. Related Works

Forecasting weather is a very challenging task because it depends on various factors such as temperature, wind, rain, humidity, etc. Currently, many types of research are working to forecast the weather using a machine learning approach. With the pace of time and research in machine learning is becoming a popular scientific method. Artificial intelligence, fuzzy logic, data mining technique has made the weather forecasting technique easier.

For instance, A H M Jakaria et al. [7] proposed a technique to forecast the weather of Tennessee. They collected real weather data for the city of Nashville and utilized a simple machine learning algorithm. The proposed machine learning technology can provide intelligent models, which are much simpler than traditional physical models. Amy McGovern et al. [8] provide an overview of improved AI techniques applied for predicting high-impact weather. They provide a data mining based predictive model to identify weather applications. Amit Kumar Agarwal et al.[9] recommended a machine-learning-based artificial intelligence model. They employed neural Networks & probabilistic model bayesian networks, vector machines in their application. Meera Narvekar et al.[10]

performed weather forecasts for the next days for accurate and speedy prediction. Their research mainly presented the artificial neural network with error backpropagation. Their result proved that ANN suits the best classification technique among machine learning algorithms. Mark Holmstrom et al. [11] to analyze linear regression and variation regression for weather forecasting. Maximum temperature and minimum temperature are the main climatic factors of their work. Nazim Osman Bushar et al. [12] studied weather forecasting of Sudan. They applied 14 data-mining algorithms, Gaussian Processes, Linear Regression, Multiplayer Perceptron, IBk, KStar, Additive Regression, Bagging, Random Subspace, Regression by Discretization, Decision Table, M5Rules, M5P, REPtree, User Classifier, Multilayer Perceptron, IBk, KStar, Additive, Regression, Bagging, Random Subspace, Regression by Discretization, Decision Table, M5Rules, M5P.KStar is the best performance model among 14 algorithms. Ingsrisawang et al. attempted [13] to predict rainfall in the northeastern part of Thailand. They analyze the performance of Decision Tree, Artificial Neural Network (ANN), and Support Vector Machine (SVM) algorithm. According to their result, Decision Tree is more accurate than the Artificial Neural Network (ANN), and Support Vector Machine (SVM). Yajnaseni Dasha et al. [14] investigated the performance of K-nearest neighbor (KNN), artificial neural network (ANN), and extreme learning machine (ELM) for the rainfall prediction in the Kerala state during the summer monsoon and post-monsoon period. Shabib Aftab et al.[15] designed the rainfall prediction of Lahore city using the data mining technique. Result obtained from the research showed that the accuracy rate is too low for all the algorithms. In Bangladesh, numerous studies have been done using a machine learning algorithm. However, a few numbers of researches have focused on weather prediction of Bangladesh using artificial intelligence techniques. Risul Islam Rasel et al. [16] tried to predict the weather in the Chittagong district. They applied support Vector Regression (SVR) and artificial Neural Networks (ANN) algorithms. Their proposed model is implemented with the use of the last six years of data. Taohidul Islam et al. [17] proposed an Artificial Neural Network (ANN) algorithm for the weather forecasting of Barisal city. They concluded that the experiment result was 83% accurate using Artificial Neural Network (ANN).

However, none of these systems focused on the entire northern area in Bangladesh which is dominating the economy of Bangladesh. We use the northern area weather history dataset, both ANN and ELM algorithms implemented for the first to predict the temperature of the northern part. We evaluated the performance of two artificial intelligence techniques. The current physical weather prediction system heavily relies on complex physical models and should be run on enormous PC frameworks including several HPC hubs. Regardless of utilizing these expensive and complex gadgets. there are regularly off base estimates given inaccurate starting estimations of the conditions or a deficient comprehension of forecasting. Our model can be run on minimal effort and less asset serious figuring frameworks yet can give speedy and exact enough conjectures to be utilized in our everyday life.

III. METHODOLOGY

A. DATA SET

For forecasting weather, we use the last 30 years of data from 1986 to 2017, weather data such as temperature, wind, rain, humidity. We collect data from seven weather stations in the north-western part of Bangladesh. Stations are in Dinajpur district, Rangpur district, Bogra district, Rajshahi district, Iswardi at Pabna district, Saidpur in Nilpahamari district.

B. TRAINING AND TESTING DATA SET

The dataset is summarized and split the set as training and testing dataset. 80% of data is used for training and 20% of data used for the testing from the total dataset. This dataset contains day wise with every 24-hours weather condition detail in every district of the northwestern regions. Table I represents the sample data set of Rajshahi city temperature data for the last 30 years used for testing and training purposes.

TABLE I. SAMPLE DATA OF TRAINING DATASHEET OF RAJSHAHI DISTRICT OF JANUARY MONTH FOR LAST 30 YEARS

Year	Month	Day	Dew Point Drop	Max Temp.	Min Temp.	Avg Temp.
1988	January	1	20	35.7	19	20
1997	January	1	19	39.7	22	21
2007	January	1	23.4	38.6	21	23
2017	January	1	18	30.8	15	22

Two machine learning algorithms are artificial neural networks and extreme learning machine used in this study.

C. ARTIFICIAL NEURAL NETWORK

The artificial neural network is a computational network inspired by biological networks. An artificial neural network is a software system that executes its programs as similar to the human brain central nerve system. Regular neurons get motions through neuron transmitters situated on the dendrites or layer of the neuron. Whenever the signals are sufficient (outperform a certain limit), the neuron is initiated and discharges a flag to the axon. This flag may be sent to another neural connection and might initiate different neurons. The complexity of real neurons is quite abstracted when modeling artificial neurons. In this process, inputs are multiplied by the weights. Then mathematical function computed the result [18][19]. For Applying ANN, a non-linear activation function is necessary, otherwise, the linear combination of input will be the output of the equation. We can write down the single neuron equation as follows.

$$y_m = f_{abc}(m + n_i w_i) \quad (1)$$

$$y_m = f_{abc}(W_i) \quad (2)$$

A feed-forward ANN is worked by interfacing numerous layers together. The contributions to the system are associated with the contributions of the principal shrouded layer [20]. The principal shrouded layer would then be able to be associated with progressively concealed layers. The last concealed layer interfaces with the yield layer. The yield of the ANN is given by this yield layer [21]. Applying ANN, a non-linear activation function is necessary for a nonlinear combination of input. We can write down the single neuron equation as following [22].

We can have a lot of inputs such as $(M_1, M_2, \ldots\ldots M_n)$ and it will produce output such as $(K_1, K_2, \ldots\ldots K_n)$.In a feed-forward network, the error rate should be minimum. Error in ANN can be calculated through the following equations[23][24].

$$\text{Error}=\sum_{i=1}^{n}(x_i - y_i)^2 \quad (3)$$

D. EXTREME LEARNING MACHINE

Extreme learning machine is one of the most popular machine learning algorithms which is used in many applications for prediction and measuring performances, like weather prediction, wind power measurement, sales prediction of a company, etc. ELM is a very first algorithm that generates results so quickly for the theoretical and much practical application. [25]

$$X=\begin{bmatrix} x_{11} & x_{12} & x_{1n} \\ x_{21} & x_{22} & x_{2n} \\ x_{m1} & x_{m2} & x_{mn} \end{bmatrix} y \times l \quad (4)$$

Here x is the weight between the input and output layer. 'l' is the hidden node in the output layer, while y is defined as the number of input nodes[26].

$$\alpha = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \alpha_{2n} \\ \alpha_{m1} & \alpha_{m2} & \alpha_{mn} \end{bmatrix} x \times y \quad (5)$$

The real matrix of the ELM network can be defined as below:

$$J = [j_1\, j_2 \,\ldots\ldots\, j_n] x \times y \quad (6)$$

From the above equations, we can write down the matrix of ELM as follow

$$m_j = \begin{bmatrix} m_1 \\ m_2 \\ \ldots . \\ m_n \end{bmatrix} n \times l = \begin{bmatrix} \sum_{i=1}^{n} \alpha_{i1} m(y_i z_j + c_i) \\ \sum_{i=1}^{n} \alpha_{i2} m(y_i z_j + c_i) \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . \\ \sum_{i=1}^{n} \alpha_{in} m(y_i z_j + c_i) \end{bmatrix} \text{(j 1,2,3,4,.p)} \quad (7)$$

Where $y_i = [y_1, y_2, \ldots\ldots, y_n]$ and $z_j = [z_{1j}, z_{1j}, z_{1j}, z_{1j} \ldots . z_{nj}]^T$ g(x) is an activation function in the hidden layer of the ELM.

E. COMPUTING PERFORMANCE

Computing the performance of various artificial model different parameters is necessary. We describe various parameters like Mean absolute error (MAE), root means square error (RMSE, mean absolute scaled error (MASE), and performance parameter (PP). Lower error scores of MAE (in percentage), RMSE (in percentage), and MASE in the below equations[14].

$$\text{MAE} = \frac{100}{x} \sum_{i=1}^{n} \left| \frac{Observed_x - Predicted_x}{Observed_x} \right| \quad (8)$$

$$\text{RSME (\%)} = \sqrt{\frac{100}{m} \sum_{i=1}^{n} \left(\frac{Observed_x - Predicted_x}{Observed_x}\right)^2} \quad (9)$$

$$\text{MASE} = \frac{1}{m} \sum_{i=1}^{n} \left(\frac{|Observed_x - Predicted_x|}{\frac{1}{m-1}\sum_{i=1}^{n} |Observed_x - Predicted_{x-1}|} \right) \quad (10)$$

$$\text{PP} = 1 - \left(\frac{RSME}{SD(obs)}\right) \quad (11)$$

IV. RESULT & DISCUSSION

A. IMPACT OF HIDDEN NODE ACCURACY

In our proposed model ELM performs better results than ANN. The accuracy of the two models relies on different weather parameters. This investigation has inspected the effect of the concealed hubs on exactness utilizing the ANN and ELM methods. There is no fixed guideline to choose the number of hidden nodes in the neural system. Along these lines, it is exceptionally alluring to research the effect of the hidden nodes when the unpredictability of information is higher. Hidden nodes are generously influencing the exactness of the outcomes. In the table, we measured MAE and RSME using ANN and ELM algorithms for weather prediction in the North-Western part of Bangladesh. Randomly we choose hidden nodes using both algorithms. MAE performs better results for the ANN algorithm when it has 20 hidden nodes. For ELM algorithm MAE performs better results in 15 hidden nodes. Along these lines, the last structure of the ANN show comprised 8 input neurons, 20 hidden nodes in the hidden layer, and 1 output neuron dependent on the precision of the results. So, the last ELM show utilized here was with 8 neurons in information, 15 nodes in the hidden layer, and 1 neuron in the output layer. Table 2-5 describes hidden nodes of ANN and ELM for our parameters rainfall, temperature, wind, and humidity with MAE and RSME (in percentage).

TABLE II. RAINFALL USING ANN AND ELM ALGORITHM ON THE DATASET (2007-2017)

Total Hidden Node	Algorithm	MAE	RSME
10	ANN	8.134	11.675
15	ANN	5.345	8.545
20	ANN	7.398	9.432
10	ELM	5.324	5.889
15	ELM	6.231	4.658
20	ELM	6.456	9.234

TABLE III. TEMPERATURE USING ANN AND ELM ALGORITHM ON THE DATASET (2007-2017)

Total Hidden Node	Algorithm	MAE	RSME
10	ANN	5.134	9.675
15	ANN	4.345	7.565
20	ANN	6.695	9.532
10	ELM	3.324	6.892
15	ELM	4.231	6.456
20	ELM	4.456	8.436

TABLE IV. WIND PRESSURE USING ANN AND ELM ALGORITHM ON THE DATASET (2007-2017)

Total Hidden Node	Algorithm	MAE	RSME
10	ANN	3.89	4.675
15	ANN	2.535	2.565
20	ANN	3.695	7.132
10	ELM	2.324	5.842
15	ELM	4.231	6.446
20	ELM	3.456	7.436

TABLE V. HUMIDITY USING ANN AND ELM ALGORITHM ON THE DATASET (2007-2017)

Total Hidden Node	Algorithm	MAE	RSME
10	ANN	8.164	6.675
15	ANN	8.345	6.345
20	ANN	6.398	7.432
10	ELM	5.324	9.892
15	ELM	4.231	4.456
20	ELM	5.356	9.233

B. PREDICTION PERFORMANCE OF ARTIFICAL INTELLIGENCE MODEL

Table 6-10 represents the performance of our predicted weather data set from (2007-2017) in Rajshahi district. We apply the ANN and ELM algorithm for weather prediction. Our parameters for the performance measurement observed mean, predicted mean, the standard deviation of observation and prediction, mean absolute error (MAE) in percentage, root mean square error (RMSE) in percentage, mean absolute scaled error (MASE), performance parameter (PP) and correlation coefficient (CC).

TABLE VI. PREDICTION PERFORMANCE FOR THE RAINFALL ON THE DATASET (2007-20017)

Performance Score(2007-2017)	ANN	ELM
Mean (Observed) in mm	1745.367	1721.281
Mean (Predicted) in mm	1825.095	1493.34
SD(Observed) in mm	414.833	404.548
SD(Predicted) in mm	337.693	370.723
MAE (%)	6.189	3.075
RMSE (%)	0.212	0.100
PP	.678	.715
CC	.979	.551

TABLE VII. PREDICTION PERFORMANCE FOR THE TEMPERATURE ON THE DATASET (2007-20017)

Performance Score(2007-2017)	ANN	ELM
Mean (Observed) in mm	25.5	22
Mean (Predicted) in mm	37	32
SD(Observed) in mm	35	30
SD(Predicted) in mm	34	32
MAE (%)	0.512	0.900
RMSE (%)	.52	0.100
PP	.678	.715
CC	.979	.551

TABLE VIII. PREDICTION PERFORMANCE FOR THE WIND PRESSURE ON THE DATASET (2007-2017)

Performance Score(2007-2017)	ANN	ELM
Mean (Observed) in mm	2.5	3.5
Mean (Predicted) in mm	1.5	3.5
SD(Observed) in mm	5	4
SD(Predicted) in mm	2	6
MAE (%)	1.149	3.075
RMSE (%)	0.212	0.100
PP	.678	.715
CC	0.979	0.557

TABLE IX. PREDICTION PERFORMANCE FOR THE HUMIDITY ON THE DATASET (2007-2017)

Performance Score(2007-2017)	ANN	ELM
Mean (Observed) in mm	75	65
Mean (Predicted) in mm	60	56
SD(Observed) in mm	40	50
SD(Predicted) in mm	55	59
MAE (%)	2.456	2.045
RMSE (%)	0.501	1.643
PP	.287	.767
CC	0.279	0.857

From the above tables, we can observe that ELM performs better than the ANN for the rainfall, temperature, wind and humidity MAE scored (in percentage). We also found the same result for RSME, MASE, PP, CC prototypes. ELM algorithm is far better compared to the ANN algorithm.

In Fig: 2,3,4,5 we represent the MAE score of both ANN and ELM techniques. It is seen that the ELM score is lower than ANN. Visualization represents a better picture of the comparison of both algorithms.

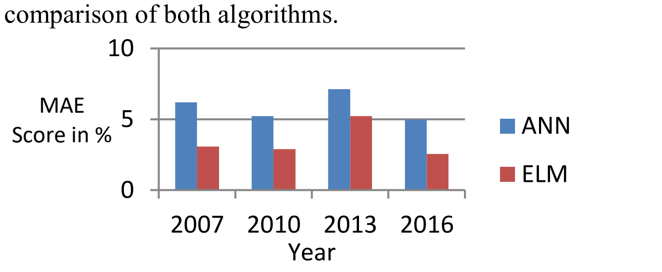

Fig 2. Visualization of MAE score (%) of ANN and ELM for Rainfall

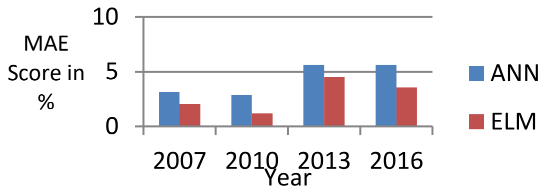

Fig 3. Visualization of MAE score (%) of ANN and ELM for Temperature

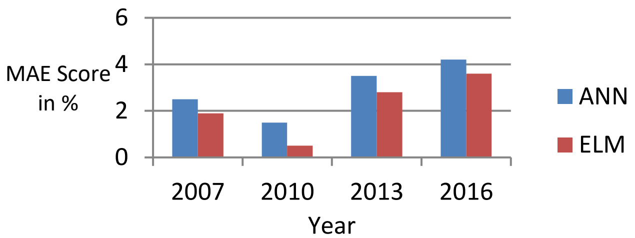

Fig 4. Visualization of MAE score (%) of ANN and ELM for Wind Pressure

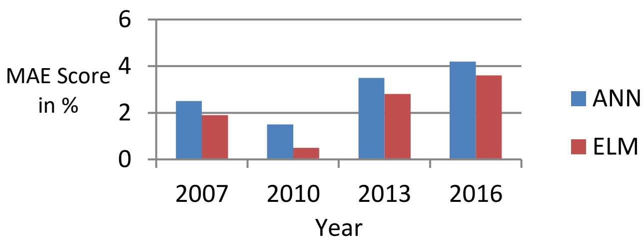

Fig 5. Visualization of MAE score (%)of ANN and ELM for Humidity

We also visualized the prediction result of both ANN and ELM for the test data (2007-2017) in Fig 6,7,8,9 found that ELM algorithm performance is better than ANN. ELM provides a 95% accuracy and a 70% high-performance rate rather than the ANN algorithm.

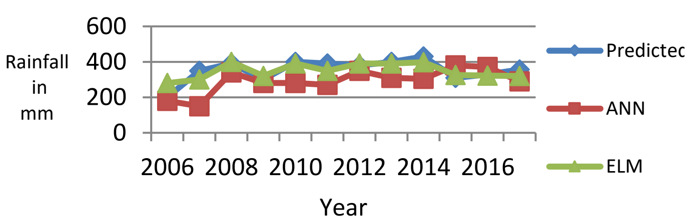

Fig 6. Prediction results for average Rainfall by using ANN and ELM algorithm on the data set (2007–2017)

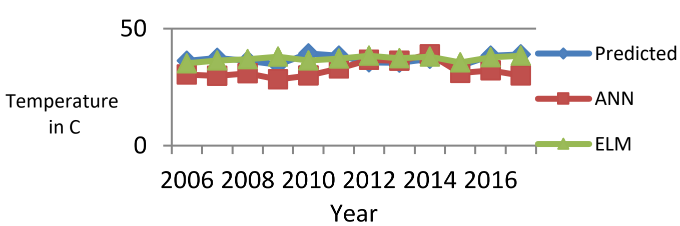

Fig 7. Prediction results for average Temperature by using ANN and ELM algorithm on the data set (2007–2017)

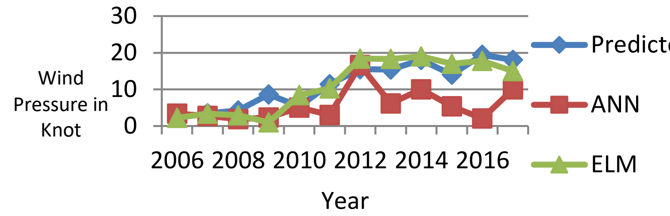

Fig 8. Prediction results for average Wind Pressure by using ANN and ELM algorithm on data set (2007–2017)

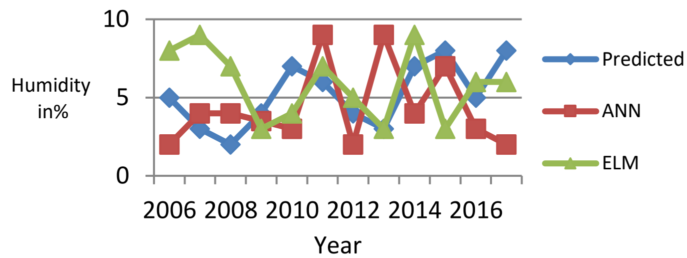

Fig 9. Prediction results for average Humidity by using ANN and ELM algorithm on the data set (2007–2017)

The computational time required by each of the three calculations was additionally figured and it was found that ANN requires progressively computational time than ELM.ANN and ELM used time as 50.512 and 20.565 seconds, respectively. Be that as it may, the expectation blunder of ANN is higher when contrasted with ELM strategies. The ANN system might be requiring more time for the execution procedure because of its iterative weight refreshing instrument followed by the back-proliferation learning rule.

V. CONCLUSION

A robust weather forecasting system can aid people and country to minimize economic losses. In this paper, Dataset is collected from the Dhaka Metrological department which states the seven weather forecasting stations of the northern area of Bangladesh. Both ANN and ELM algorithm is used to tackle the weather forecasting problem that is currently causing for traditional systems. ELM performs better than ANN based on the parameters of rain, temperature, wind, and humidity. Hidden nodes in the artificial neural network also have a huge impact on weather forecasting system. Our system provides a total accuracy rate for ELM algorithms 95% and ELM 78%, as a result, ELM is far better than ANN. However, this study is focused on only one of the biggest parts of Bangladesh. In the future, we will try to cover all the 64 districts in Bangladesh to get the idea of climate change in whole Bangladesh. Moreover, environmental factors and other extreme weather events will also be studied with different parameters as we have used only four weather attributes in our current experiment.

ACKNOWLEDGEMENT

This study is done upon the data of the Bangladesh Metrological Department. All the information, opinions, and conclusions are recommended by the authors. These materials do not reflect the opinions of the Bangladesh Metrological Department.

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