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A Study on Rainfall Calibration and Estimation at the Northern Part of Bangladesh by Using Mamdani Fuzzy Inference System

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Abstract

In this paper, the Mamdani fuzzy inference system has been used to estimate the average rainfall behaviour in the north part of Bangladesh. The authorized rainfall data of Bangladesh Meteorological Department were calibrated for better estimation. To perform the fuzzy inference system, knowledge base and the fuzzy reasoning or decision making functional components were used. The m^n rules of fuzzy-logic principles were used to make operations for both the cases of fuzzification operation and defuzzification operation. The triangular membership functions were used for three major parameters (Temperature, Humidity, Wind speed) of Environment. In addition, the input and output variables were initially partitioned into five linguistic ranges Very high, High, Medium, Low, and Very Low. The developed system was then applied to the calibrated data to find the actual estimation. In this study, we have found the observed data and the estimated result makes a good agreement. The developed fuzzy rule-based model shows flexibility and ability in modelling an ill-defined relationship between input and output variables. The model estimation error was found below the 5% significance level. The RMS value of the estimated result was 0.51%. The study of fuzzy logic based rainfall prediction method by using the Mamdani fuzzy inference system may be successively used for different environmental problem estimation to mitigate unexpected meteorological problems.

Keywords

Fuzzy Logic, Membership Function, Rainfall Estimation, Rules-Based, FIS, Fuzzy Levels, Fuzzification, Defuzzification

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1. Introduction

Fuzzy logic is a branch of artificial intelligence that deals with reasoning algorithms used to emulate human thinking and decision making in machines. These algorithms are used in applications where process data cannot be represented in binary form [1]. In fuzzy logic, values of variables are expressed by linguistic terms, the relationship is defined in terms of IF-THEN rules and the outputs are also fuzzy subsets which can be made crisp using Defuzzification techniques [2]. First the crisp values of system variables are fuzzified to express them in linguistic terms [3]. Fuzzification is a method for determining the degree of membership that a value has to a particular fuzzy set. This is determined by evaluating the membership function of the fuzzy set for the value [4]. In classical models variables have real number values, the relationships are defined in terms of mathematical functions and the outputs are crisp numerical values [5-7]. In crisp sets, which are collection of objects with the same properties, the objects either belong to the set or not. In practice, the characteristics value for an object belonging to the set is coded as 1 and if it is outside the set then the coding is 0. The key idea in fuzzy logic is the allowance of partial belongings of any object to different subsets of the universal set instead of belonging to a single set completely [8] Mamdani-type inference, expects the

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output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs Defuzzification [9]. It is possible, and in many cases much more efficient, to use a single spike as the output membership functions rather than a distributed fuzzy set. This type of output is sometimes known as a singleton output membership function, and it can be thought of as a pre-defuzzified fuzzy set. It enhances the efficiency of the Defuzzification process because it greatly simplifies the computation required by the more general Mamdani method, which finds the centroid of a two-dimensional function. Rather than integrating across the two-dimensional function to find the centroid, the weighted average of a few data points are used. High humidity also characterizes the climate. There are two distinct seasons, the rainy and dry seasons. The rainy season lasts for about seven months (April to October). The rainfall is about 1524mm per year. The atmospheric temperature ranges between 28°C and 31°C and a mean annual relative humidity of about 80 per cent [10]. The data used in this research was collected from a weather station, which consists of many atmospheric surface parameters such as the relative humidity, temperature, and wind speed [11]. Numerical weather prediction is the prediction of weather phenomena by then numerical solution of the equations governing the motion and changes of condition of the atmosphere [12]. Numerical weather prediction techniques, in addition to being applied to short-range weather prediction, are used in such research studies as air-pollutant transport and the effects of greenhouse gases on global climate change [13]. The first operational numerical weather prediction model consisted of only one layer and therefore it could model only the temporal variation of the mean vertical structure of the atmosphere. Computers now permit the development of multilevel (usually about 10–20) models that could resolve the vertical variation of the wind, temperature and moisture. These multilevel models predict the fundamental meteorological variables for large scales of motion [14]. Meteorological estimation is an important issue in research. Typically, the estimation is performed at “global level”, by gathering data in a large geographical region in Rangpur district. Rainfall estimation can have many different forms, depending on required applications. For example in airport it is far more important to know about the climate visibility a few hours ahead rather than temperature. Also in buildings, weather estimate can play an important role in saving the energy. This can be done by controlling the heat and cool factors of buildings. On the other hand, data uncertainty plays a special role in these environment and such data are not perfect from many reasons: incomplete data, precision of measurements discreet description of connective phenomena, inherent part reflecting our understanding of things, keyboard error, hand writing error, device error. However Meteorological data are uncertain (fuzzy) in nature and Information on weather is vaguely defined. Uncertain data is consisting of noises and outliers that decrease quality of data. Noise is a random error or a parasite that comes from sensor network, error hand writing, and keyword error writing and so on. Noise is invalid value but outlier is valid it means, An outlier is an observation of the data that deviates from other observations so much that it arouses suspicions that it was generated by a different mechanism from the most part of data. However by removing noise and detecting outliers we can get high quality of data. On the other hand, Rainfall prediction system is developed based on the data set, therefore to get accurate model based on the dataset we should improve the quality of dataset to get true result. Consequently in this study we reviewed several methods which have been focusing in this area (Rainfall estimate) so far. These methods are not considering noise and outlier parameters and only applicable to local area. Moreover, global area estimate by these methods are not possible, because large time consuming process.

In this research work, the focus is on Calibration and Estimation rainfall at the Rangpur district in Bangladesh by Using Mamdani Fuzzy Inference System.

2. Location Area of the Study

Rangpur division area 16320.26 sq. km, located in between 25°20' and 26°37' north latitudes and in between 88°50' and 89°53' east longitudes. It is bounded by west Bengal state of India on the north, joypurhat, bogra and jamalpur districts on the south, Assam state of India on the east, West Bengal state of India on the west. Water bodies Main Rivers: Brahmaputra, jamuna, punarbhaba, karatoya, atrai, tista, mahananda. The biggest irrigation project of the country, Tista Barrage Project (length 615 m) is located at Doani of Hatibandha upazila. The soil (80%) of the Teesta River basin and the remaining is baring soil. The temperature ranges from 32°C to 11°C and the annual rainfall average 2931 mm. Current study we selected Rangpur District of the marking region from the figure bellow.

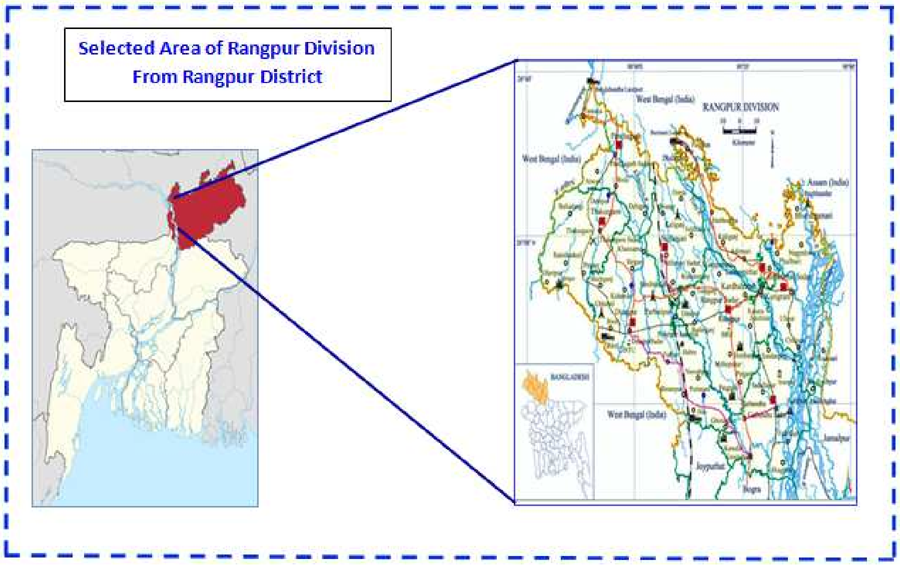

Figure 1. Selected region of Rangpur district from Rangpur division map.

3. The Methods

Fuzzy Logic is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multichannel PC or workstation based data acquisition and control systems [15-17]. It can be implemented in hardware, software, or a combination of both. Fuzzy logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned [18]. Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Because of its multidisciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy systems [19]. Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology. Mamdani's method was among the first control systems built using fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani's effort was based on Lotfi Zadeh's 1973 paper on fuzzy algorithms for complex systems and decision processes [20]. Although the inference process described in the next few sections differs somewhat from the methods described in the original paper, the basic idea is much the same.

3.1. Definition of Fuzzy Set

Let X be a universal set. Then A is called a (Fuzzy) subset of X if A is a set of ordered pairs.

$$A = \{(x, \mu_A(x)) : x \in [0,1]\} \qquad (1)$$

Where, μ_A is the membership function of A.

$\mu_A(x)$ is the grade of the membership function x in A

3.2. Fuzzification

The process that allows converting a numeric value (or crisp value) into a fuzzy input is called Fuzzification. There are two ways to do Fuzzification:

$$A_{ui} \text{ is a fuzzy singleton } \mu_{Aui} = \begin{cases} 1 \text{ if } u = u_i \\ 0 \text{ otherwise} \end{cases} \qquad (2)$$

A_{ui} is a fuzzy set such that

$$\mu_{Aui}(u) = \begin{cases} 1 \text{ if } u = u_i \\ \text{decreases from } 1 \text{ asumoves from } u_i \end{cases} \qquad (3)$$

Singleton Fuzzification is generally used in implementation where there is no noise.

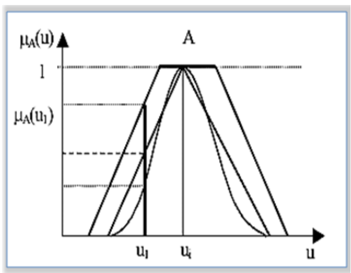

Figure 2. Fuzzification in different membership function.

Let μ be a fuzzy subset of X; the support of A, denoted sup (A), is the crisp subset of X whose elements all have nonzero membership grades in A. More recently, fuzzy systems have gained attention. First introduced by Zadeh (1965) fuzzy logic and fuzzy set theory are used in modelling the ambiguity and uncertainty in decision making. He introduced processing of the linguistic uncertainties by fuzzy logic and opened a wide spectrum of applications in many fields. The basic idea in fuzzy logic is rather simple according to which statements are not just "true" or "false" but they are partial true and practically acceptable. Fuzzy application areas include estimation, prediction, control, approximate reasoning, intelligent system design, machine learning, image processing, machine vision, pattern recognition, medical computing, robotics, optimization, civil, chemical and industrial engineering, but in hydrology and meteorology are new areas of fuzzy applications.

3.3. Defuzzification

Defuzzification is the reverse process of Fuzzification. Mathematically, the Defuzzification of a fuzzy set is the process of conversion of a fuzzy quantity into a crisp value, i.e. rounding off from its location in the unit hypercube to the nearest vertex. This may be necessary if we wish to output a number to the user. For example, if we do an expert system for blood pressure control, we will probably want to tell the user of what a blood pressure is expected to be in X hours.

3.4. Fuzzy Logic Model of Rainfall Estimation System

Fuzzy logic model is also known as a fuzzy inference system or fuzzy controller. The fuzzy logic model adopted in this work composed of two functional components. One is the knowledge base, which contains a number of fuzzy if–then rules and a database to define the membership functions of the fuzzy sets used in the fuzzy rules. Based on this knowledge base, the second component is the fuzzy reasoning or decision-making unit to perform the inference operations on the rules.

Two operations are performed for fuzzy logic modelling. When data are ready, a Fuzzification operation is processed to compare the input variables with the membership functions on the premise part to obtain the membership values of each linguistic fuzzy set. These membership values from the premise part are combined through a min operator to get firing strength (weight) of each rule in order to generate a qualified consequent (either fuzzy or crisp) of each rule depending on this firing strength. Then the second operation is the Defuzzification to aggregate the qualified consequents to produce a crisp output. The fuzzy inference engine extracts and evaluates rules from the rule base and produces fuzzy outputs. The fuzzy inference engine presented in Akpan (2011) is studied and adopted for the design of rainfall system.

In this work, a small number of linguistic terms (e.g., very high, high, medium, low, very low) referred to as fuzzy sets, are assigned to each variable (e.g., temperature, wind-speed, humidity). These fuzzy sets overlap and cover the necessary range of variation for that variable. The degree of membership (from 0 to 1) of a real valued input (e.g., temperature, wind-speed, humidity) to a particular fuzzy set is given by a membership function. This transformation of real valued inputs into a degree of membership in a particular fuzzy set is called Fuzzification.

In this application, the input variables were initially partitioned into five linguistic ranges Very high, High, Medium, Low, and Very Low. Triangular membership functions can use. In general there could be m^n rules where n is the number of inputs and m is the number of partitions. However, as the number of rules increases, the complexity of the formulation also increases leading to what is referred to as the curse of dimensionality. The fuzzy expert system consists of linguistic rules relating the membership functions of the input variables to the membership function of the output variable. A series of IF-THEN statements relates the input to the output variables. Operators such as AND can be used to relate the input variables to each other to define the result as a combination of the input variables. The AND operator is mathematically applied as an intersection by either the "minimum" or "product" function. Minimum is commonly used when the input data are independent of each other, and product is often applied if input variables are inter dependent.

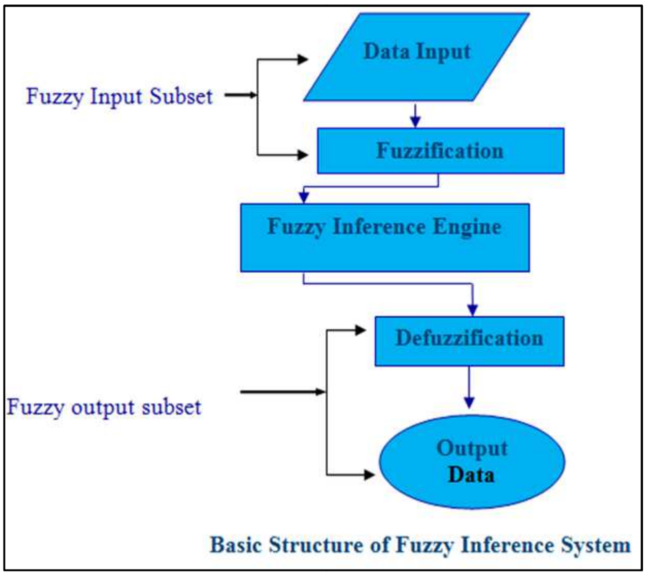

Figure 3. The general structure of a fuzzy system Diagram.

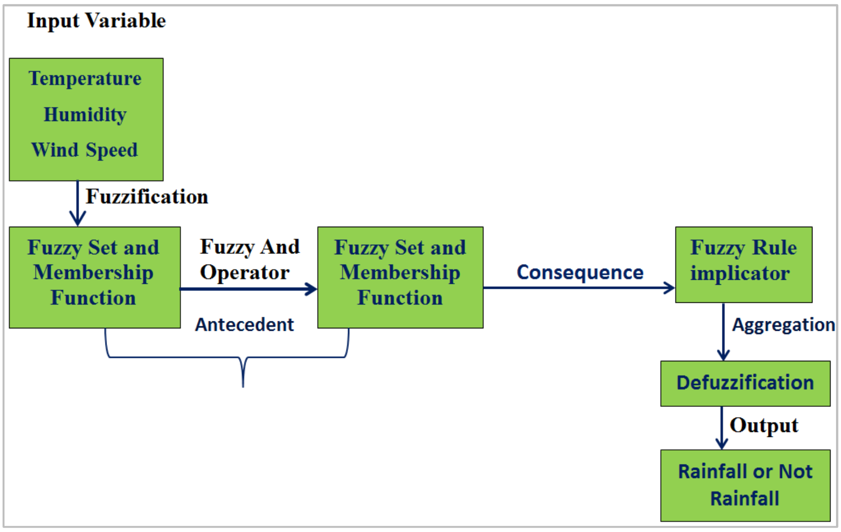

Figure 4. Model of rainfall fuzzy inference procedure

In a rule-based model, the relationship between input variables and the results are easily understood by simply reading the rule. Rules are influential in selecting the number of variables and membership functions to be modelled because the model becomes exponentially more complex as the number of variables or membership functions increases. This is because a rule must be available for each possible combination of input variable membership functions and potential outcome membership functions. Fuzzy Logic is present trend for decision making, classification and prediction where problem can be formulated by mapping input variable with output variable or where simple solution does not exists. There are three basic steps for fuzzy inference system such as Fuzzification, rule evaluation and Defuzzification.

Table 1. Linguistic labels for fuzzy variables.

S/NO	Parameters	Linguistic Labels
1	Temperature	Very high TM, High TM, Medium TM, Low TM, Very low TM
2	Humidity	Very high HU, High HU, Medium HU, Low HU, Very low HU
3	Wind speed	Very high WS, High WS, Medium WS, Low WS, Very low WS
4	Rain Fall	Very high RF, High RF, Medium RF, Low RF, Very low RF

Fuzzification means converting numeric value into linguistic value. Human intuition method is well accepted method for the membership function value assignment throughout the world. Fuzzy inference engine produce the result after rule evaluation also in terms of linguistic value. Fuzzy inference is the process of mapping with a given set of input and output through a set of fuzzy rules. Figure 3 shows the general structure of a fuzzy system.

3.5. Estimation of Annual Rainfall Using MFIS

Fuzzy inference system is non-linear models that describe the input-output relation of a real system using a set of fuzzy IF-THEN rules. Each fuzzy IF-THEN rules it a proportion of the form:

$$\text{Rule m: IF } (X_1 \ is \ A_1, m) \ and \ \left(X_2 is \ A_{2,m}\right) and \dots and \left(X_k \ is \ A_{k,m}\right) then \ Y \ is \tag{4}$$

Expressing the relation between K input variable $X_1, X_2, \dots \dots \dots X_k$ and the output Y the terms $A_{k,m}$ in the antecedents of the rules (i.e., the IF part of the rules) represent fuzzy sets used to partition the input space into overlapping region (Zadeh, 1996). A fuzzy set is generalization of the classical concept of set, in which membership defined as a question of degree rather than in a binary manner (either non –membership or full membership). Each fuzzy set $A_{k,m}$ in equation (1) is described by its membership function $A_{k,m}$ which evaluates the degree of membership of any value X_k in the fuzzy set $A_{k,m}$ through the corresponding membership value $A_{k,m}(X_k)$. The membership value $A_{k,m}(X_k)$ vary in the range (0, 1), where 0 indicates absolute non-membership and 1 indicates full membership of X_k in the fuzzy set $A_{k,m}$. The structure of the rule consequence (i.e. the THEN part of the rules) depends on the type of fuzzy inference system under consideration to state in the relation between K, the input variable $X_1, X_2, \dots \dots \dots X_k \ and \ the \ out \ put \ is \ Y$. In prior of rules $A_{k,m}$ shows the Fuzzy collection which are used are used for separating the entrant space in to the overlap's areas. A fuzzy system is a generalization of classic system which membership function is introduced as a subject of degree in Binary form (each of no membership or perfect membership).

Below Stage was considered to collect the model of rainfall forecasting:

i. Dividing the entrances and output into fuzzy periods

ii. Marking fuzzy rules depends on the exits information.
iii. Using the fuzzy rules for predicting.

The Fuzzy membership function are collected in triangular from of one tenth was used to collect the rain fuzzy membershipfunction. The index prepard to prevent from deficies exiting in normal present method in this thesis, MathLab Software was used to collect the fuzzy membership functions depend on the indes of one tenth. It is necessary to mension that this general division, was reviesed depend on the result sensitivity analysi of fuzzy model. In next stages the final structer of fuzzy membership function was ascertained. Peroids of selected rainfall depend on classification of the index of one tenths. Fuzzy regions were divided in to five area such as very low, low, medium, high and very high. After the anaysis of sensitivity for rain fuzzy division and avove-mentioned signals, the general from of a collected fuzzy membership functions are assigned. Figure 3 shows the schenatic of the fuzzy model diagram which is collected for rainfall estimation.

Table 2. Values of rainfall parameters and their membership function

Rainfall Parameters	Fuzzy Set	Range of Membership Function		
	Very High TM	25.53	25.70	25.90
	High TM	25.34	25.53	25.73
Temperature	Medium TM	25.14	25.34	25.53
	Low TM	24.94	25.14	25.14
	Very Low TM	24.74	24.94	25.14
	Very High HU	80.99	81.85	82.72
	High HU	80.13	80.99	80.85
Humidity	Medium HU	79.26	80.13	80.99
	Low HU	78.41	79.26	80.13
	Very Low HU	77.55	78.41	79.27
	Very High WS	1.73	2.14	2.55
	High WS	1.13	1.73	2.14
Wind Speed	Medium WS	0.91	1.32	1.73
	Low WS	0.50	0.91	1.32
	Very Low WS	0.09	0.50	0.91

3.6. MATLab Fuzzy Logic Toolbox

MATLab fuzzy logic toolbox facilitates the development of fuzzy-logicsystems using graphical user interface (GUI) tools command line functionalit. The tool can be used for building Fuzzy Expert Systems Adaptive Neuro-Fuzzy Inference Systems (ANFIS).

3.7. Graphical User Interface Tools

There are five primary GUI tools for building, editing, and observing fuzzy inference systems in the Fuzzy logic toolbox:

1. Fuzzy Inference System (FIS) Editor

2. Membership Function Editor

3. Rule Editor

4. Rule Viewer

5. Surface Viewer

3.8. Fuzzy Inference System

Two type of inference system

Mamdani inference method

Sugeno inference method

Mamdani's fuzzy inference method, the most common methodology for rainfall Estimation.

4. Method of Error Measures

The following error measures were calculated to ascertain the efficiency of the fuzzy rule-based model.

4.1. Estimation Error

$$EE = \left|\frac{Actual_{RF} - Estimated_{RF}}{Actual_{RF}}\right| \times 100\ \% \tag{5}$$

4.2. Root Mean Square Error (RMSE)

RMSE is a good measure of Estimation accuracy. It is frequently used to measure the differences between values Estimated by a model and the values actually observed from the thing being modeled. These individual differences are also called residuals.

$$RMSE = \sqrt{\frac{\sum_i^n Y_j - \hat{Y}_j}{N}} \tag{6}$$

where Y_j are actual values, $\hat{Y}_j$ are estimated values for rainfall and N is the number of observation.

5. Result and Discussions

All the districts are not equal weather situation for all weather component so, it will be quite interesting and useful to examine the level of weather situation of different stations separately temperature, sunshine hour, wind speed, cloud, rainfall, sea-level, pressure, humidity. The composite index of meteorological situation therefore, estimated for three stations separately for each sector. The Annual rainfall of the country has been determined using historic available data from the Bangladesh Meteorological Department (BMD). Rainfall is considered as the measure of climate change in a particular region. In this Study, Figure 5, Figure 6 and Figure 7 are the input variables were initially partitioned into five linguistic ranges Very high, High, Medium, Low, and Very Low. Triangular membership functions can use. And Figure 8 is the output variable of five linguistic ranges.

In general, there could be m^n rules where n is the number of inputs and m is the number of partitions. However, as the number of rules increases, the complexity of the formulation also increases leading to what is referred to as the curse of dimensionality. In this work, the Table 3 reveal that the summary of the result from fuzzy logic system. This table consists of firing strength for an acceptable rule, total records column is obtained from January 2008 to December 2017 rainfall record data from Bangladesh Meteorological Department (BMD), correctly classified record column shows how many records from the total records were classified correctly and the estimation error of the classification. Table 3 shows the amount of observatory rain and estimation rain. It is necessary to mention that these results were calculated for January 2008 to December 2017 which was test period of the model. It is necessary to remember that the amount of estimated rainfall in the third column is obtained after de-Fuzzification of model output achieved by non-Fuzzification of selected region of Rangpur district. Therefore this amount shows the gravity of the output fuzzy series.

Table 3. Annual average rainfall estimation by using MFIS.

Year	Actual Rainfall	Estimated Rainfall	Estimation Error	RMSE
2008	5.22	5.27	0.96%	.
2009	6.07	5.88	3.13%	.
2010	5.76	5.69	1.21%	.
2011	5.29	5.32	0.57%	.
2012	5.14	5.88	14.40%	0.51%
2013	5.25	5.51	4.95%	.
2014	4.48	5.88	31.25%	.
2015	6.62	6.01	9.21%	.
2016	5.93	6.25	5.40%	.
2017	5.18	5.88	13.51%	.

The model results consideration shows the difference between the rain observed and estimated is in the acceptable range of the selected year rainfall. And this model can estimate the rain with the acceptable error in 0.51% of with ten years. In figure 13 observed that, the model could estimate the five category of rainfall like as low, very low, medium, high and very high rainfall. Very high rainfall represents dark blue colour and light blue colour indicates the high rainfall of selected region in Rangpur district. The reason of this matter is that these years were not repeated during estimation model calibration and by this reason the collective fuzzy rules did not include these events. Now we find out the estimation rainfall by using Figure 11 “Rule Viewer by Fuzzy Engine” and then we sitting all the actual rainfall data and estimated data on MS-Excel and finally plotted the graph of Figure 14 comparison between actual rainfall and estimated rainfall. We observed that it has some average 8.46% error of estimated error and 0.51% RMS error of this calculation. But RMS error is a good measure of estimation accuracy. In this study we are successfully used Mamdani Fuzzy inference system for estimating rainfall in Rangpur district.

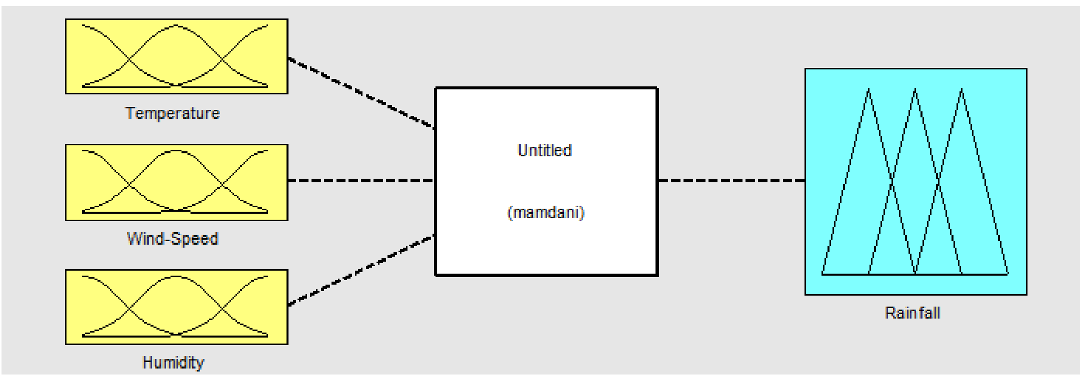

Figure 5. Fuzzy inference system category editor.

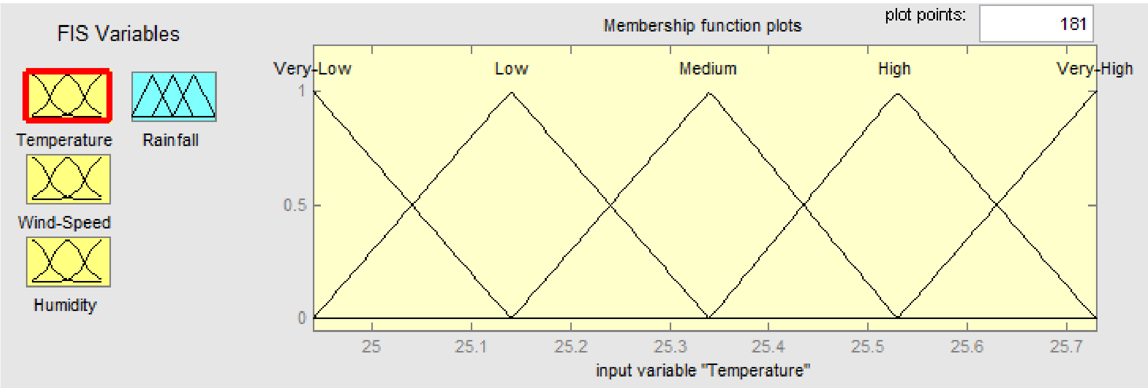

Figure 6. Membership function of five category temperature input variable.

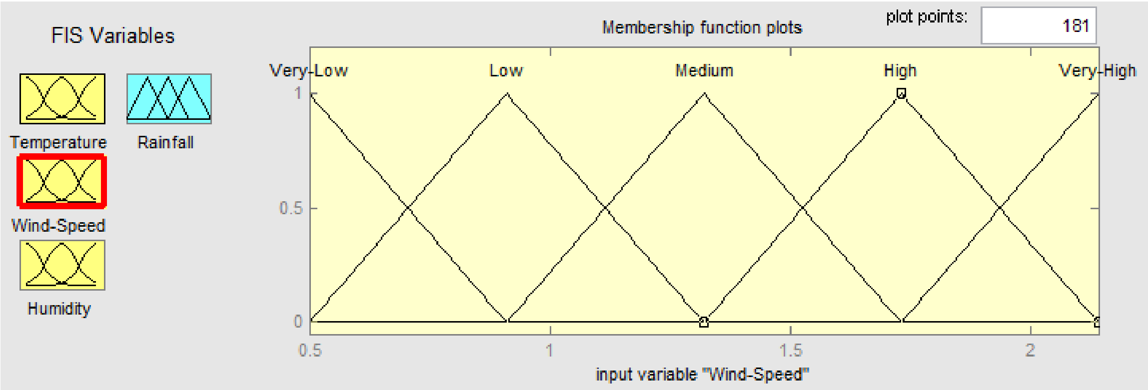

Figure 7. Membership function of five category wind speed input variable.

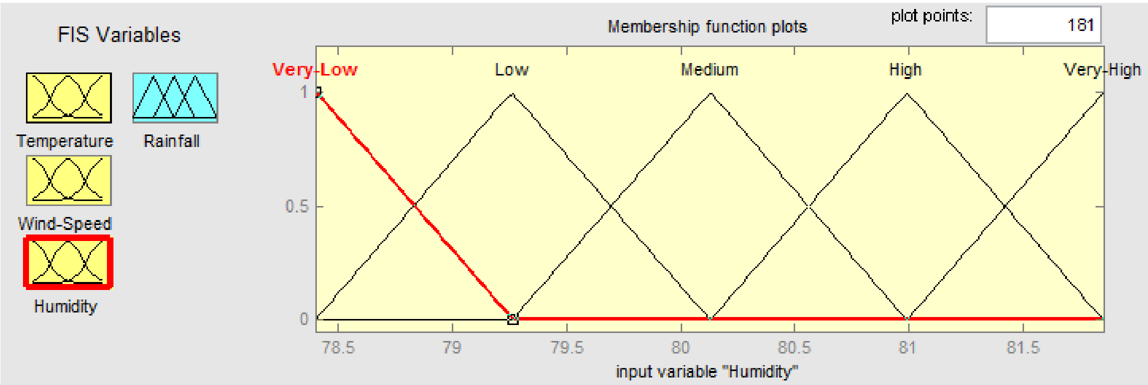

Figure 8. Membership function of five category humidity input variable.

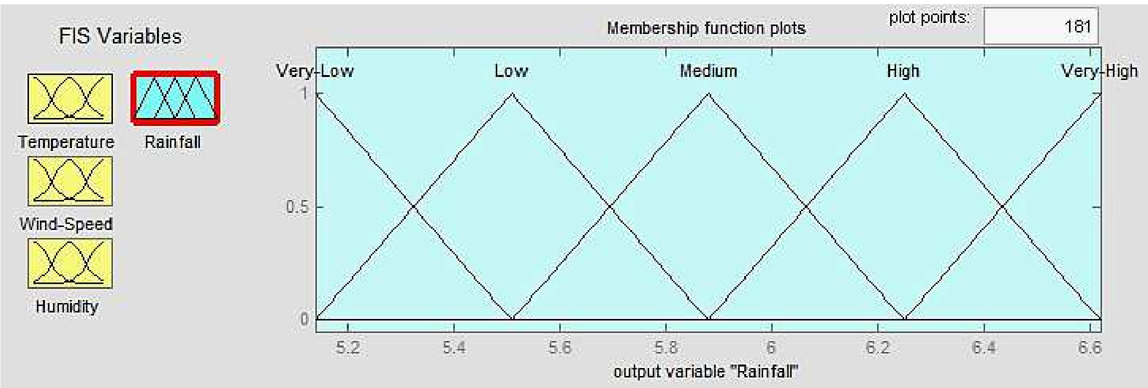

Figure 9. Membership function of five category rainfall output variable.

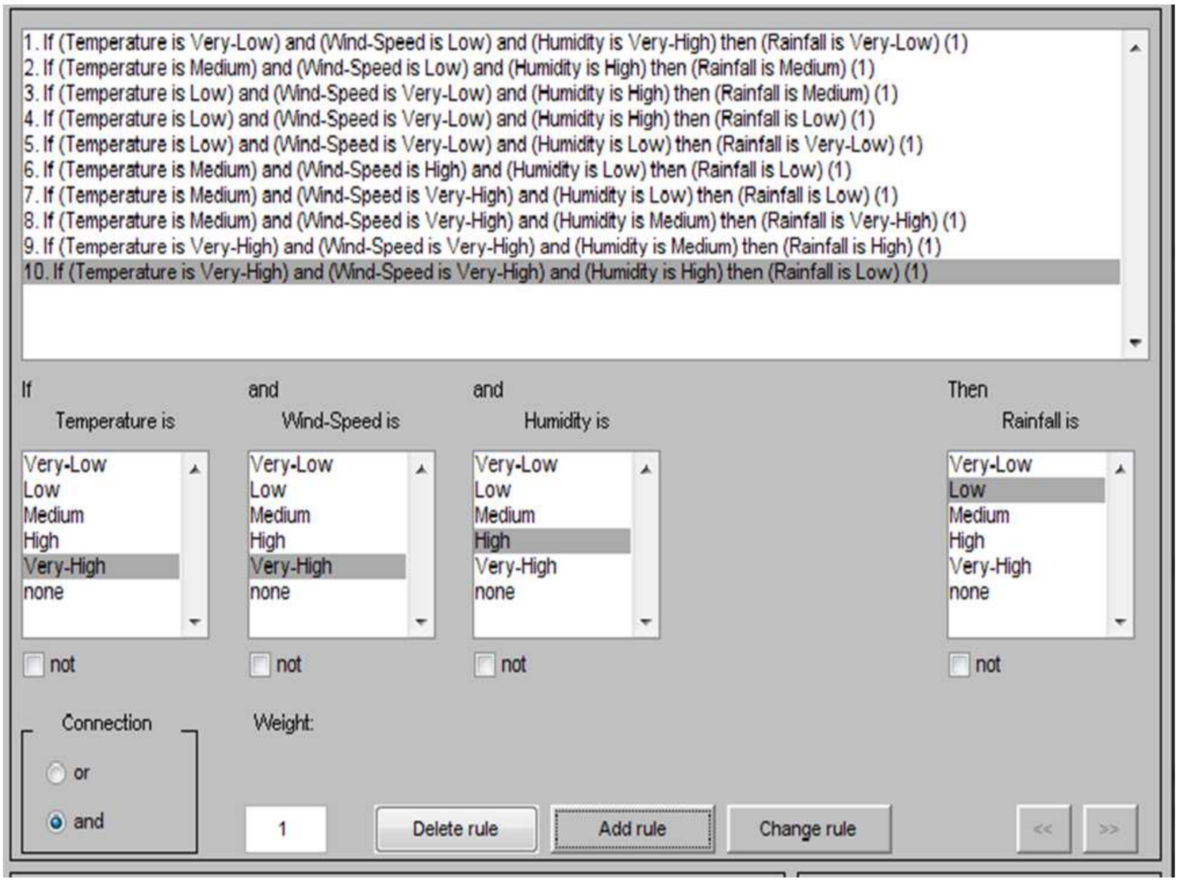

Figure 10. Rule editor by fuzzy engine.

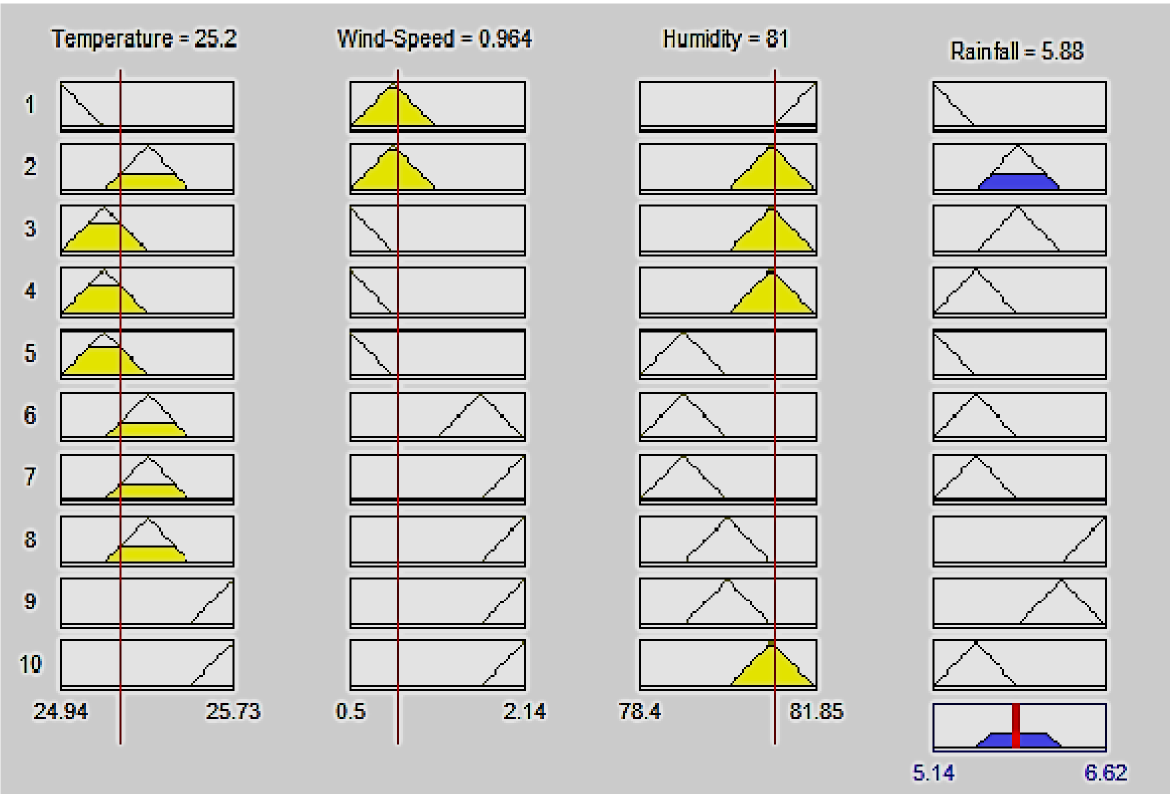

Figure 11. Amount of estimation rainfall viewer by fuzzy engine.

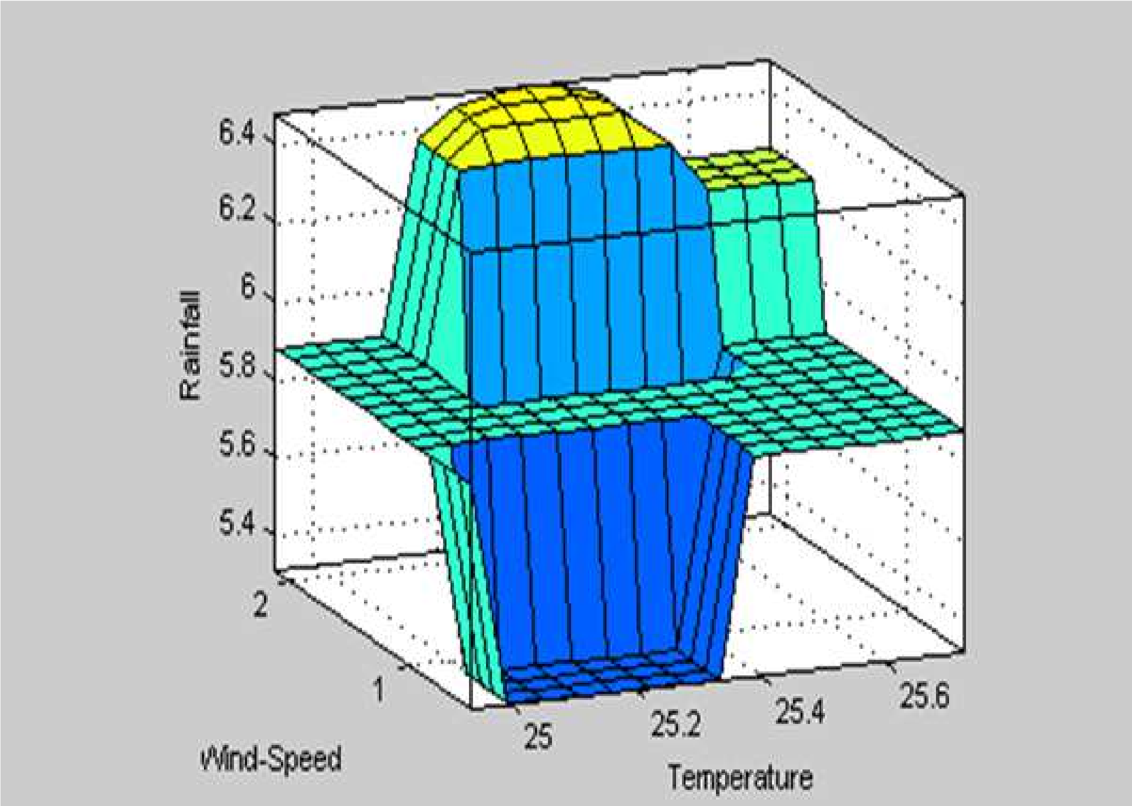

Figure 12. 3D shape of surface in the selected area of estimated rainfall.

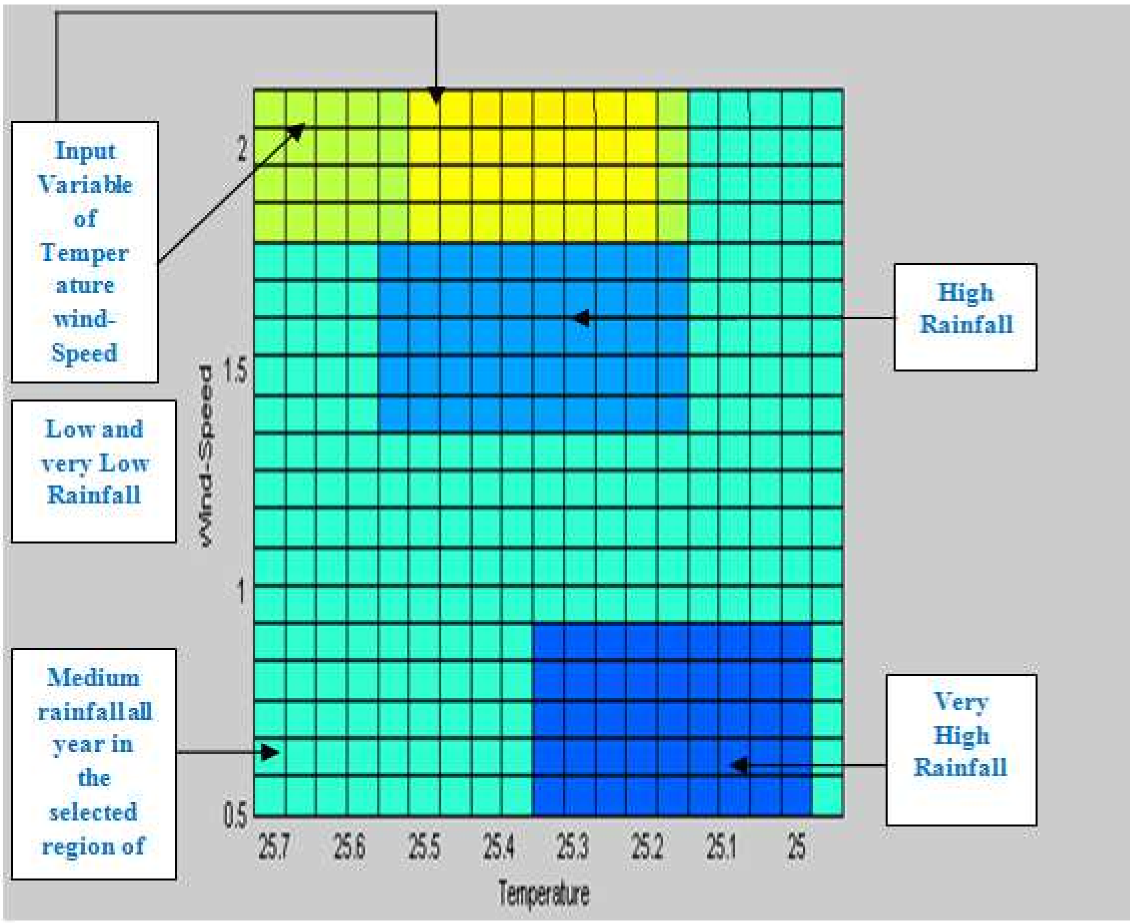

Figure 13. 2D shape of surface in the selected area of estimated rainfall.

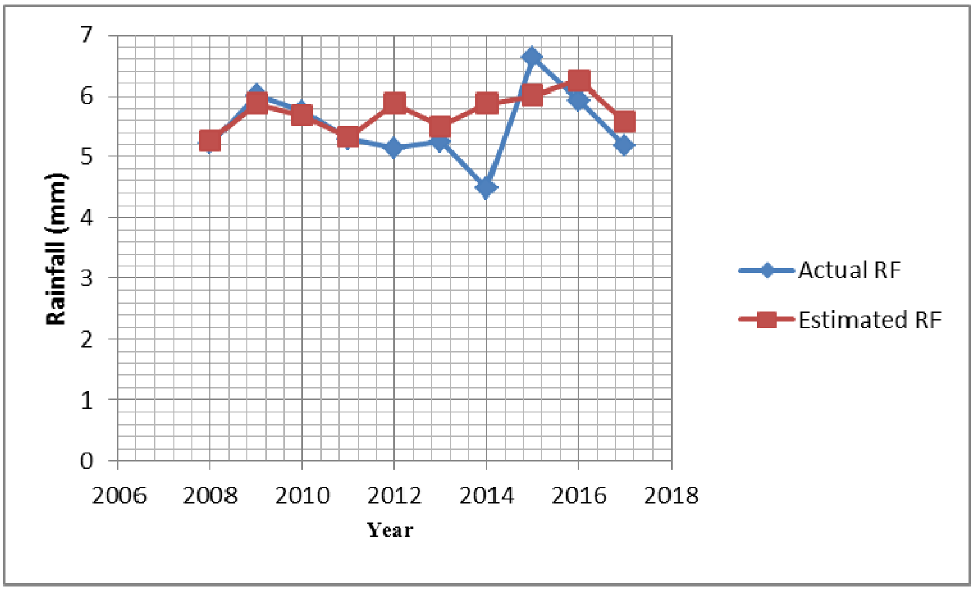

Figure 14. Comparison between actual rainfall and estimated rainfall in the area which was studied by Mamdani fuzzy inference system

The principle aim of this study was to examine "A Study on Rainfall Calibration and Estimation at the Northern Part of Bangladesh by Using Mamdani Fuzzy Inference System" The rainfall pattern is easily determined using MFIS that are very low, low, medium, high and very high rainfall area in the selected region of Rangpur district in Bangladesh. The comparison of both techniques is given in the above result. The present chapter is providing the discussions of findings and conclusion for the study which will be helpful for further future research. In this work we are used previous ten years data from BMD for calculated January 2008 to December 2017. Mamdani Fuzzy inference system is the most important rainfall estimation rule based on fuzzy set theory.

In this study we observer that the study area of Rangpur where was the annual average maximum rainfall of actual data is 6.62 (mm) in 2015 and minimum rainfall data is 4.48 (mm). But we have using rule viewer by fuzzy engine in figure 11 where was the maximum rainfall is 6.25 (mm) in year 2016 and minimum rainfall is 5.27 (mm) in the year of 2008. The total record column is obtaining from January 2008 to December 2017 rainfall record from Bangladesh meteorological department (BMD). In this work reveal that, five category rainfall measurements of selected study area and shows the difference between the actual rainfalls and estimated is in the acceptable ranges of the study year rainfall. In this work, the parameters used for the estimated of rainfall are temperature, humidity and wind speed. The values of these parameters were arranged as a string separated by comma to form a single record. These records were further normalized and fuzzified to be used to generate the rules used for estimation by the fuzzy logic system.

We can infer from the above discussion that the variables used in the rainfall forecast model have been able to detect that the distribution pattern of rainfall in the region and can act as predictors in rain forecast models. It must be noted that all the signals selected in this study confirm to the cyclonic routes of the Middle East and Iran which were studied by Alijani (2002). This is confirmed by the result of the research. A comparison of the results of the study with those of other researches such as karamonz et al., (2005) in the western part of the country, or Mousavi Baygi et al., (2008) in the region of khorasan including three provinces of Razavi, Northern and Southern khorasans, indicates the high efficiency of such models as neural network, adaptive neuron-fuzzy network in estimating the rainfall.

Thus, based on the information from the previous years, the model would estimate the amount of rainfall to be expected in each ten years an interval January 2008 to December 2017. Finally, the observed data and estimated data have plotted as shown figure 14. This result showed that MFIS model is promising and efficient and can successfully amount of rainfall in 99.49% (buy using RMSE) of the years in the selected study area.

6. Conclusion

Application of fuzzy set theory has rapidly increased with establishing its utility in numerous areas of the scientific world. Any system consisting of vague and ambiguous input variables may contribute to an ultimate effect. In fuzzy logic approach, it is possible to express crisp intervals in terms of linguistic subsets by fuzzy expressions like low, very low, medium, high, very high. The MFISs are built by domain experts and are used in automatic control, decision analysis, and various other expert systems. Fuzzy logic modelling for this modest application brings the advantage of controlling at any moment the situation as for "T" temperature and "W" wind speed and "H" humidity then estimate "R" amount of rainfalls. In this study, we attempted to estimate the rainfall rule-based on Mamdani fuzzy inference System technique. As evident from Table 3, there have been few deviations of the estimation rainfall value from the actual. The performance evaluation of the Fuzzy Logic model was done by calculating estimation error (EE), Root Mean Square Error (RMSE). As the EE, RMSE, values on data were comparatively less, the estimation model is reliable and efficient and can be used for rainfall estimation. The Fuzzy Logic technique could be improved upon by combining it with another method i.e., Artificial Neural Network, time series analysis, forecast and Genetic Algorithm for its optimization purpose. Also the Fuzzy Inference System could be further improved on by using larger data sets and more rainfall parameters.

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