ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. 9, Issue 7, July 2023

Application of Rainfall Prediction Model by Using Fuzzy Logic in Trichy District

Rajan D [1], Sugunthakunthalambigai R[2],

Associate Professor, Department of Mathematics, TBML College, Porayar - 609307, Tamil Nadu, India [1]

Assistant Professor, Department of Mathematics, Agricultural Engineering College and Research Institute, TNAU, Kumulur, Tamil Nadu, India [2]

***Abstract*—Rainfall events have been used as the meteorological phenomenon to illustrate fuzzy technique in this case. The majority of people are aware of how weather significantly affects the agriculture sector. In fact, the basic factors that affect agricultural production—precipitation, temperature, atmospheric (barometric) pressure, relative humidity, daylight hours, cloudiness, wind speed, evapotranspiration, etc.—are crucial for crops. Extreme rain or drought during pivotal stages of a crop's growth can have a significant impact on productivity and yields. Rainfall has the greatest impact on human lives of all-weather events. The knowledge base and the fuzzy reasoning or decision-making units are the two functional parts of the created fuzzy logic model. On the fuzzy logic model, the fuzzification and the defuzzification operations were carried out**

***Index Terms*— fuzzy logic, rainfall, membership, temperature, wind speed.**

I. INTRODUCTION

Weather forecasting is one of the most imperative and demanding operational responsibilities carried out by meteorological services all over the world. It is a complicated procedure that includes numerous specialized fields of know-how (Guhathakurata, 2006). Forecasting the rainfall at different time scales is important to both short-term and long-term planning in agricultural production for successful crop selection and crop rotation planning. An accurate and timely rainfall forecast is crucial for reservoir operation and flooding prevention because it can provide an extension of lead-time of the flow forecast, larger than the response time of the watershed, in particular for small and medium-sized mountainous basins. In the short term, this requires a good idea of the upcoming season. In the long term, it needs realistic projections of scenarios of future variability and change (Abraham et al., 2001).

Karamouz et al. (2004) used a model based on fuzzy rules and neural networks using large-scale climatic signals to predict rainfall in the western Iran (the basins of Karoon, Karkheh and the western border). Their results showed that except for the southwest region, where both models had similar errors of above 35%, in the northwest and the western regions, the error of the fuzzy model was 8.4%; that is, 13% lower than that of neural network.Bardossyet al.(1995) instigated fuzzy logic in cataloguing atmospheric circulation patterns. Ozelkan et al.(1996) compared the concert of regression analysis and fuzzy logic in studying the relationship between monthly atmospheric circulation patterns and precipitation.

The fuzzy logic possibility and its degree of effect due to the ambiguous input variables are considered by some as being generated in the human mind and is often referred to as expert knowledge. Expert knowledge is expressed as a vague or ambiguous expression and not inform of any quantified value. Based on the generated idea that the possibility and degree of effect from vague and abstruse inputs exists, then the knowledge based rule can be expressed in the form of statements, called fuzzy statements or production rules.

In this research work, the focus is on the fuzzy logic model for predicting rainfall in Trichy district.

II. BASICS OF FUZZY LOGIC

Fuzzy Logic is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded microcontrollers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. 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. 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-rulebased systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy systems.

Definition 1. (Fuzzy set) Let X be a nonempty set. A fuzzy set A in X is characterized by its membership function $\mu_A: X \rightarrow [0, 1]$ and $\mu_A(x)$ is interpreted as the degree of membership of element x in fuzzy set A for each $x \in X$.

It is clear that A is completely determined by the set of tuples $A = \{(u, \mu_A(u))|u \in X\}$. Frequently we will write A(x) instead of $\mu_A(x)$. The family of all fuzzy sets in X is denoted by F(X) . If $X = \{x_1, \cdots, x_n\}$ is a finite set and A is a fuzzy set in X then we often use the notation $A = \mu_1/x_1 + \cdots \mu_n/x_n$ where the term μ_i/x_i , $i = 1, \cdots, n$ signifies that μ_i is the

ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. 9, Issue 7, July 2023

grade of membership of xi in A and the plus sign represents the union.

Definition 2. (Support) Let A be a fuzzy subset of X; the support of A, denoted supp(A), is the crisp subset of X whose elements all have nonzero membership grades in A. supp(A) = {x ∈ X|A(x) > 0}.

Definition 3. (Normal fuzzy set) A fuzzy subset A of a classical set X is called normal if there exists an x ∈ X such that A(x) = 1. Otherwise A is subnormal.

Definition 4. (α−cut) An α-level set of a fuzzy set A of X is a non-fuzzy set denoted by $[A]^{\alpha}$ and is defined by

$[A]^{\alpha} = \{t \in X | A(t) \geq \alpha\}$ if $\alpha > 0$

Cl (supp A) if $\alpha = 0$

Where cl (supp A) denotes the closure of the support of A.

Definition 5. (Convex fuzzy set) A fuzzy set A of X is called convex if $[A]^{\alpha}$ is a convex subset of X∀α ∈ [0, 1].

Definition 6. (Fuzzy number) A fuzzy number A is a fuzzy set of the real line with a normal, (fuzzy) convex and continuous membership function of bounded support. The family of fuzzy numbers will be denoted by F.

Definition 7. (Quasi fuzzy number) A quasi fuzzy number A is a fuzzy set of the real line with a normal fuzzy convex and continuous membership function satisfying the limit conditions $\lim_{t\to\infty} A(t) = 0$, $\lim_{t\to-\infty} A(t) = 0$.

Fuzzy number:

Let A be a fuzzy number. Then $[A]^{\gamma}$ is a closed convex (compact) subset of R for all γ ∈ [0, 1]. Let us introduce the notations $a_1(\gamma) = \min[A]^{\gamma}$, $a_2(\gamma) = \max[A]^{\gamma}$

In other words, $a_1(\gamma)$ denotes the left-hand side and $a_2(\gamma)$ denotes the right-hand side of the γ-cut. It is easy to see that If α ≤ β then $[A]^{\alpha} \supset [A]^{\beta}$

Furthermore, the left-hand side function $a_1 : [0, 1] \to R$ is monotone increasing and lower semicontinuous, and the right-hand side function $a_2 : [0, 1] \to R$ is monotone decreasing and upper semicontinuous. We shall use the notation $[A]^{\gamma} = [a_1(\gamma), a_2(\gamma)]$. The support of A is the open interval $(a_1(0), a_2(0))$. The support of A is $(a_1(0), a_2(0))$. If A is not a fuzzy number then there exists an γ ∈ [0, 1] such that $[A]^{\gamma}$ is not a convex subset of R.

Definition 8. (Triangular fuzzy number) A fuzzy set A is called triangular fuzzy number with peak(or center)a, left width α > 0 and right width β > 0 if its membership function has the follow form A(t)

$$= \begin{cases} 1 - \frac{a-t}{\alpha} & \text{if } a - \alpha \leq t \leq \alpha \\ 1 - \frac{t-a}{\beta} & \text{if } a \leq t \leq a + \beta \\ 0 & \text{if otherwise} \end{cases}$$

and we use the notation A = (a, α, β).It can easily be verified that

$[A]^{\gamma} = [a - (1 - \gamma)\alpha, a + (1 - \gamma)\beta]$, ∀γ ∈ [0, 1] The support of A is (a − α, b + β). A triangular fuzzy number with center a may be seen as a fuzzy quantity.

Definition 9. (Trapezoidal fuzzy number) A fuzzy set A is called trapezoidal fuzzy number with tolerance interval [a, b], left width α and right width β if its membership function has the following form A(t) =

$$= \begin{cases} 1 - \frac{a-t}{\alpha} & \text{if } a - \alpha \leq t \leq \alpha \\ 1 & \text{if } a \leq t \leq b \\ 1 - \frac{t-b}{\beta} & \text{if } a \leq t \leq b + \beta \\ 0 & \text{if otherwise} \end{cases}$$

and we use the notation A = (a, b, α, β). It can easily be shown that $[A]^{\gamma} = [a - (1 - \gamma)\alpha, b + (1 - \gamma)\beta]$, ∀γ ∈ [0, 1]. The support of A is (a − α, b + β). A trapezoidal fuzzy number may be seen as a fuzzy quantity ”x is approximately in the interval [a,b]”.

Definition 10. Any fuzzy number A∈ F can be described as

$$A(t) = \begin{cases} L\left(\frac{a-t}{\alpha}\right) & \text{if } t \in [a - \alpha, a] \\ 1 & \text{if } t \in [a, b] \\ R\left(\frac{t-b}{\beta}\right) & \text{if } t \in [b, b + \beta] \\ 0 & \text{if otherwise} \end{cases}$$

where [a, b] is the peak or core of A,

$L : [0, 1] \to [0, 1]$, $R : [0, 1] \to [0, 1]$

are continuous and non-increasing shape functions with L(0) = R(0) = 1 and R(1) = L(1) = 0. We call this fuzzy of LR-type and refer to it by $A = (a, b, \alpha, \beta)_{LR}$.

Let $A = (a, b, \alpha, \beta)_{LR}$ be a fuzzy number of type LR. If a = b then we use the notation $A = (a, \alpha, \beta)_{LR}$ and say that A is a quasi-triangular fuzzy number. Furthermore if L(x) = R(x) = 1 − x then instead of $A = (a, b, \alpha, \beta)_{LR}$ we simply write A = (a, b, α, β).

Definition 11. (subsethood) Let A and B are fuzzy subsets of a classical set X. We say that A is a subset of B if A(t) ≤ B(t), ∀t ∈ X.

Definition 12. (Equality of fuzzy sets) Let A and B are fuzzy subsets of a classical set X. A and B are said to be equal, denoted A = B, if A ⊂ B and B ⊂ A. We note that A = B if and only if A(x) = B(x) for x ∈ X.

Definition 13. (Empty fuzzy set) The empty fuzzy subset of X is defined as the fuzzy subset ∅of X such that ∅(x) = 0 for

ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. 9, Issue 7, July 2023

each x ∈ X. It is easy to see that ∅⊂A holds for any fuzzy subset A of X.

Definition 14. The largest fuzzy set in X, called universal fuzzy set in X, denoted by 1_X , is defined by $1_X(t) = 1$, for all t ∈ X. It is easy to see that A⊂ 1_X holds for any fuzzy subset A of X.

Definition 15. (Fuzzy point) Let A be a fuzzy number. If supp(A) = $\{x_0\}$ then A is called a fuzzy point and we use the notation A = $\bar{x}_0$. Let A = $\bar{x}_0$ be a fuzzy point. It is easy to see that $[A]^\gamma = [x_0, x_0] = \{x_0\}$, for all γ ∈ [0, 1]

III. Features of Membership Functions

Fig. 1. Map of Study Area

Tiruchirappalli district is located in the Cauvery River in Tamill Nadu, India. Tiruchirappalli district lies within Tamil Nadu. The district has an area of 4,404 square kilometers. It is bounded in the north by Salem district, in the northwest by Namakkal district, in the northeast by Perambalur district and Ariyalur district, in the east by Thanjavur District, in the southeast by Pudukkottai district, in the south by Madurai district and Sivagangai district, in the southwest by Dindigul district and, in the west by Karur district. The Kaveri river flows through the length of the district and is the principal source of irrigation and drinking water.

Rainfall is heaviest between October and December because of the northeast monsoon winds, and from December to February the climate is cool and moist. The winter season being cool is pleasant and enjoyable. Period of hot summer prevails till June when South West monsoon sets which brings scanty rains. This monsoon period ends in August. The heaviest rainfall occurs during October to December when the North East monsoon sets in.Tiruchirappalli has a tropical climate. The summers are much rainier than the winters in Tiruchirappalli. Temperatures are relatively consistent throughout the year; with average high temperatures ranging from about 28–36°C and average low temperatures between approximately 21-28°C. The average temperature in Tiruchirappalli is 28.8 °C. The average annual rainfall is 841.9 mm.

IV. Rainfall Prediction Using Fuzzy Logic Modeling

A 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.

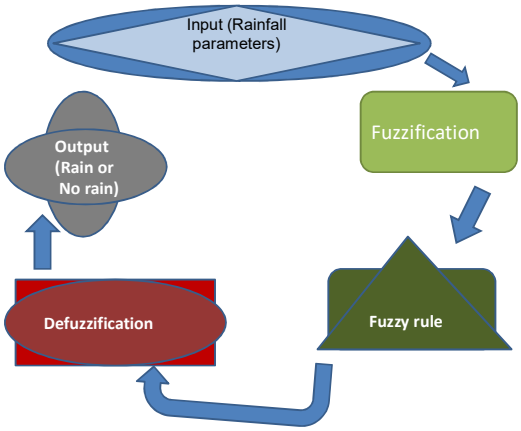

Fig. 2. Fuzzy model structure of rainfall predicting

In this work, a small number of linguistic terms (e.g., high, medium, low) referred to as fuzzy sets, are assigned to each variable (e.g., temperature). 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) to a particular fuzzy set A (e.g., high) 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. Fuzzification of linguistic variables involves classification of parameters into linguistic labels and assigning membership functions for each of the variable. [10] discussed about the combination of Graph cut liver segmentation and Fuzzy with MPSO tumor segmentation algorithms. The system determines the elapsed time for the segmentation process. The accuracy of the proposed system is higher than the existing system. The algorithm has been successfully tested in multiple images where it has performed very well, resulting in good segmentation. It has taken high computation time for the graph cut processing algorithm. In future work, we can reduce the computation time and improves segmentation accuracy

This method resides of two input variables and one output variable. The month wise wind speed and the temperature are the input variables and the amount of rainfall anticipated will

ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. 9, Issue 7, July 2023

be the output of each month. The values of the input variables (Temperature and Wind Speed) are alienated into five linguistic variable terms, which are Very high, High, Medium, Low, and Very low.

TABLE 1 LINGUISTIC LABEL FOR FUZZY VARIABLES

S No	Parameters	Linguistic Labels
1	Temperature	Very high, High, Medium, Low, and Very low
2	Wind Speed	Very high, High, Medium, Low, and Very low

TABLE 2 LINGUISTIC VALUES

S No	Parameters
Very High	VH
High	H
Medium	M
Low	L
Very Low	VL

The month wise temperature and wind speed of Trichy district is given in FIGURE 2. The minimum and maximum temperature in this district was 28℃ and 36℃ respectively. Also the minimum and maximum wind Speed of the district in the year 2020 was 16 Km/hr and 24 Km/hr. The data was collected from statistical department of Trichy district. The district rainfall data was chosen from the areas such as Lalgudi, Musiri, Srirangam, Thiruverambur and Pullambadi. [8] discussed that Biomedical and anatomical data are made simple to acquire because of progress accomplished in computerizing picture division. More research and work on it has improved more viability to the extent the subject is concerned. A few tech- niques are utilized for therapeutic picture division, for example, Clustering strategies, Thresholding technique, Classifier, Region Growing, Deformable Model, Markov Random Model and so forth. This work has for the most part centered consideration around Clustering techniques, particularly k-implies what's more, fluffy c-implies grouping calculations. These calculations were joined together to concoct another technique called fluffy k-c-implies bunching calculation, which has a superior outco- me as far as time usage. The calculations have been actualized and tried with Magnetic Resonance Image (MRI) pictures of Human cerebrum. The proposed strategy has expanded effectiveness and lessened emphasis when contrasted with different techniques. The nature of picture is assessed by figu- ring the proficiency as far as number of rounds and the time which the picture takes to make one emphasis. Results have been dissected and recorded. Some different strategies were surveyed and favorable circumstances and hindrances have been expressed as special to each. Terms which need to do with picture division have been characterized nearby with other grouping strategies

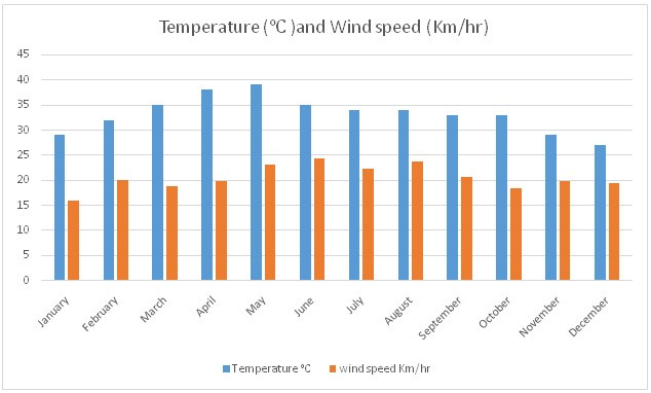

Fig. 3. Temperature and wind speed of Trichy district

. temperature is defined as:

$$\mu VL\ (T) = \begin{cases} 0 & if\ \ T > 30°C \\ -0.5T + 15 & if\ \ 28°C \le T \le 30°C \end{cases}$$

$$\mu L\ (T) = \begin{cases} 0.5T - 14 & if\ 28°C \le T \le 30°C \\ -0.5T + 16 & if\ 30°C \le T \le 32°C \\ 0 & if\ \ T > 32°C \end{cases}$$

$$\mu M\ (T) = \begin{cases} 0.5T - 15 & if\ \ 30°C \le T \le 32°C \\ -0.5T + 17 & if\ \ 32°C \le T \le 34°C \\ 0 & if\ \ T > 34°C \end{cases}$$

$$\mu H\ (T) = \begin{cases} 0.5T - 16 & if\ \ 32°C \le T \le 34°C \\ -0.5T + 18 & if\ \ 34°C \le T \le 36°C \\ 0 & if\ \ T > 34°C \end{cases}$$

$$\mu VH\ (T) = \begin{cases} 0 & if\ \ T < 36°C \\ 0.5T - 17 & if\ 34°C \le T \le 36°C \end{cases}$$

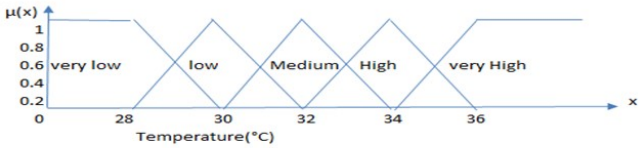

Fig 4. Graph of membership function of temperature and corresponding fuzzy levels

Wind Speed Equation: The temperature sorts from 16 Km/hr - 24 Km/hr. The membership value of the wind speed is defined as:

$$\mu VL\ (W) = \begin{cases} 0 & if\ \ W > 18 \\ 0.5W + 9 & if\ \ 16 \le W \le 18 \end{cases}$$

$$\mu L\ (W) = \begin{cases} 0.5W + 8 & if\ \ 16 \le W \le 18 \\ -0.5W + 10 & if\ 18 \le W \le 20 \\ 0 & if\ \ W > 20 \end{cases}$$

ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. 9, Issue 7, July 2023

$$\mu M(W) = \begin{cases} 0.5W - 9 & if\ 18 \le W \le 20 \\ -0.5W + 11 & if\ 20 \le W \le 22 \\ 0 & if\ W > 22 \end{cases}$$

$$\mu H(W) = \begin{cases} 0.5W - 10 & if\ 20 \le W \le 22 \\ -0.5W + 12 & if\ 22 \le W \le 24 \\ 0 & if\ W > 24 \end{cases}$$

$$\mu VH(W) = \begin{cases} 0 & if\ W < 24 \\ 0.5W - 11 & if\ if\ 22 \le W \le 24 \end{cases}$$

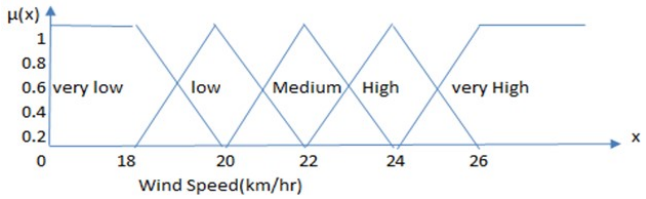

Fig. 5.: Graph of membership function of wind speed and corresponding fuzzy levels

V. Result & Discussion

The factors used for the prediction of rainfall are temperature and wind speed. The output variable value is clustered into five linguistic variables which are very poor, poor, medium, High, Very High.

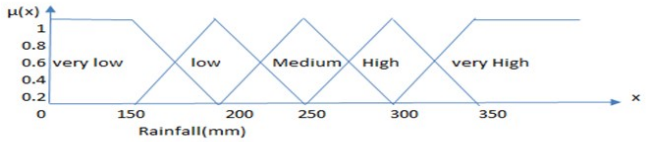

Fig. 6. Graph of membership function of temperature and wind speed

TABLE 3: RELATIONSHIP BETWEEN TEMPERATURE, WIND SPEED AND AMOUNT OF RAINFALL

	VL	L	M	H	VH
VL	VL	VL	L	L	M
L	VL	VL	L	M	M
M	L	L	M	M	H
H	L	M	M	H	H
VH	M	M	H	H	VH

Defuzzification implicates transformation of the linguistic variables to numerical or crisp values; these workings embrace the centroid defuzzification method. The formula for this system is given by $Y = \sum\mu(V_k)x\ V_k / \sum\mu(V_k)$ where k = 1,2…n and V_k is the value of the variable, $\mu(V_k)$ is the membership of the variable and Y is the crisp rainfall value.

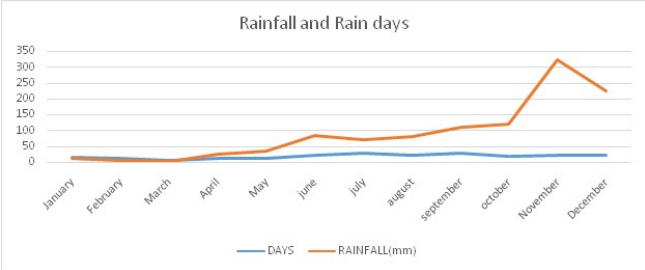

Fig. 7. Few deviations in the actual rainfall and predicted rainfall data.

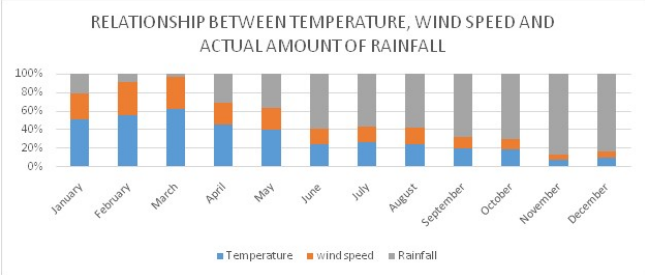

Fig. 8. Graph of relationship between temperature, wind speed and Actual amount of rainfall.

VI. Conclusions

In the present paper, Fuzzy set theory has been used for predicting the Rainfall. Two input variables are temperature and wind speed at a particular time and output variable is the amount of predictable rainfall. Temperature and wind speed are selected because which is the main factors of the influence the occurrence of rainfall. Temperature and wind speed are constructed eight equations which belong to the membership values and implements the diagram of the graph. In this method, the fitting membership functions for all parameters .The heaviest rainfall occurs during October to December when the North East monsoon.

References

[1] Agboola, A.H., Gabriel, A.J., Aliyu, E.O., and Alese B.K., (2013)," Development of a Fuzzy logic based Rainfall prediction model", International journal of Engineering and Technology, Volume 3, N0.4, 427- 435.

[2] Arumugam , P, Karthik S.M, "Prediction of Seasonal Rainfall Data in India using Fuzzy Stochastic modeling" Journal of pure and Applied mathematics ,Vol. 13, No.9 (2017), PP 6167 – 6174.

[3] Bardossy, A., Duckstein, L. and Bogardi ,I.,(1995), "Fuzzy rule-based classification of atmospheric Circulation patterns", International journal of climatology, Volume 15, 1087-1097.

[4] Center, B. and Verma, B.P.,(1998), "Fuzzy logic for biological and agricultural systems", International Journal of Applied Sciences, Volume 8, 213-225.

[5] Edvin and Yudha (2008). Application of Multivariate ANFIS for Daily Rainfall Prediction: Influences of

[6] Hasan, T., Zenkai, S., 1999. A new modeling approach for predicting the maximum daily temperature from a time series. Turkish Journal of the Engineering and Environmental Science 23, 173–180Training Data Size.Makara, Sains, 12, 7-14.

[7] Jimoh, R. G., Olagunju, M., Folorunso, I. O., &Asiribo, M. A. (2013). Modeling Rainfall Prediction Using Fuzzy Logic. International Journal of Innovative Research in Computer and Communication Engineering, 1, 929-936.

[8] Christo Ananth, S.Aaron James, Anand Nayyar, S.Benjamin Arul, M.Jenish Dev, "Enhancing Segmentation Approaches from GC-OAAM and MTANN to FUZZY K-C-MEANS", Investigacion Clinica, Volume 59, No. 1, 2018,(129-138)

ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. 9, Issue 7, July 2023

[9] Kevin, M. P., & Stephen, Y. (1998).Fuzzy Control. Berkeley, CA: Addison Wesley Longman Inc.
[10] Christo Ananth, D.R.Denslin Brabin, "ENHANCING SEGMENTATION APPROACHES FROM FUZZY K-C-MEANS TO FUZZY-MPSO BASED LIVER TUMOR SEGMENTATION", Agrociencia, Volume 54, No. 2, 2020,(72-84).
[11] Mahbub Hasan1, Xingzhong (Frank) Shi2, Teferi Tsegaye3, Nesar U. Ahmed1, Salam Md. Mahbubush Khan4, "Rainfall Prediction Model Improvement by Fuzzy Set Theory" JWARP, volume 5 , January, 2013, pp 1-11.
[12] Nasher, N. M. R. (2013). Impact of Climate Variability on Temperature and Rainfall Trend in Bangladesh: A Case of Two Cities. European Journal of Climate Change, 11, 5-10.
[13] Pant, L.M., Ashwagosh, G., 2004. Fuzzy rule-based system for prediction of direct action avalanches. Current Science 87 (1), 99–104
[14] Ross, T. J. (1997). Fuzzy Logic with Engineering Applications (p. 33). New York: McGraw-Hill International Editions
[15] Somia A. Asklany, in "Rainfall events prediction using rule-based fuzzy inference system", Atmospheric Research, ISSN:101, volume issue 1, 2011,pp-228-236
[16] Zadeh , L.A., " The Concept of a Linguistic Variable and its Application to Approximate Reasoning-part I". Information sciences, Vol. 8, PP. 199 -249, 1975
[17] Zadeh, A.L., 1965. Fuzzy logic. Information and Control 8 (3), 338–353
[18] https://www.scirp.org/
[19] https://www.researchgate.net
[20] https://www.ijsce.org
[21] http://www.kss.or.kr/
[22] https://www.scirp.org/