Application of the Fuzzy Logic Model for Prediction of the Monthly Evaporation Rate

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Abstract

Evaporation is the most influencing parameter of the hydrologic cycle and it is a key component playing an important role for development and the management of various water resource projects in arid/semi-arid climatic regions. Fuzzy logic is being used widely as the decision-making tool. In various past studies, Fuzzy Logic has been used to predict the values of various hydrological parameters with much less error. Present study intended to determine the application of Fuzzy Logic to predict the monthly evaporation. A Fuzzy model was developed from the observed data of average monthly maximum temperature, wind speed, relative humidity, and water temperature from Jan-2017 to Jan-2018. The predicted values of evaporation, by Fuzzy model, are compared with the actual field observations to evaluate its performance.
Keyword- Fuzzy, Fuzzy Model, Evaporation, Arid Climate

I. INTRODUCTION

The important major loss which affects the design of most of the irrigation and water conserving structure is the evaporation loss. Large amount of water is being lost on daily and yearly basis in some of the semi-arid and arid region from irrigation fields and reservoirs. Thus, managing water in such an area is a challenging task and study of the evaporation becomes important. Moghaddamnia et al., (2008) in areas with little rainfall, evaporation losses can represent a significant part of the water budget for a lake or reservoir, and may contribute significantly to the lowering of the water surface elevation. Therefore, accurate estimation of evaporation loss from the water body is of primary importance for monitoring and allocation of water resources, at farm scales as well as at regional scales.

Evaporation depends on various natural parameters such as temperature, wind speed, solar radiation, humidity etc. thus determining rate of evaporation needs to determine the all the mentioned parameter value on daily basis. There are many direct and indirect methods developed to measure the evaporation losses. In direct methods, Penman method is being conventionally used. Some other methods use formulas based upon measured parameter. In some cases, when it is not possible to install the instrument in a particular topography, indirect methods can prove helpful to determine evaporation from observed meteorological parameter during that period of time.

Patel and Balve (2016) have used the fuzzy approach to determine the evapotranspiration and compared it with Penman-Monteith Method. It showed that fuzzy has predicted quite near values of evapotranspiration. Goyal et al. (2014) have applied various methods to determine the evaporation rate such as ANN, LS-SVR, and fuzzy logic and concluded that LS-SVR and fuzzy logic are the better model than others.

The present study intends to evaluate performance of the developed Fuzzy Model to predict the evaporation rate from the observed meteorological parameter for the study area and time.

II. FUZZY LOGIC METHODOLOGY

Erol Keskin et al., (2004) First introduced by Zadeh (1965), fuzzy logic and fuzzy set theory are used in modelling the ambiguity and uncertainty in decision making. Zadeh 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 partially true. There are interrelationships between the numbers and fuzzy linguistic approximations. Likewise, in fuzzy logic, values of variables are expressed by linguistic terms the relationships are defined in terms of IF-THEN rules, and the outputs are also fuzzy subsets which can be made “crisp” using defuzzification techniques. First the crisp values of system variables are fuzzified to express them in linguistic terms. Fuzzification is a method for determining the degree of membership that a value has to a particular fuzzy set. Fuzzy Logic has wide application areas including estimation, prediction, control, approximate reasoning, intelligent system design, machine learning, image processing, pattern recognition, medical computing, robotics, optimization, civil, chemical and industrial engineering, etc. but, fuzzy applications in hydrology and meteorology are relatively less common.

Vedula and Mujumdar (2007) Fuzzy logic involves Membership Functions. A membership function (MF) is a function normally represented by a geometric shape that defines how each point in the input space is mapped to a membership value between 0 and 1. A membership function can be of any valid geometric shape. Some commonly used membership functions are of triangular, trapezoidal, and bell shape.

In most of the study researchers have used the triangular membership function. Kulkarni and Anaokar (2016) used the triangular membership function to predict the evaporation rate using fuzzy logic in their study. The current model is also developed using triangular membership function as the value of the evaporation is directly affected by other parameter for example - as temperature increases evaporation increases, windspeed increases evaporation same way decrease in the mentioned parameter will result in the decrease of the evaporation rate.

An attempt has been made in the present study to test the applicability of FL in hydrology and meteorology.

III. STUDY AREA AND DATA COLLECTION

The observed meteorological data of Irrigation Department at weather station in Surat district of Gujarat state, India is used in this study. The station is located in west zone at 21.2160 latitude 72.7918 longitude. The climatic parameters including maximum temperature, relative humidity, evaporation, wind speed, and water temperature are taken as the input parameter from January 2017 to August 2018. The range of the collected climatic data is shown in Table 1.

	Maximum temperature C°	*Relative Humidity %*	*Average Windspeed m/s*	*Water Temperature C°*
January -17	*27.8*	*63.4*	*1.6*	*26*
February -17	*30.1*	*60.3*	*1.9*	*28.4*
March -17	*31.4*	*58*	*2.4*	*29.9*
April -17	*31.6*	*58.7*	*5.7*	*30.1*
May-17	*32.2*	*60.8*	*7.1*	*30.8*
Jun-17	*31.4*	*68.2*	*6.3*	*30.1*
July -17	*29*	*81*	*3.8*	*27.9*
August-17	*29.1*	*80.8*	*2.9*	*27.9*
September -17	*31.7*	*72*	*0.7*	*29.4*
October-17	*40.7*	*70.6*	*0.8*	*29.4*
November -17	*31.1*	*66.4*	*0.7*	*28.5*
December -17	*27.1*	*67.5*	*0.3*	*26.6*
January -18	*27*	*67*	*0.4*	*26.8*
February-18	*30.6*	*62.3*	*0.6*	*27.6*
March-18	*35.9*	*51*	*0.9*	*31.4*
April-18	*38.7*	*55.6*	*1.5*	*33.4*
May-18	*37.4*	*43*	*4.6*	*34.5*
Jun-18	*33.9*	*66.9*	*6.1*	*30.1*
July-18	*28*	*81.8*	*3.3*	*25.8*
August-18	*30.4*	*79.1*	*4.9*	*28.3*

Table 1: Range of the collected monthly Average Climatic Data (Irrigation Deptt.)

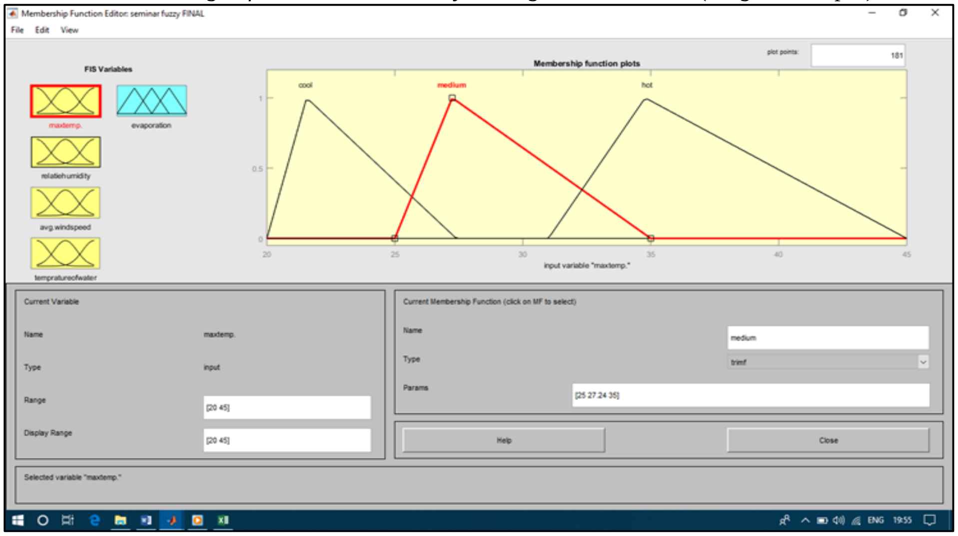


Fig. 1: Input window of the membership function

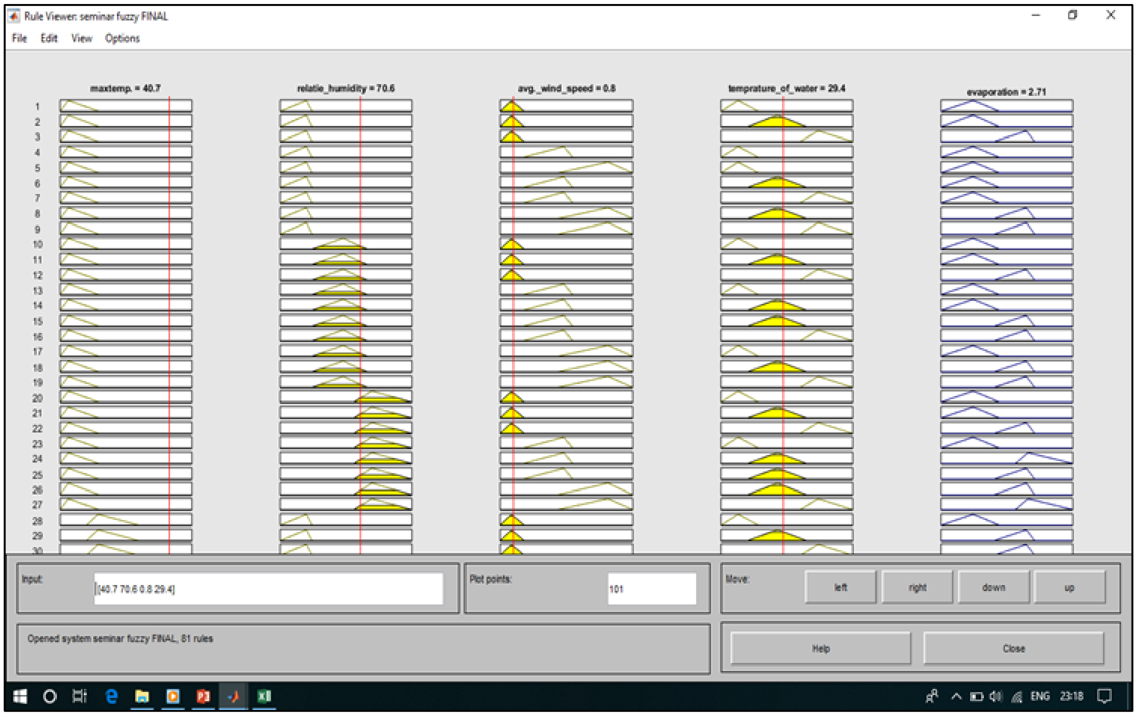


Fig. 2: Rule Base

A. Result

In this study ability of Fuzzy logic is used for predicting the monthly evaporation rate. The model was constructed using fuzzy approach in MATLAB 2018a. After developing the model from the observed data, the same data and new data are used in order to check the performance of developed model. Performance of the model is evaluated with statistical parameter such as R2 and percentage error. Developed model showed the less percentage error (Table 2) and value of R2 obtained is 0.6119 (Figure 3). Also, from (Figure 4) it can be seen that both observed and predicted values follow same trend.

Pan Evap. In mm	*Fuzzy Result*	*Error*	*% Error*
4.083	*4.39*	*0.307*	*7.52*
4.95	*4.61*	*-0.34*	*-6.87*
4.73	*4.59*	*-0.14*	*-2.96*
5.63	*5.97*	*0.34*	*6.04*
6.064	*5.99*	*-0.074*	*-1.22*
5.32	*4.83*	*-0.49*	*-9.21*
4.4	*4.1*	*-0.3*	*-6.82*
4.445	*4.02*	*-0.425*	*-9.56*
4.69	*4.2*	*-0.49*	*-10.45*
4.94	*4.31*	*-0.63*	*-12.75*
3.99	*4.46*	*0.47*	*11.78*
3.8	*4.3*	*0.5*	*13.16*
4.17	*4.29*	*0.12*	*2.88*
4.43	*4.43*	*0*	*0.00*
4.74	*4.53*	*-0.21*	*-4.43*
5.75	*4.74*	*-1.01*	*-17.57*
5.53	*5.91*	*0.38*	*6.87*
4.93	*4.91*	*-0.02*	*-0.41*
4.53	*3.99*	*-0.54*	*-11.92*
4.3	*4.35*	*0.05*	*1.16*
		Avg. % Error	*-2.42*

Table 2: Comparison of the Observed and the Predicted value

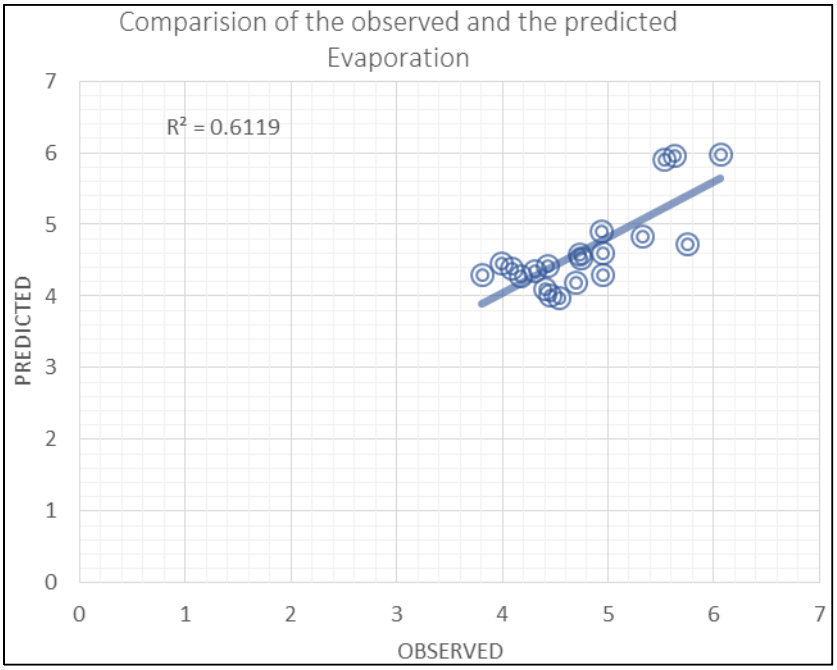
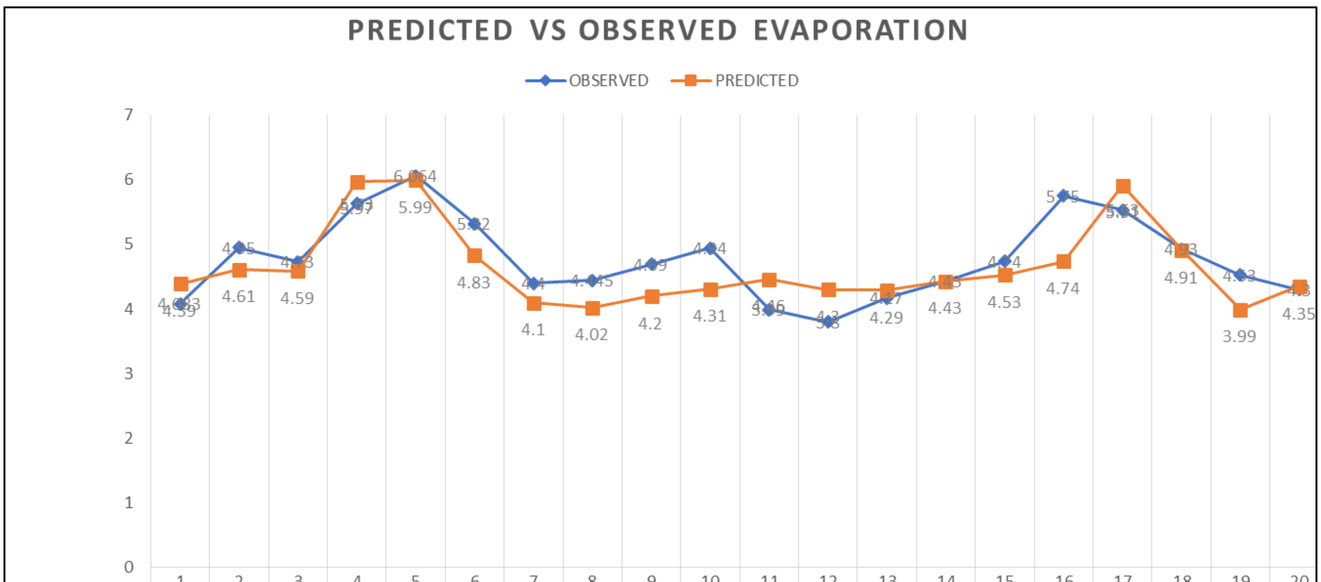


Fig. 3: Graph of coefficient of determination (R^2)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
OBSERVED	4.083	4.95	4.73	5.63	6.064	5.32	4.4	4.445	4.69	4.94	3.99	3.8	4.17	4.43	4.74	5.75	5.53	4.93	4.53	4.3
PREDICTED	4.39	4.61	4.59	5.97	5.99	4.83	4.1	4.02	4.2	4.31	4.46	4.3	4.29	4.43	4.53	4.74	5.91	4.91	3.99	4.35

Fig. 4: Plot of the predicted VS observed value

IV. Conclusion

From the result it can be concluded that the developed model is performing quite well with some acceptable error. Thus, it can be used to predict the rate of evaporation of the study area and similar area.

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