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Integrated Approach for Evaporation Assessment in Al-Wand River Basin

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Abstract

Estimating evaporation is crucial for planning and developing water resource development. The study discusses fuzzy logic's ability to model monthly pan evaporation by MATLAB for Khanaqin Meteorological Station to the period (1981-2000). The model includes monthly maximum and minimum temperatures, wind speed, and relative humidity data gathered from stations situated in Al-Wand River Basin were used as input components in the model. The fuzzy logic results were evaluated with monthly average evaporation from Khanaqin Station using the coefficient of determination (R^2). The results showed a converged value between the value of evaporation between Khanaqin Station and fuzzy logic, the coefficient of determination (R^2) reached to 92% with the accepted trend in monthly evaporation for twenty years.

Keywords: Fuzzy Logic; Khanaqin Station; Matlab 2014; SPSS.

1-Introduction

In arid and semi-arid climate zones, evaporation plays a significant role in the construction and administration of various water resource projects since it is the most efficient hydrologic cycle parameter. [1]. First introduced by Zadeh (1965), fuzzy logic and fuzzy set theory are used in modeling ambiguity and uncertainty in decision-making [2]. Zadeh introduced the processing of 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 numbers and fuzzy linguistic approximations [2].

In fuzzy logic, linguistic phrases are used to convey the values of variables. The outputs are also fuzzy subs that may be made "crisp" via defuzzification techniques, and the relationships are described in terms of IF-THEN rules. To convey system variable values in language terms, the crisp values must first be fuzzified. Fuzzification is a technique for figuring out how much a value belongs to a specific fuzzy set. Fuzzy applications in hydrology and meteorology are relatively uncommon compared to other application areas for fuzzy logic, such as estimation, prediction, control, approximate reasoning, intelligent system design, machine learning, image processing, pattern recognition, medical computing, robotics, and optimization. Vedula and Mujumdar (2007) involve Fuzzy logic Membership Functions (MF), MF specifies how each point in the input space is converted to a membership value between 0 and 1, often represented by a geometric form. Any legal geometric form can be used for a membership function. Triangular, trapezoidal, and bell-shaped membership functions are a few often used types. [3]. Fuzzy logic solves complicated issues that are challenging to solve

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with the traditional method due to nonlinear, time-varying behavior, and inaccurate measurement data. Such complicated systems may be handled using fuzzy logic, imprecise system states, and a collection of imprecise language sets. [3].

Many researchers utilize fuzzy logic as a technique for making decisions. Fuzzy Logic has been utilized in a number of earlier research to more accurately anticipate the values of several hydrological parameters. The current investigations sought to establish how fuzzy logic may be used to forecast monthly evaporation. Patel and Balve (2016) compared the Penman-Monteith Method with the fuzzy technique to calculate evapotranspiration. It revealed that fuzzy had projected evapotranspiration numbers that were quite close. [4]. Numerous techniques, including ANN, LS-SVR, and fuzzy logic, have been used to calculate the evaporation rate. It has been determined that these techniques and fuzzy logic are superior to others [5, 6 and 7].

In most of the studies, 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 the triangular membership function as the value of the evaporation is directly affected by another parameter for example - as temperature increases evaporation increases, wind speed increases evaporation same way a decrease in the mentioned parameter will result in a decrease of the evaporation rate[8]. Modeling monthly pan evaporation with the use of a novel technique called a dynamic evolving neural-fuzzy inference system. Data from two sites in Turkey, including monthly maximum and lowest temperatures, solar radiation, wind speed, and relative humidity are utilized as inputs for the models [9]. A comparison of the Penman technique and classical and fuzzy logic models reveals that the fuzzy model's estimates and measurements of daily pan evaporation agree more closely than those of the Penman approach [10]. The average monthly maximum temperature, wind speed, relative humidity, and water temperature observed data were used to create a fuzzy model. To assess the Fuzzy model's performance, the projected values of evaporation are contrasted with the actual field data. There are many methods for predicting climate data, one of which is remote sensing products, which have proven their effectiveness using data, as correlation coefficient values approached 1 and on different topographical areas of Iraq [11]. This allows room for the comparison of remote sensing outputs with Fuzzy Logic.

This study's objective is to assess the relevance of fuzzy logic in meteorology data, Matlab program was used to estimate evaporation depending on temperature, relative humidity, and wind speed. On the other hand, evaporation from fuzzy Inference is compared with actual evaporation values and evaluated in the correlation coefficient.

2-Methodology

2-1 Study Area and Data Collection

The study area is located in the Diyala Governorate in the east of Iraq. It is situated in the center of Iraq, close to the Iranian border and north-west of the town of Khanaqin, and has crossed with Iran (Monthiriah and Mandali). It is also the fastest route to Baghdad. According to Fig. 1, the Al-Wand River Basin is situated between latitudes (34° 18′) and (34° 30′) north and longitudes (45° 12′) and (45° 24′) east. It is one of the southern Diyala River's most significant tributaries. The basin that feeds the Al-Wand River covers roughly (3340 km2) [12, 13].

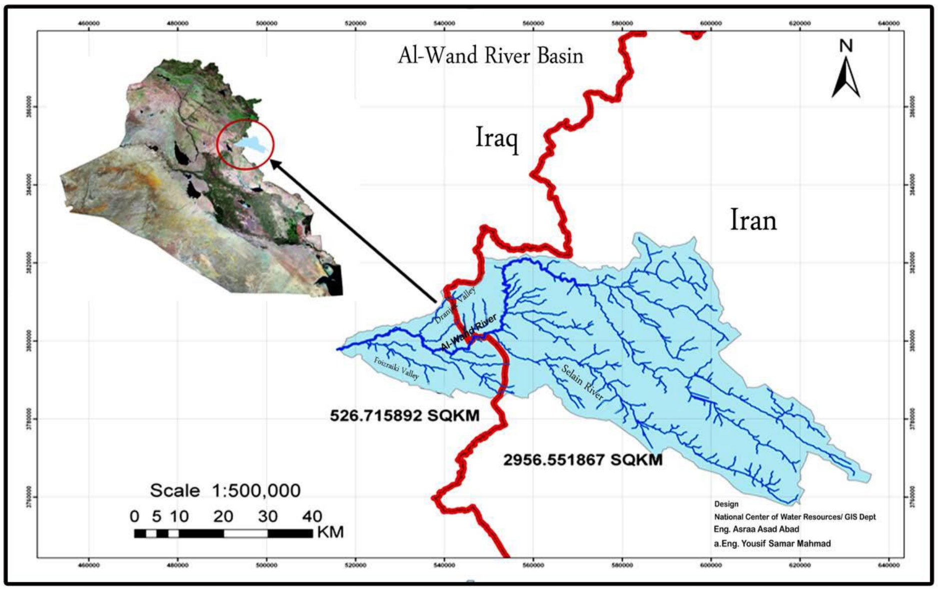

Fig. 1. The geographic and location of the Al-Wand River Basin [14].

2-2Climate

The weather information was gathered from Khanaqin Meteorological Station, which is close to an irrigated region at latitude (34° 18') and longitude (45° 26'). The average humidity over the course of 20 years is equal to (48.52%), the average winter temperature is (12Co), and the average summer temperature is (33Co), all for the period 1981–2000. These averages may be used to visualize the characteristics of the climate. (2.18 m/s) is the average wind speed, and (1981–2008) shows that the average annual evaporation was (260mm) [15], all details in Fig. 2.

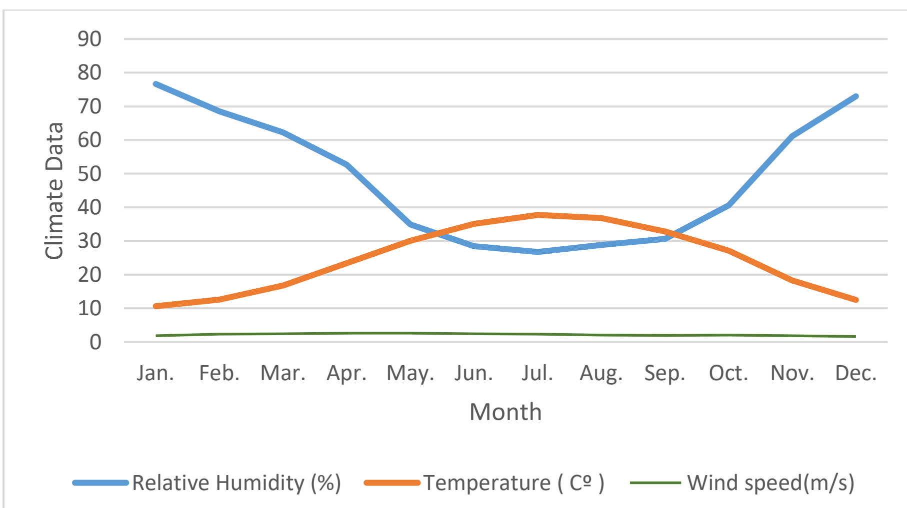

Fig. 2. Metrological Data in the Study area

2-3 Fuzzy Logic

A set's membership function links each item to its corresponding degree. There is a degree of membership associated with possessing every item in a set. The type of membership function will determine the sort of fuzzy sets that are produced. Zadeh 1965 suggested a number of membership functions that might be divided into two categories: "linear" ones produced up of straight lines, and "curved" or "nonlinear" ones, which lengthen calculation times. Thus, in real life, linear fit functions are used in the majority of applications. The modal value m, the lower limit a, the upper limit b, and the triangular membership defy each other so that a c b. When a value equals c - a, we refer to it as the b-c margin, Fig. 3:

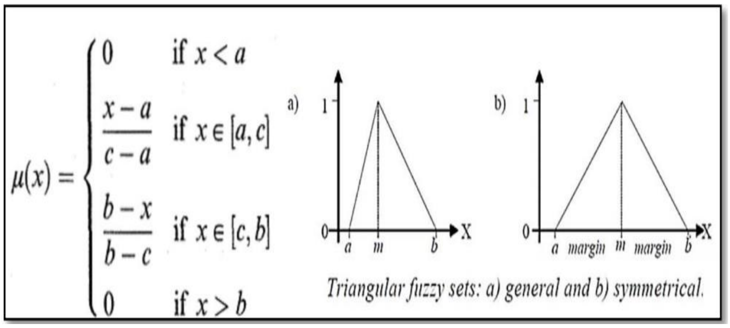

Fig.. 3. Triangular membership

2-3 Matlab Working

Because of the MATLAB integrated design, it is possible to construct customized toolboxes like the Control System Toolbox, Neural Network Toolbox, or Optimization Toolbox software, Fig.4

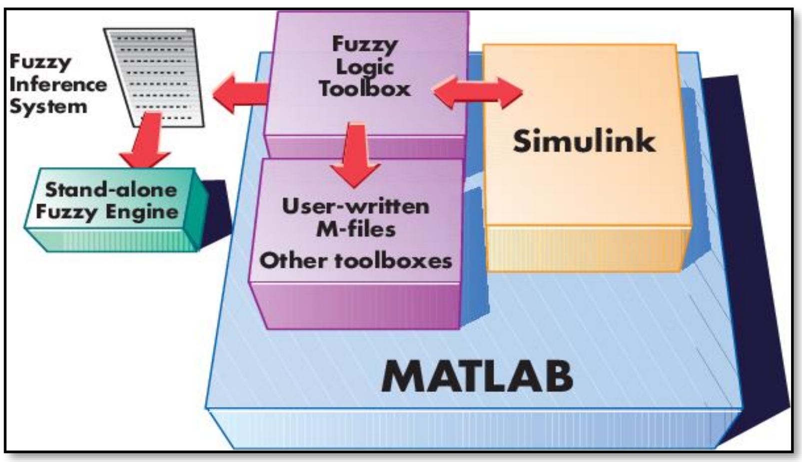

Fig.. 4. MATLAB toolbox in Fuzzy Logic

Steps of Fuzzy Inference in Matlab concluded in these steps:

1-Fuzzy logic toolbox from Matlab Help explains the type of Fuzzy logic with examples, Fig. (5).

2- Write 'fuzzy' in the m-file which opens the FIS window, Fig. (6).

3-Choose three input parameters and named ithem Mamdani fuzzy inference method; one output; triangle membership was used for inputs and output as illustrated in Fig. (7, 8, 9 and 10) respectively.

4- Cchangenge the average line the in rule base of results to obtain multi outputs values.

5- Transform the logic statements 'OR', and 'AND' to the wide space for results.

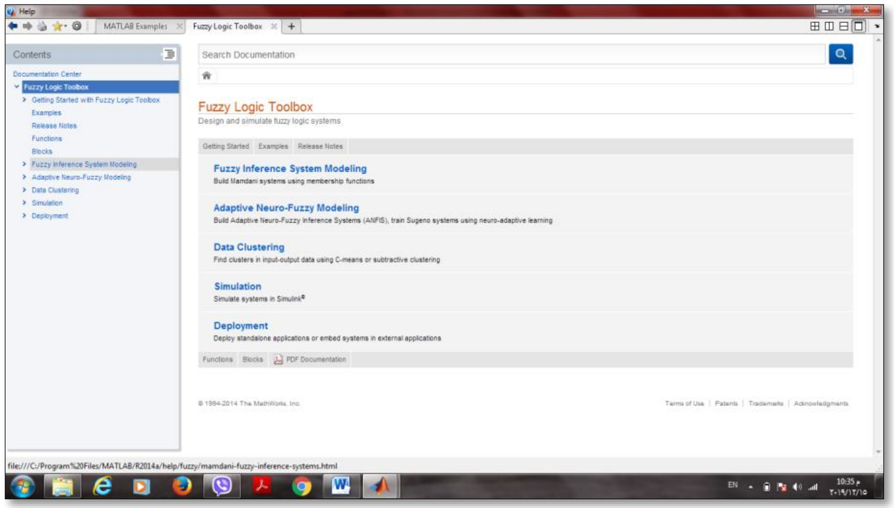

Fig. 5. Fuzzy logic Toolbox window

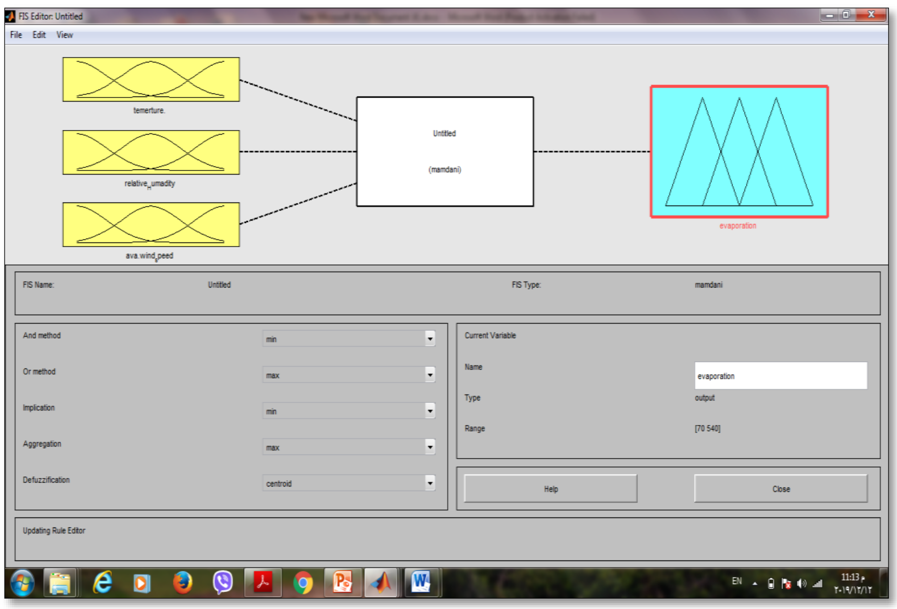

Fig.6. FIS window in Matlab.

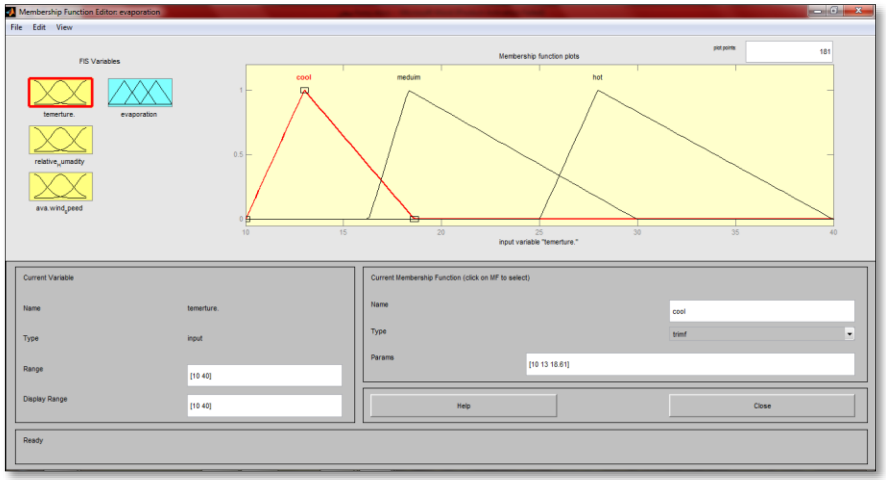

Fig.7. Input window of the membership function (temperature).

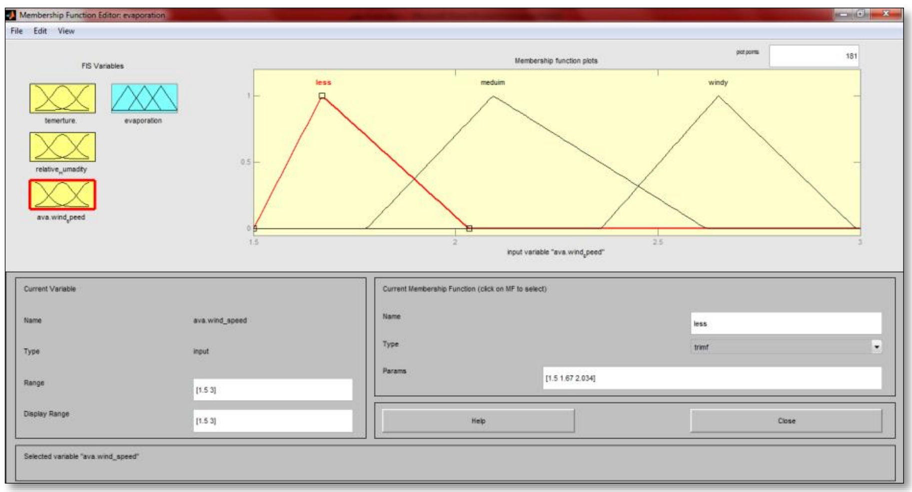

Fig. 8. Input window of the membership function (wind speed).

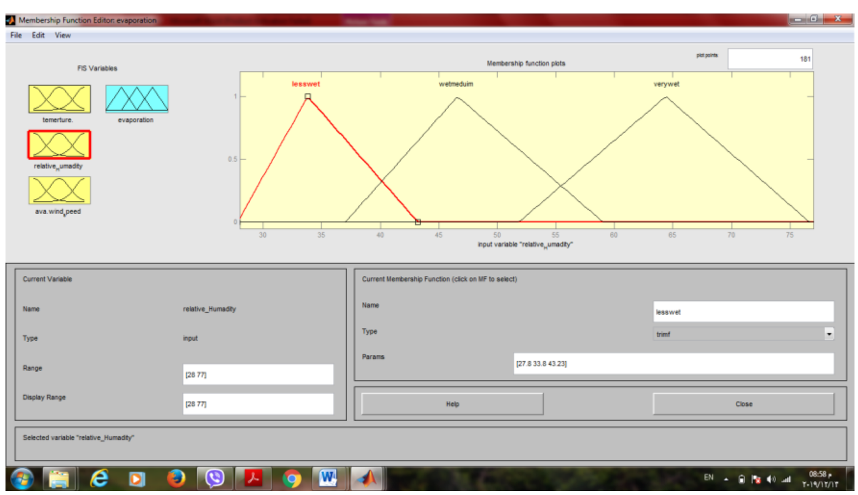

Fig .9. Input window of the membership function (relative humadity)

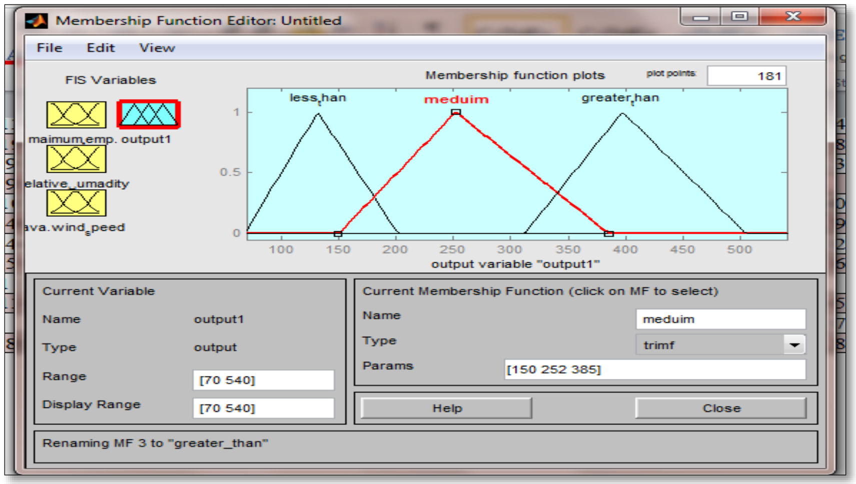

Fig. 10. Output window of the membership function (evaporation)

2.4 Statistical Analysis

The statistical index was used to evaluate the predicted evaporation (from fuzzy logic) with observed evaporation (Khanaqin Meteorological Station), this statistical index is shown below:

- A statistical measurement called the determination coefficient (R2) evaluates how well fluctuations in one variable can be explained by changes in another. To put it another way, researchers primarily use this coefficient while performing trend analysis to determine how significant the linear correlation between two variables is. [16]:

$$R^2 = \left[\frac{\sum_{i=1}^{n}(o_i - \bar{o})(p_i - \bar{p})}{\sqrt{\sum_{i=1}^{n}(o_i - \bar{o})^2}\ \sqrt{\sum_{i=1}^{n}(p_i - \bar{p})^2}}\right]$$

where: P is LST predicted value for evaporation from fuzzy logic; O is LST observed value for evaporation from Khanaqin Meteorological Station; i counts every month from January to December numerically.. The value of acceptance in and R^2 is greater than 0.5 [16].

3-Results

3-1 Fuzzy logic Results by Matlab

The ability of fuzzy logic is utilized in this work to forecast the monthly evaporation average by using MATLAB 2014a. Fig.11. explain the outputs of Fuzzy results in Matlab, which display the minimum and maximum and average for inputs data (temperature, wind, and relative humidity) to get the output data (evaporation) .The average values of temperature, wind and relative humidity are 25 ºC, 2.25 m/s and 52.5% respectively, which enables fuzzy logic to extract values for evaporation as an average 282mm/month.

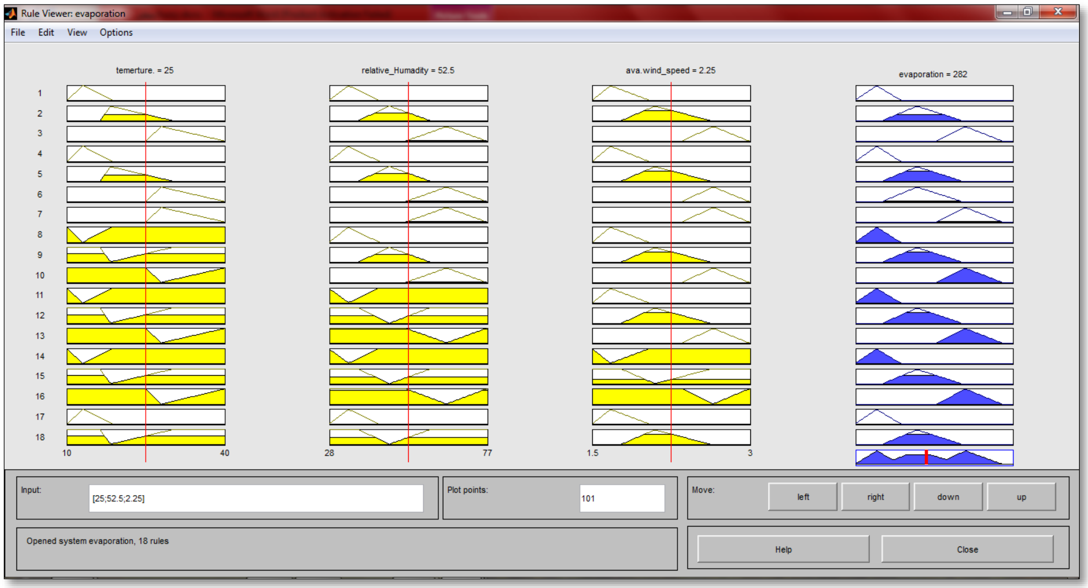

Fig.. 11. Matlab results.

3.2 Statistical Analysis Result

After developing the model from the observed data, which includes the input climate data (temperature, wind and relative humidity) must chec the performance of predicted data (evaporation) then compare with the evaporation rate observed from Khanaqin station in Fig 12 and Fig 13 demonstrates that the observed and expected values exhibit a similar pattern. Where the measured and predicted values in the month of July coincide with the value of evaporation (510 to 530) mm/month.

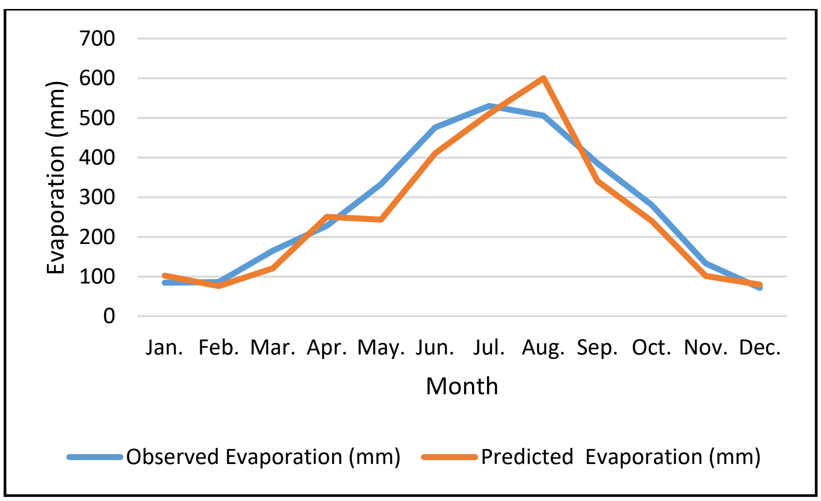

Fig.. 12 Observed evaporation and predicted evaporation

The performance of the model is evaluated with a statistical parameter such as percentage error (Table 1) and R^2 (Fig.12). The results display a smaller error percent in Table (1) obtained is 5.363% in July and a greater percentage error in May up to 27.822%.

Table. 1. The difference in evaporation **values measured from Khanaqin station and fuzzy logic results**

Month	Evaporation (mm) Observed	Evaporation predicted	Error	Error%
Jan.	84.54	102.32	-20.66	-25.300
Feb.	86.2	75.89	12.13	13.781
Mar.	165.39	120.43	47.47	28.273
Apr.	228	250.67	-30.1	-13.646
May.	333.07	243	93.67	27.822
Jun.	475.4	410.23	70.39	14.646
Jul.	530	510.65	28.94	5.363
Aug.	505.73	600	-94.98	-18.807
Sep.	385	340	55.33	13.996
Oct.	280	240	43.38	15.308
Nov.	132.9	101.32	31.77	23.871
Dec.	71.2	79.66	-9.08	-12.865

The statistical index (R^2) for this study was evaluated by using the statistical program (SPSS). Fig.13explain the coefficient of determination (R^2) result is very close to one (٠.924), which indicates the extent of agreement between the two variables (the observed and predicted values of evaporation) according to Chico et al 2021[15].

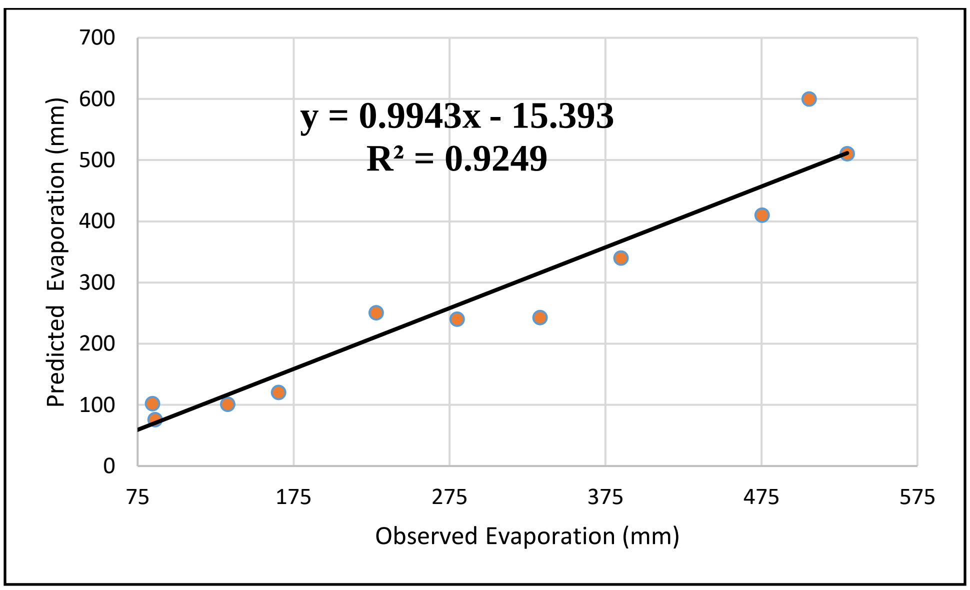

Fig. 13. Relationship between observed evaporation and predicted evaporation

4- Conclusions

This study developed monthly evaporation data and evaluation data which is established fuzzy logic by Matlab Toolbox Products for the selected period from 1981-2000. Processing statistical data included one criterion (R^2) to contrast between the observed and the predicted evaporation. Fuzzy logic enhanced the predicted value of the perspectives of R^2 for the Khanaqin station. According to the results, the coefficient of determination (R^2) result is very close to one (٠.924), which indicates the extent of agreement between the two variables (the observed and predicted values of evaporation). This study contributes to predicting the missing weather data in some exceptional circumstances, especially when the climatic ground stations are subject to closure and maintenance, which causes a shortage of data within the cut-off periods.

Conflict of Interest

The author declares a conflict of interest.

Acknowledgments

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