An ANN and Fuzzy Logic Based Automating Irrigation Techniques

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Abstract. **India is primarily an agrarian society and it is important to develop various irrigation techniques as the nature of soil varies drastically spatially. Irrigation scheduling are mainly depending upon monitoring of soil, crop, water available and weather conditions. Major limitation of this system is the under-irrigation or over-irrigation, which affects the SAR ratio of soil or excess runoff generation respectively. Effective implementation of irrigation technique is required to enhance the productivity of less fertile soil. Irrigation with variable rate and intelligent control-based system is required for the enhancement of irrigation system and higher crop yield. Study was conducted for the performance evaluation of irrigation system using ANN and Fuzzy Logic Toolbox of MATLAB. Moisture available, rainfall, evapotranspiration and water supply for wheat crop were taken as input and output variable were performance of irrigation system. Results of different irrigation techniques were evaluated and best technique were identified under their specification.**

Keywords. **Fuzzy Logic, ANN, Irrigation techniques, SAR Ratio**

I. INTRODUCTION

The availability of water is very important crop production and it is very important to use efficient irrigation methods in the field of agriculture. Factors like uncertainty in climate changes; improper soil management and poor water management pose risk to safety of food of people (Steduto, et. al., 2012). Hence, it becomes very important to design an efficient irrigation system for food safety and sustainable environment

(Villalobos, et al., 2000). Higher cost of production, agricultural risks, inadequate supply of inputs and climate change are the major hindrances in the implementation of irrigation techniques (Shabbir, et al., 2014). As a solution an automatic irrigation system capable of monitoring soil moisture, estimation of water demand for a crop and optimization of other crop parameters. With the advancement in irrigation technology, reduction in water and energy for farmers, reduction in irrigation management practices and higher cultivation yield have been observed (Golden and Peterson, 2006). Despite this, regular evaluation for the adaptation of irrigation technique to the local conditions is basic requirement, which is an important measure of the performance of irrigation system.

The conventional irrigation systems are dependent on a farmer's skills to keep an eye on the irrigation time table. These systems are also dependent on the fact that the water needs are different for different crops and there are other parameters like soil type also. In a country like India, the resources like water and electricity should be optimally utilized. The traditional irrigation systems are failed to utilize the water and also require a lot of man power to manage. So there is a big need to design and develop an automatic irrigation system for agriculture in a reasonable cost.

Crop evapotranspiration is estimated using equations expressed as a function of minimum and maximum temperature, radiation, vapour pressure and wind speed (Richard et al., 2006, Burman & Pochop, 2004).

Methodology proposed by Garcia (2007) for the economic evaluation of irrigation systems using irrigation water efficiency as a variable; was implemented in fruit trees. Whereas, to improve the predictive methods of our nature with the sustainable development, approximations to modelling studies have required. The application of the artificial intelligence in irrigation system is comparatively new to the other branches of civil engineering. Artificial intelligence are an integration of existing biological structures with computing techniques (Huang, et al., 2010). These kind of modelling the systems are helpful in effective handling, robustness and economical solutions whereas, these model come with some degree of uncertainty, imprecision and approximations. With the use of intelligent systems, significant problems can be solved, which are not effectively solved by conventional methods. Progress in computer application is a vital step in the support of implementation of artificial intelligence in several real world applications (kosko, 1992), using modelling technologies such as: fuzzy systems (FS), artificial neural networks (ANN) and genetic algorithms (GA). Fuzzy logic have been extensively used in agricultural sciences for modelling and prediction, fuzzy clustering, control, classification and optimization (Huang et al., 2010).

Several studies have been conducted in the area of irrigation control, where solar powered water pump were used for irrigation to increase the crop production rate to meet the demand for the rapidly increasing population (Naik, 2012). Water application was also improved by the application of water in the fields using water guns to increase the surface area with the minimum supply of water (Suresh et al., 2014). Variation in temperature on field were also found studied in various papers using fuzzy logic controller (Sngahala, 2014). In this study, fuzzy logic system have been used as a tool to evaluate the performance of irrigation technique using set of

indicators for the optimum water use. The irrigation system was checked using three different irrigation techniques in wheat planting under climatic conditions of Haryana, India.

II. MATERIAL AND METHODOLOGY

Study have been conducted in Gurgaon, Haryana, India having mostly alluvial valleys of semi dry and dry climate Study area falls in the ranges of foots of aravalli hills correspond to kind of terraces and slopes that are formed from varying granulometry of alluviums. Slope of the area not varies significantly, with ranging from 0.3% and 7%. Topography of the area ranges from flat to gently undulate, texture of soil is sandy. Water generally available in few meters below the ground level. Three different irrigation methods applied are drip irrigation, surface irrigation, and control of crop without irrigation. Irrigation started with application of water at rate of 5 mm/d. Irrigation system were evaluated after every month for six months to identified the impact on crop yield. Irrigation infrastructure requirement, identification of best technology and improvement in the irrigation system are the basic needs for the evaluation and performance identification of irrigation systems (Moreno, et al. 2000; Sánchez, et al. 2006). These set of indicators shows the product of the crop cultivated per unit of water and land, for comparing the crop yield and economic valuation of the irrigation systems to be evaluated (Molden et al., 1998).

Fuzzy logic controller

A fuzzy logic control (Langari, 2009) is based upon fuzzy sets. The fuzzy sets are based on the membership of elements to a particular set. Fuzzy sets provide flexibility by using degree of membership function which ranges from 0 to 1. The membership function is very important in mapping every element of universe to the fuzzy set associated with it using an interval [0, 1]. However, in case of crisp logic membership of an element is either 0 or 1 (true or false) showing that an element belongs to one set only while in case of fuzzy logic the element may belong to more than one set at a time with different membership values. And hence the truth values are multivalued like absolutely false, absolutely true, partly false or partly true and so on, which when represented numerically forms a range from 0 to 1 (Javadi et al., 2009). An expert knowledge can be included in a control system with the help of fuzzy logic the input to the fuzzy system in categorized with the help of fuzzification process, then the decision rules are applied and in the last defuzzification is done to get the results back from the decision rules. The control actions, in a fuzzy controller, are generated by the inference unit by applying the rules and utilizing the knowledge base on the current process state. The result of the fuzzy controller is the degree of membership for an element to belong to different labeled groups. As depicted in fig 1 there are seven stages to implement fuzzy logic control algorithm.
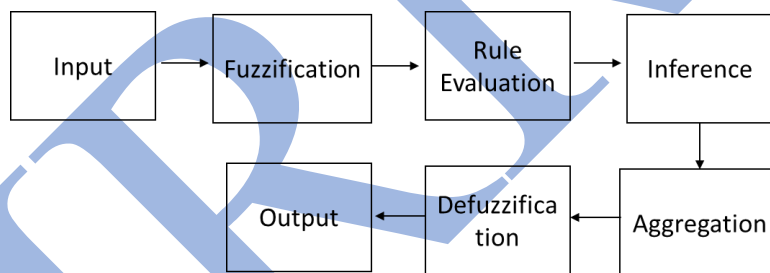

Fig. 1. Fuzzy Logic controller block diagram

Fuzzy logic has been a very useful tool to process the information which is vague, not precise, noisy, incomplete and ambiguous to help arriving on a conclusion by stimulating expert knowledge in a particular domain. The input variables are chosen to start the process and cropped area and water supply remains the output parameter and it remains the performance indicator for the proposed irrigation system. An action range is also established for each of the system variables. Thereafter the qualitative variables are defined for these system variable ANFIS toolbox in MATLAB 2015 has been employed to design the structure of the proposed model based on fuzzy logic and here range of variables, membership functions and active rules are selected, also the response is analysed to verify the system.

Neural Network Classifier

We have also used Neural Network back propagation Toolbox. Neural Networks Simulates human brain which is composed of processing elements which are organized in different way to form network structure and each of the processing element receives inputs, processes inputs and delivers a single output (Philip et al., 2000) as shown in figure 2. Some of the advantage of neural networks are fault tolerance, self-organisation, fast learning, real time operation and high tolerances to noisy data (Bahat et al., 2000).
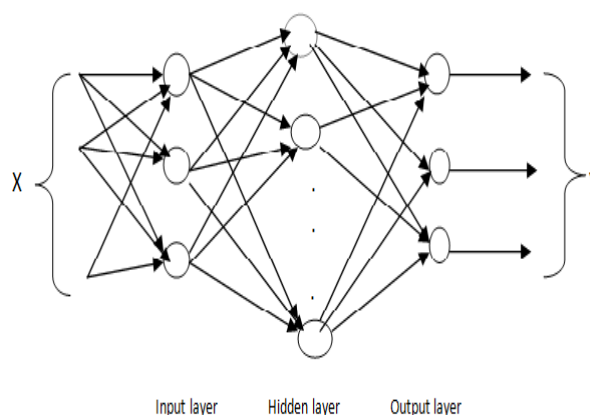

Fig. 2: Neural network Architecture

III. RESULTS AND DISCUSSION

Water Usage and Efficiency

The average rain fall in Haryana is ranging from 115 mm to 130 mm in the monsoon season, which starts in the month of June and goes up to August. Western disturbances also led to

some rainfall in the month of December and January; with average monthly precipitation ranging between 80 to 90 mm. Total annual rainfall of season reaches up to the value of 970 mm and it remains the highest in the month of July with a value 150 mm. Periods of water deficit causes the generation of drought periods. Water use efficiency estimated from the crop growth applied to the climatic conditions of Haryana. Values of water efficiency are estimated on per hectare per year basis. Crops are compared between surface irrigation and drip irrigation. The income rate, per hectare land cultivated, comes out to be two times more between drip irrigation system and surface irrigation system. It concludes that the profit in case of surface irrigation is larger than drip irrigation system because of implementing drip irrigation is way higher than the former. If the water supply remains less then it will result in deficiency in the water need of the crop and if water supply is excessive then it will create a situation of flood and in result hamper the

crop production. So there is a big need of developing and implementing an automatic irrigation system to minimize the resistance to water stress.

IV. DEVELOPMENT OF FUZZY LOGIC SYSTEM AND ANN

The proposed system is implemented in MATLAB 2015 (Nhivekar et al., 2011) in artificial neuro fuzzy inference system (ANFIS) toolbox, as depicted in Figure-4.

The performance of the proposed system is estimated under the climate conditions of Gurgaon (Haryana), on the basis results obtained for wheat production per cropped area and water supply provided. Back propagation type artificial neural network of MATLAB 2015 were also applied for the comparison of performance of irrigation system (figure-3).
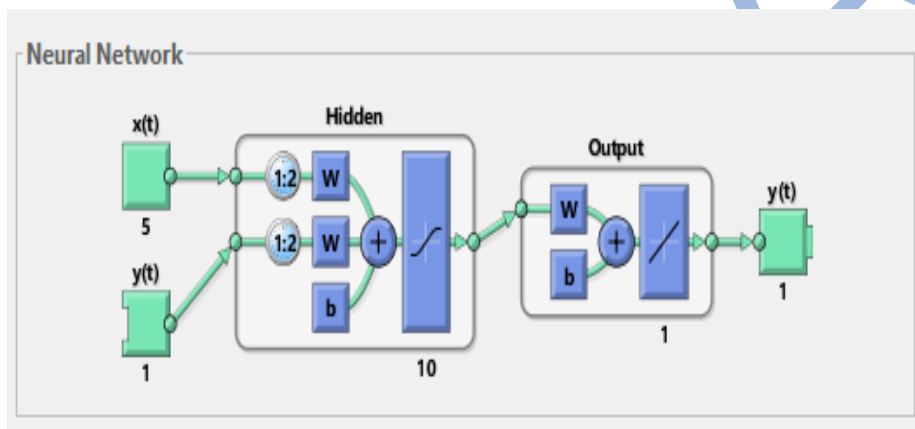

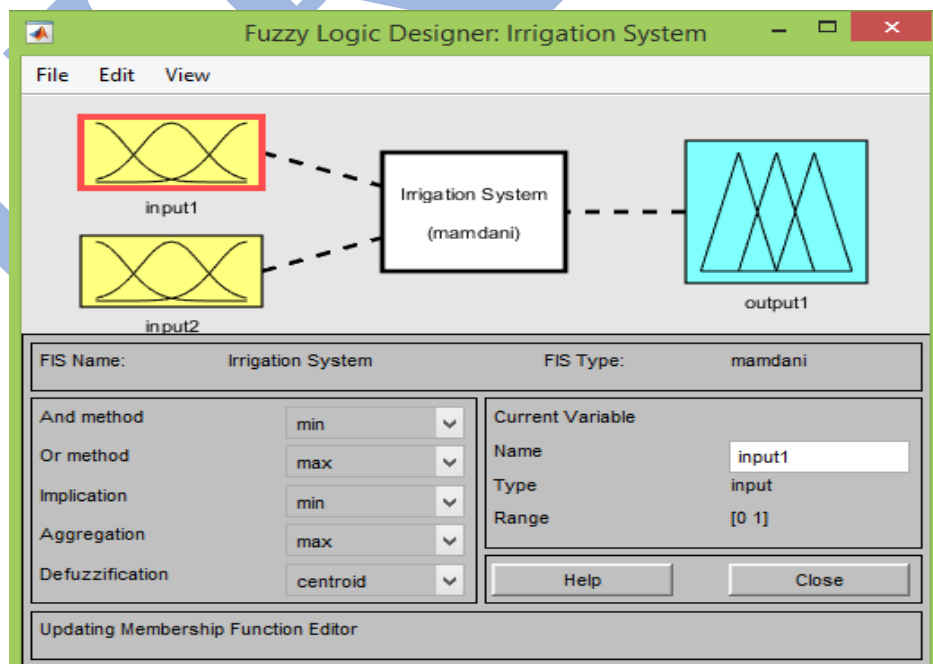Fig. 3. ANN tool model to evaluate the irrigation system performance.

Fig. 4. Fuzzy logic inference tool to evaluate the irrigation system performance.

In table 1, the selected input variables are depicted as labels and defined by membership functions and range. The "triangular type" membership functions are used for fuzzy system as it is easy to easy to implement, adequate for function

type and require only three parameters. Labels, ranges and membership function of output variable are shown in Table-2. Interface function to define the output variable performance is shown in Figure-5.

Table 1. Input Functions for fuzzy logic

Input Variable	Income per hectare of irrigation	Water Supply
Range	1200-10000	0-5
Classification	mf1: 1280-3500	0.1-1.1
	mf2: 3550-7850	1.2-2.5
	mf3: 7880-10000	2.6-5
Function	Triangular	Triangular

Table 2. Output variable for fuzzy logic

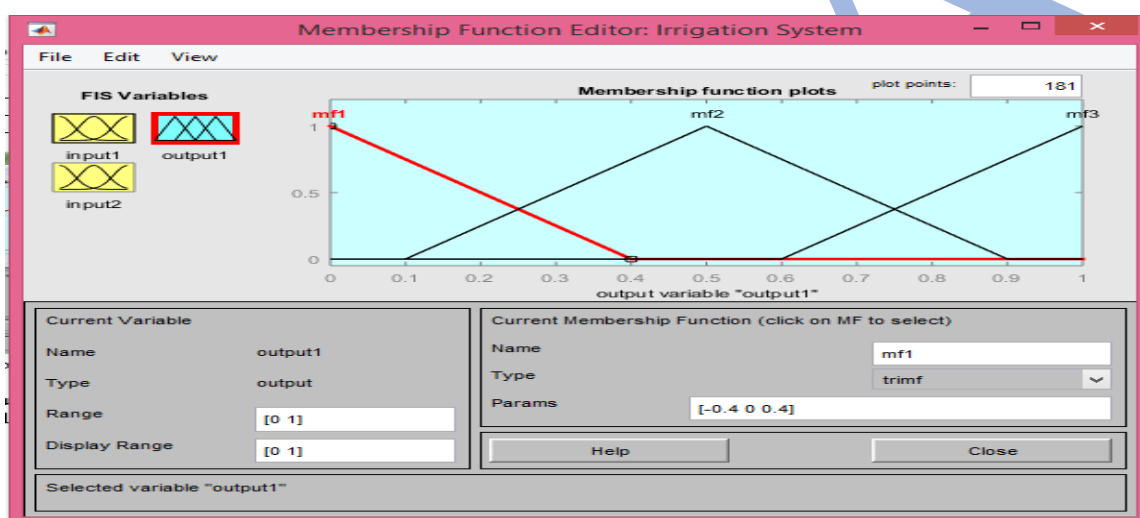| Output Variable	Performance of system (%)
Range	0-100
Classification	0-40
	41-80
	81-100
Function	Triangular

Fig. 5. Membership function of output variable

Labelling of the output variables represented with three options level 3(high), level 2 (medium) and level 1 (low) due to the system complexity. Fuzzy system rules are defined using this interpretation. System which uses the water supply with maximum efficiency, results in greater production and with led to more income for the farmers will be interpreted as the high performance irrigation system. Whereas, ineffective use of water resources, insignificant production changes will be interpreted as the low performance irrigation system. Fuzzy logic system rules were defined are shown in Table-3. Rules reflects the conditional statement in if-then form logic analysis and logical operator used were AND in this case (Philips, 2013, Gómez-Melendez, 2011).

Table 3. Rule base of fuzzy logic system

	Input Variables		Output
No.	Income per hectare of irrigation	Water supply	Performance of system
1	level 1	level 1	level 1
2	level 1	level 2	level 3
3	level 1	level 3	level 1
4	level 2	level 1	level 1
5	level 2	level 2	level 3
6	level 2	level 3	level 2
7	level 3	level 1	level 2
8	level 3	level 2	level 3
9	level 3	level 3	level 2

Evaluation of fuzzy logic and ANN
The evaluation of the proposed system and ANN is performed using the defined input variables, the output variable and rule base. Using the drip irrigation system for crop cultivation, input variable were: output per cropped area was 5286 and supply of water was 1.23. Performance identified from the output variable irrigation system using the activated fuzzy logic rules 4, 5 and 6 was 50% (fig-6). Due to the insignificant

rainfall in the study area, control of system without irrigation produces the system performance as "low" irrigation (18%); average annual rainfall in the region is not able to meet the water consumption requirements for the crops and generate the situation of water deficit. Whereas, surface irrigation produces the better results considered as "high" performance system (89%) due to the lesser costs of implementation of irrigation technique as compared to drip irrigation (53%). Production rate is also greater from surface irrigation than drip irrigation. However, surface irrigation requires significant amount of water and hence does not forge an efficient use of water resource. Drip irrigation system makes the best use of water resources but presents the "medium" (53%) performance of the irrigation system. Cost of implementation of drip system

for irrigation is much higher than the other methods, which reduces the profit margin of drip irrigation system. Using ANN drip irrigation system produces better result and considered as high performance system with the correlation to the original system up to 77%, whereas surface irrigation considered as medium performer with the correlation up to 67%. Control of system without irrigation also remains as low performer with ANN tool and reflects only 23% of correlation. On comparison between the two tools of Matlab 2015, as the Fuzzy system is supported with the rule base and combination of logic toolbar with the neural system, results obtained from the Fuzzy logic controller is adopted for the estimation of performance of the irrigation system.
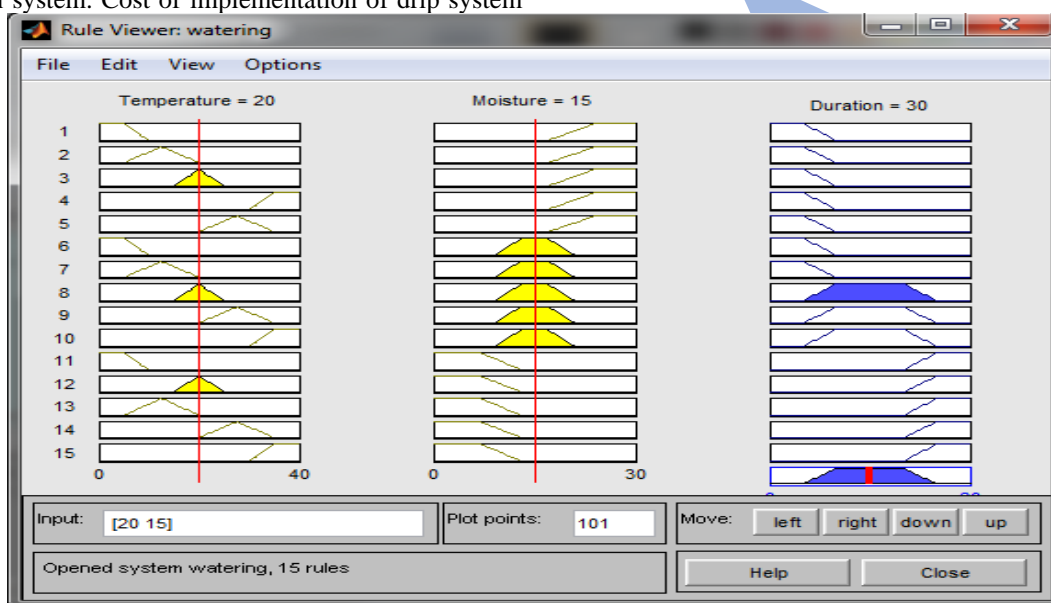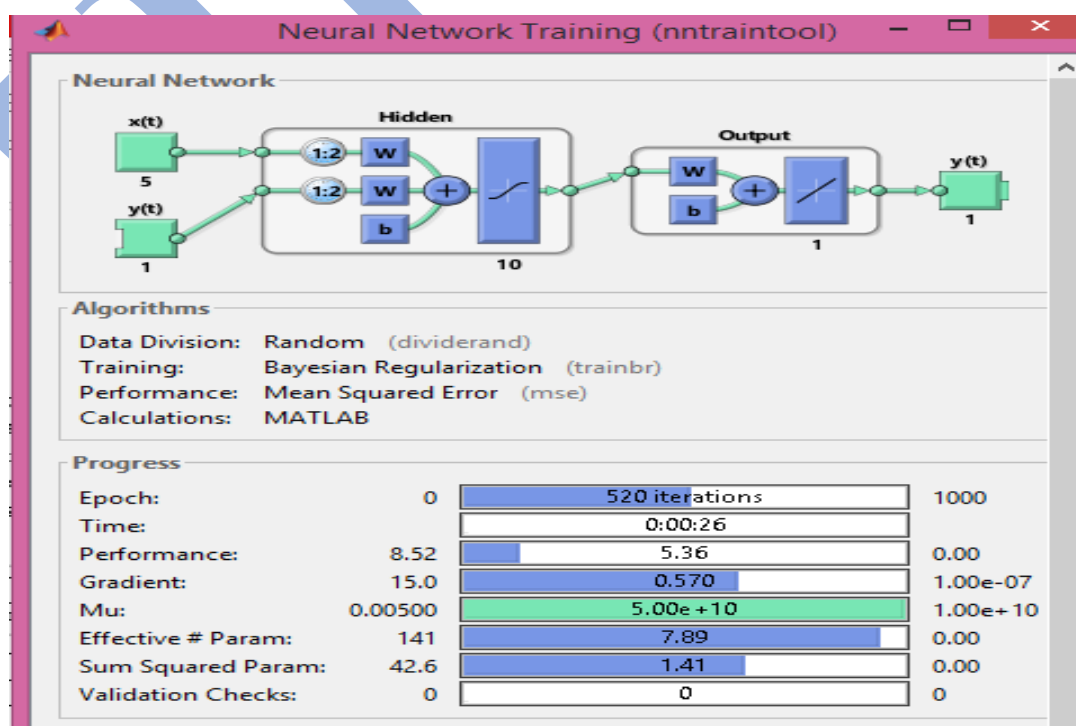

Fig 6. Evaluation of irrigation system using Fuzzy

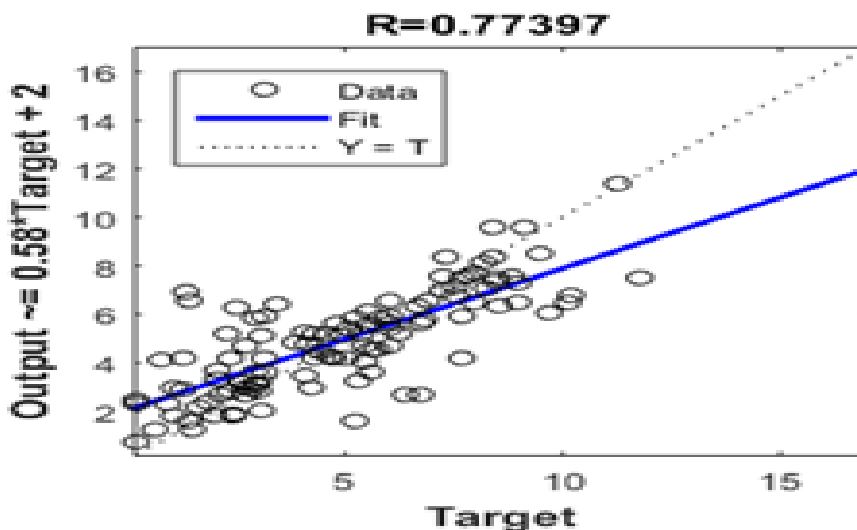Fig 7. Evaluation of irrigation system using ANN

Fig. 8. Correlation of ANN model

V. CONCLUSIONS

In this work the development of Mamdani-type fuzzy logic inference system and ANN backpropagation-based irrigation controller is proposed using two major indicators, to determine the performance of irrigation systems. The economic performance and growth of irrigation system helps in estimation of infrastructure requirements for irrigation system and identification of best technology for the improvement of the system operation. In order to estimate the performance of irrigation system, ANN and fuzzy logic was implemented based on the two input variables taken as output per cropped area and water supply. These variables are assessed for the same type of crop with different irrigation techniques to produce the innovative solution, which could be helpful in decision making for the professional agricultural. Out of ANN and Fuzzy logic, results of Fuzzy logic was found suitable for the assessment of the performance of irrigation system, same have been considered for the result analysis. Out of three methods used for estimation for the performance, the surface irrigation technique results in a "High" performance (89%) due to the lower implementation cost, whereas, irrigation system without control has a "Low" performance (21%) and the performance has been observed as "Medium" in case of drip irrigation system.

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