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"PREDICTION OF GROUND WATER QUALITY INDEX OF SURAT REGION USING ANFIS"

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Abstract* — Adaptive Neuro Fuzzy Inference System (ANFIS) approach is employed in the present study to observe its applicability on Prediction and Forecasting of Groundwater Quality Index Prediction in Surat Region. As per classification based on Groundwater Quality Index, Groundwater Quality of Surat Region lies between poor water to very poor water during pre-monsoon season, while Groundwater Quality lies between good Water to Poor Water. ANFIS system is one of the developing powerful tools to predict such heavy constrained problem with time series analysis by hybrid technique. First Part of the study is to find the GWQI of the Surat Region. Second part of the study is to study is to identify the Best ANFIS model which satisfying two Statistical measures (RMSE, and R2) during training and validation processes for the duration of 2013 to 2016 of Surat Region.

Keywords- Ground Water quality index, Adaptive Neuro-fuzzy inference system, Surat region

I. INTRODUCTION

Water resources have been the most exploited natural system, since man strode the earth. As a result of increasing, civilization, urbanization, industrialization and other developmental activities, our natural water system is being polluted by different sources. The pollutants coming as a waste to the water bodies are likely to create nuisance by way of physical appearance, odour, taste, quality and render the water harmful for utility. This has resulted in the decrease in the quality of drinking water available.Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available. Their influence is generally greatest when available water quantities are low and maximum use must be made of the limited resource; for example, high salinity is a frequent problem in arid and coastal areas.

Water quality modeling is the development of abstractions of phenomena of river systems. The main objective of river water quality modeling is to describe and to predict the observed effects of a change in the river system. The usual application of a water quality model is for forecasting changes in water quality parameters resulting from changes in the quality, discharge or location of the point or non-point input sources (Crabtree et al., 1986). Water quality models can be used to predict the characteristics of water quality conditions in aquatic systems in order to ensure the water quality objectives will be maintained under a wide variety of conditions. Models provide the ability to develop a credible and defensible water quality management program. They are continually being developed and improved to optimize the demands of environmental regulations and protection. There are a large number of available in the literature and the Internet, which can be used for water quality and waste load allocation predictions.

There are mainly three models namely Adaptive Neuro Fuzzy Inference System (ANFIS), Artificial Neural Network (ANN) and Monte Carlo Simulations (MCS) are used to describe the input and output relationships of the water quality data. In these studies, for each step, some important points related to model reliability are answered by discussing and applying the method and tools to analyze the behavior of the model and to prepare actions that are to be taken to reduce error in outputs. New techniques such as fuzzy logic (FL) and adaptive neuro fuzzy inference system (ANFIS) have been recently used as efficient alternative tools for modeling of complex water resources systems and widely used for forecasting. FL is a rule based system consisting of three conceptual components, including (1) a rule-base, containing a selection of fuzzy if-then rules; (2) a data-base, defining the membership functions used in the fuzzy rules; (3) an inference system, performing the inference procedure upon the rules to derive an output. FL models focus on the use of heuristics in the system description.

II. STUDY AREA AND DATA COLLECTION

Surat district is located at the southernmost tip of Gujarat, near Gulf of Khambhat in the Arabian Sea. It is located at 20.9667° N latitude and 73.0500° E longitude. Land area of Surat district is 4418 sq. kilometers covering total of 729 villages. There are ten talukas viz. Surat city, Bardoli, Choryasi, Kamrej, Olpad, Palsana, Umarpada, Mahuva, Mandvi, Mangrol. Average rainfall is 1500 to 2200 mm. Main rivers of the Surat district are Tapi, Mindhora, Purna, Kim, Ambika. There are unconfined and confined aquifers.

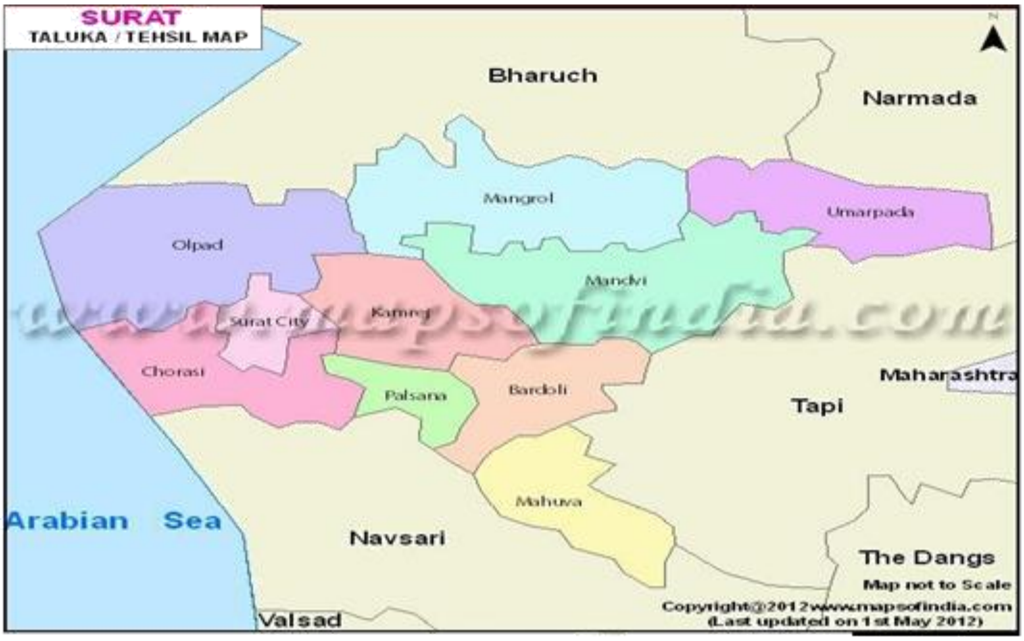

Figure 1. Map of study area

TABLE 1.Location of well

Sr. No	Sample Location
1	Water Project Status Borewell At Baleswar Ind.Area(Lucky Filling Stn),Monthly / S
2	Water Project Status Borewell At Bsnl Pandesara Gidc,Monthly / S
3	Water Project Status Borewell At Garg Tex-O Feb Pvt.Ltd. Olpad,Monthly / S
4	Water Project Status Borewell At Gspcl Hazira,Monthly
5	Water Project Status Borewell At Neelam Fiber Kim Ind Area Plot-202 ,Monthly / S
6	33261 - Water Project Status Borewell At Sachin Gidc(Siel),Monthly / S
7	Water Project Status Open Well At Hazira
8	Water Project Status Borewell At Primal Glass Tarsadi At Kosamba
9	Water Project Status At Phc Kadodra

III. METHODOLOGY

3.1 Water Quality Index

Water quality index is one of the most effective tools to monitor the surface as well as ground water pollution and can be used efficiently in the implementation of water quality upgrading programs. It is one of the aggregate indices that have been accepted as a rating that reflects the composite influence on the overall quality of numbers of precise water quality characteristics.

For computing WQI three steps are followed. In the first step, each of the all parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table-2). The maximum weight of 5 has been assigned to the parameter Nitrate due to its major importance in water quality assessment. BOD and DO, which is given the minimum weight of two by itself, may not be harmful. In the second step, the relative weight (Wi) is computed from the following equation: 1

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \quad (1)$$

Where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters. Calculated relative weight (Wi) values of each parameter are also given in Table-2.

TABLE 2. Relative Weight (Wi) Values Of Each Parameters

Water Quality Factors	weightage	Unit Weight (Wi)
pH	2	0.05
Total hardness - TH as CaCO3 (mg/L)	5	0.125
Fluoride - FLU (mg/L)	4	0.1
Total dissolved solids - TDS (mg/L)	4	0.1
Calcium - CAL (mg/L)	5	0.125
Chloride - CHL (mg/L)	2	0.05
Nitrate-N (mg/L)	5	0.125
Magnesium - MAG (mg/L)	5	0.125
Total alkalinity - TA as CaCO3 (mg/L)	4	0.1
Biological oxygen demand - BOD (mg/L)	2	0.05
Dissolved oxygen - DOX (mg/L)	2	0.05

In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS and the result multiplied by 100.

$$qi = \left(\frac{Ci}{Si}\right) * 100 \quad (2)$$

Where, qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/L, Si is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the BIS.

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation.

$$SI = Wi * qi \quad (3)$$

$$WQI = \sum_{i=1}^{n} SIi \quad (4)$$

Where, SIi is the sub index of i_{th} parameter, qi is the rating based on concentration of i_{th} parameter, n is the number of parameters. The computed WQI values are classified into five types, “excellent water” to “water, unsuitable for drinking”.

TABLE 3. Water Quality Classification Based On WQI Value

WQI Value	Water Quality
<50	Excellent Water
50-100	Good Water
100-200	Average Water
200-300	Poor Water
>300	Unstable for Drinking

3.2 Adaptive Neuro Fuzzy Inference System (ANFIS)

Adaptive neuro-fuzzy inference system (ANFIS) is result of combination between artificial neural networks (ANN) and fuzzy inference system (FIS) in MATLAB. A neural network and fuzzy logic are related and complementary technology to each other. The data and feedback can be learned by neural network, however understanding the knowledge or trend of data can be difficult. However, fuzzy logic models and toolboxes are easy to execute because of the linguistic terms like IF-THEN rules. An Adaptive Neuro-Fuzzy Inference System consists of five important functional building parts of the fuzzy logic toolbox, those are (i) rule base, (ii) data base, (iii) decision making unit, (iv)fuzzification interface and (v) defuzzification interface. Figure 2 shows typical architecture of ANFIS.

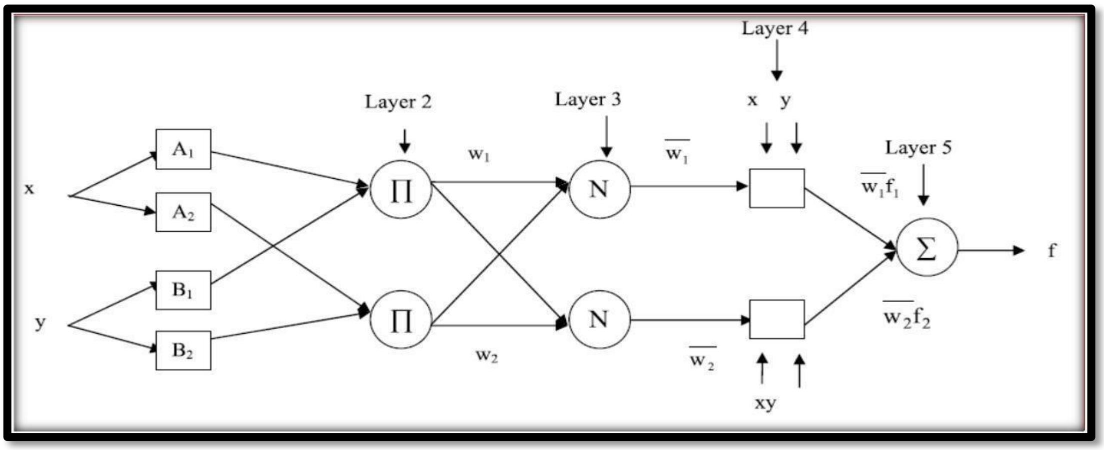

Figure 2: ANFIS Architecture

3.2.1 Development of WQI Prediction Model in ANFIS

In ANFIS, the datasets divided into training and validation data, and loaded in ANFIS editor as training and testing data keeping 10 water Quality parameters (pH, Total hardness - TH as CaCO3 (mg/L), Fluoride - FLU (mg/L), Total dissolved solids - TDS (mg/L), Calcium - CAL (mg/L), Chloride - CHL (mg/L), Nitrate-N (mg/L), Magnesium - MAG (mg/L), Total alkalinity - TA as CaCO3 (mg/L), Biological oxygen demand - BOD (mg/L), Dissolved oxygen - DOX (mg/L)) as input and Water Quality Index as output of model. The ANFIS editor GUI, MATLAB is shown in figure 3 with loaded data.

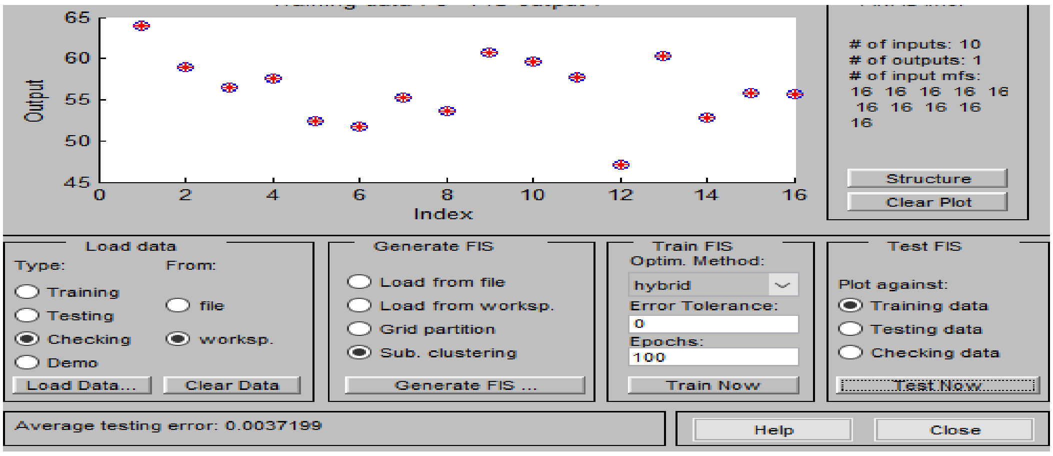

Figure 3: ANFIS Editor GUI

The FIS generated for Subtractive Clustering function, which produces accurate outputs values by using a large number of membership function. The FIS is then train for 100-epoch and 0-error tolerance in order to generate output as Water Quality Index Value.

IV. RESULTS AND ANALYSIS

4.1 Water Quality Index

After Analysis and Calculation of WQI, the following result is conducted for Surat Region
.

TABLE 4: Water Quality Classification based on WQI Value – Surat Region

GWQI Value	Water Quality	Percentage of Water Samples		
		Pre Monsoon (%)	Post Monsoon (%)	Overall (%)
<50	Excellent Water	0	0	0
50-100	Good Water	9	20	15
100-200	Poor Water	60	56	57
200-300	Very Poor Water	7	4	5.5
>300	Unstable for Drinking	24	20	22

As shown in Table 4, the GWQI for 204 Ground water samples ranges from 61.882 to 1120 almost 88 percent of the samples exceeded 100, the upper limit for drinking water. About 58 percent of water samples are poor in quality and 27.5 percent of water samples are of very poor quality and for drinking should not use directly for drinking purpose. As per the classification based on groundwater quality index 15 percent ground water samples shows good quality of water.

4.2 Adaptive Neuro Fuzzy Inference System (ANFIS)

Two models are developed to predict water Quality of Purna River at two different stations using ANFIS.

1. **ANFIS Model-1: 70%-30%**
2. **ANFIS Model-2: 80%-20%**

After developing the best Water quality index prediction Model using ANFIS for each station with the training & validation datasets with two combination, comparison is carried out to conclude the best ANFIS model for Surat Region.

TABLE 5: Best ANFIS Model Developed for post monsoon season

	Phase	ANFIS Model-1 (70%-30%)		ANFIS Model-2 (80%-20%)	
		RMSE	r	RMSE	r
Pre monsoon	Training	0.793	0.9739	0.8789	0.9835
	Validation	0.890	0.948	0.6821	0.9835
Post monsoon	Training	0.4702	0.9934	0.7863	0.9933
	Validation	0.99	0.9932	0.599	0.9932

From the above Table-5 shows that the ANFIS Model-2 having RMSE and r value of **0.8789** and **0.9835** respectively during training and RMSE and r value of **0.6821** and **0.9835** during Validation. Hence **ANFIS Model-2** is the best model for pre monsoon season for Groundwater Quality Index Prediction. While ANFIS models having RMSE and r value of **0.7863** and **0.9933** respectively during training and RMSE and r value of **0.599** and **0.9932** during Validation, Hence **ANFIS Model-2** provides best result for Post monsoon season for Groundwater Quality Index Prediction.

So we conclude that MODEL-2 is Better model comparing to MODEL-1 and The value of Coefficient of correlation (R) is very close to 1 for MODEL -2 for training values but compare to checking values for this station training values give more accurate result And from the values it can be concluded that observed WQI is very near to predicted WQI.

Graphs given below shows correlation between Predicted WQI vs. Observed WQI of ANFIS Model-2 during training and validation during pre-monsoon and post-monsoon of Surat region. It has observed that during training and validation, Predicted WQI and Observed WQI values are highly correlated during post-monsoon.

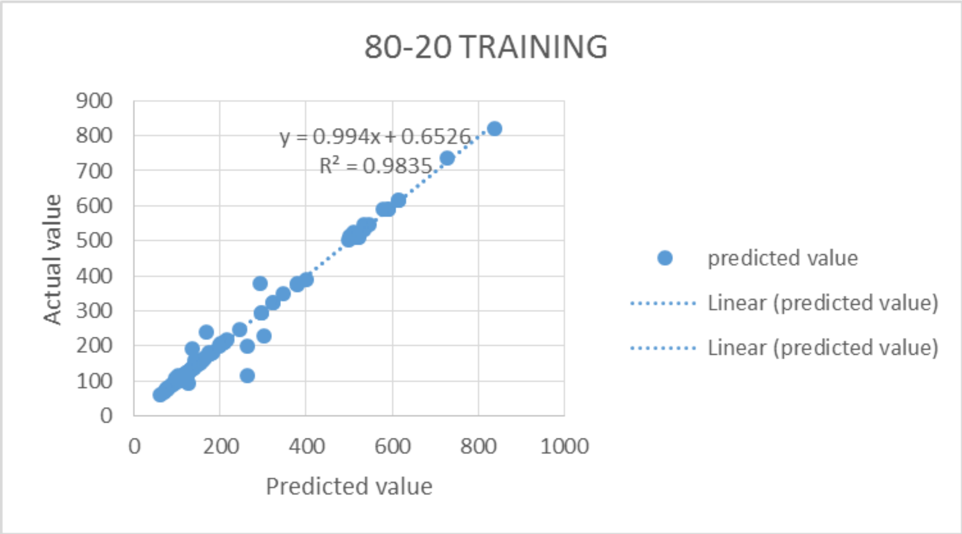

Figure 4: Correlation between Predicted WQI vs. Actual WQI of ANFIS Model-2 for PRE MONSOON during Training

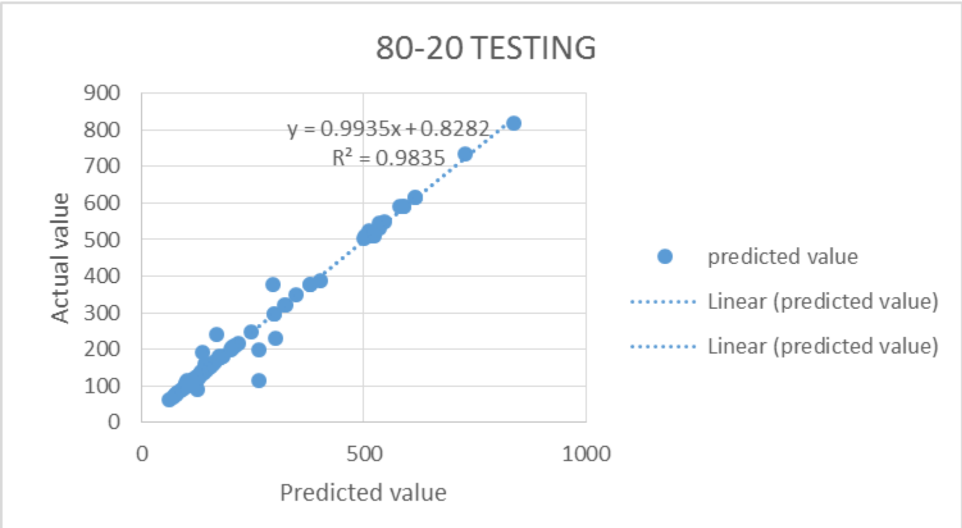

Figure 5: Correlation between Predicted WQI vs. Actual WQI of ANFIS Model-2 for PRE MONSOON during Testing

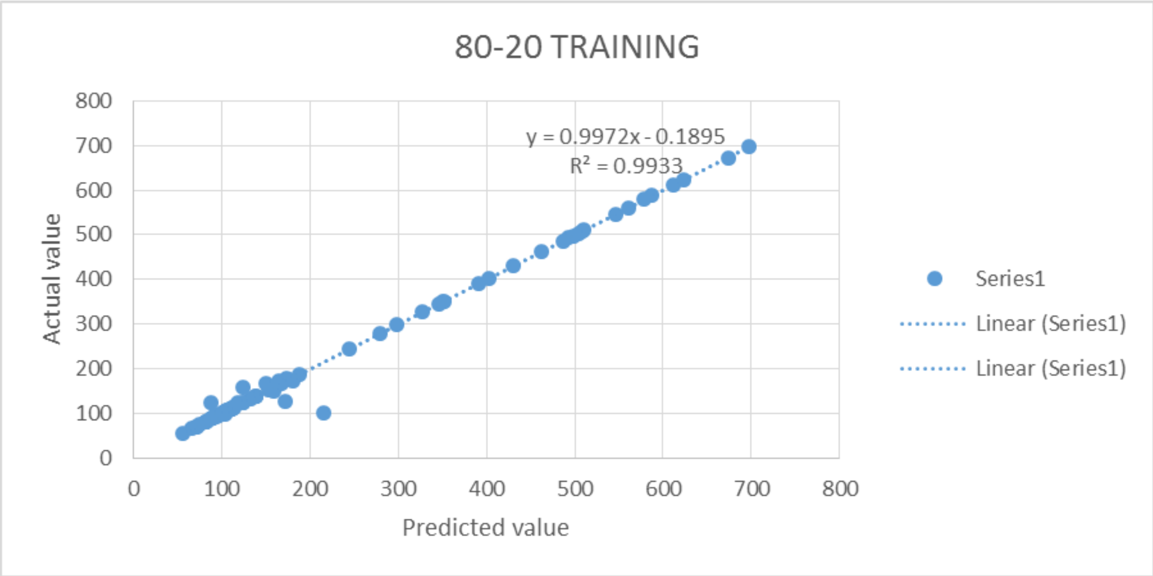

Figure 6:Correlation between Predicted WQI vs. Actual WQI of ANFIS Model-2 for POST MONSOON during Training

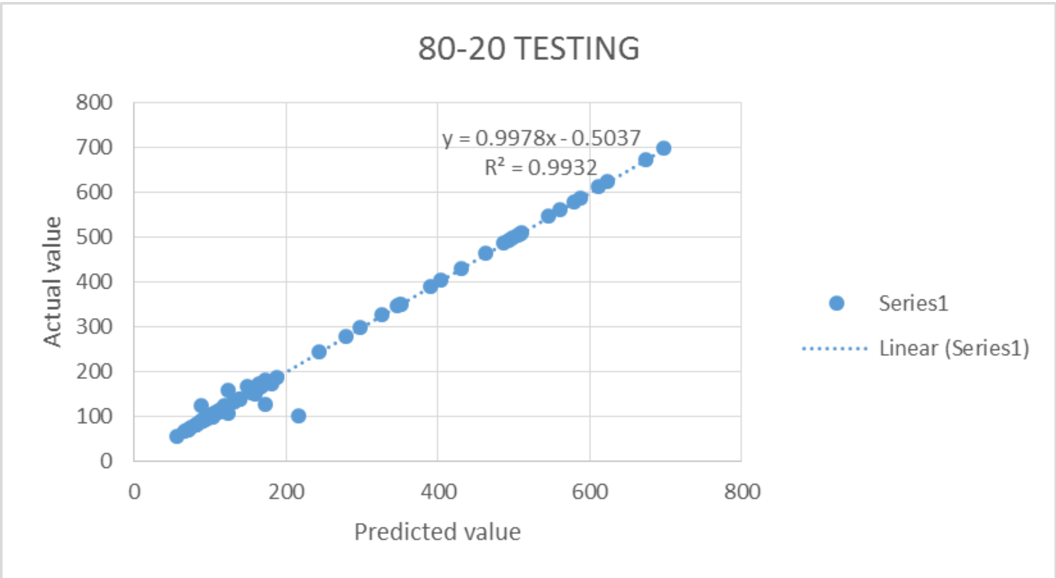

Figure 7:Correlation between Predicted WQI vs. Actual WQI of ANFIS Model-1 for POST MONSOON during Testing

V. CONCLUSIONS

- From the result one can conclude that most of water quality in pre-monsoon season lies between poor to very poor water, while in post-monsoon season most of water quality lies between good to poor water, also the water quality index values slightly improves in the post-monsoon season comparatively to the pre-monsoon season.
- Water quality index values slightly improves in the post-monsoon season comparatively to the pre-monsoon season.
- It is clear that the the ANFIS Model-2 having RMSE and r value of 0.8789 and 0.9835 respectively during training and RMSE and r value of 0.6821 and 0.9835 during Validation. Hence ANFIS Model-2 is the best model for pre monsoon season for Groundwater Quality Index Prediction. While ANFIS models having RMSE and r value of 0.7863 and 0.9933 respectively during training and RMSE and r value of 0.599 and 0.9932 during Validation, Hence ANFIS Model-2 provides best result for Post monsoon season for Groundwater Quality Index Prediction.

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