MODELLING OF ANFIS FOR PREDICTING WATER QUALITY INDEX OF SURFACE WATER ADJACENT TO THE WASTE DISPOSAL SITE IN KHULNA

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ABSTRACT

In present time, Fuzzy Inference System (FIS) is considered as a powerful apparatus for arrangement of numerous unpredictable designing frameworks when obscurity and uncertainity is related with the frameworks. ANFIS is generally known as legitimate insightful model for execution assessment of transient displaying and spatial variety of surface water quality factors. Recently, artificial insight calculations that are suitable for non direct estimating and furthermore managing vulnerabilities have been introduced to several areas of water quality guaging. As a rule, WQI refers a dimensionless number running from 0 to 100 (best quality) and assumes a significant job in assessing the surface water quality. The detailing of the WQI includes a progression of steps that incorporate creating scientific conditions called files dependent on watched water quality parameters, allotting a weighting element to every parameter contingent upon its significance in the examination, and finally applying a reasonable averaging equation to land at a solitary numeric worth. These means frequently make the calculations unwieldy and simultaneously limit the defined record to a specific parameters and topographical territories. Given the multifaceted nature of building up a WQI, there is a need to build up a computerized framework for information extraction from water quality information, which in this manner simplifies the estimation of the WQI and simultaneously covers an expansive scope of water quality criteria for a bigger extent of use. In this study, surface water samples were sampled from fourteen (14) stations within a selected waste disposal site at Rajbandh, Khulna, Bangladesh. In the laboratory, the concentrations of physical, chemical and biological parameters including pH, conductivity, chlorides, nitrates, phosphates, sulphates and TDS were measured. For ANFIS modelling thses studied parameters were considered as input parameters. In addition, ANFIS was proposed and its presentation is assessed with the assistance of expectation of water quality file utilizing a genuine informational index parameters. The present study was performed through MATLAB by using different types of ANFIS modelling like Subtractive Clustering (SC) and Grid Partition (GP) based on FIS for water quality index determination of surface water. Individual model was utilized to prepare, approve and test the list that was acquired from a few water quality parameters. Also, both models correlation coefficient value were compared to Pearson's product moment correlation coefficient which helped for identifying the best model. According to study, ANFIS-SC showed comparatively better performance than ANFIS-GP model for predicting the WQI of surface water and gave best correlation coefficient. Furthermore, sensitivity analysis of each station with respect to water quality index was performed where different types of models with different membership functions were fluctutated from existing water class. Among them, ANFIS-GP dsigmoid membership function was deviated largely from very poor water quality class which generally the highest existing water class. Other membership functions were laid in the tolerable limit between excellent and very poor. Since fuzzy framework is a decent expectation apparatus for loose and uncertainity data, the methodology would be the most fitting procedure for demonstrating the forecast of surface water quality.

Keywords: *Waste disposal site, surface water, water quality index, FIS, ANFIS, Khulna.*

1. INTRODUCTION

Water is viewed as one of the most bottomless items in nature yet in addition abuse one. Today surface water is most vulnerable against contamination because of its simple availability for transfer of poisons and wastewater (Puri, Meshram, Rana, & Yenkie, 2015). Overall, water quality is represented by complex human exercises and characteristic procedures including enduring disintegration, hydrological highlights, environmental change, precipitation, modern exercises, farming area use, sewage release, and the human abuse of water assets (Malvi, Nouri, Babael, & Nabizadeh, 2005). During the most recent decade, far reaching disintegration in water nature of inland oceanic frameworks has been accounted for because of quick improvement of ventures, agribusiness, and urban spread (Vie, Hilton-Taylor, Stuart, & Eds., 2009). Water quality assessment is a matter that indicates the consideration of administrative organizations on numerous occasions to shield different expected employments. In such manner, constant water quality observing is attempted in order to survey the water quality and applied adequate measures for its evaluation.

Water quality evaluation assumes a significant job in ecological administration and basic leadership and it gives a scientific premise to balanced use and assurance of water assets. Customary techniques barely introduce the non-linearity, subjectivity as well as multifaceted nature of the reason effect connections between factors and status of water quality, also there are not a for the most part acknowledged strategy up until now. A few strategies are typically utilized to assess the status of water quality, using fuzzy manufactured assessment (Liu, Zhou, An, Zhang, & Yang, 2010), matter component model, calculated bend model, trait acknowledgment model and ANN). The ANN technique is viewed as a conceivably helpful apparatus for demonstrating complex on-straight frameworks as well as has been broadly utilized for classification of water class as well as assessment (Zou & Wang, 2007).

New methods, for example, fuzzy logic as well as ANFIS have introduced as of late utilized as efficient elective apparatuses for displaying of complex water assets frameworks and generally utilized for forecasting. FL is a standard based framework comprising of three calculated parts, including (1) a standard base, containing a choice of fuzzy in the event that rules; (2) an information base, defining the function capacities utilized in the fuzzy guidelines; (3) a deduction framework, playing out the surmising methodology upon the principles to infer a yield (Zhang, 2009). FL models mainly focused on the utilization of theoretical in the framework analysis. This technique can be viewed as consistent models that utilization on the off chance that rules to set up subjective and numbering connections between factors. Their standard nature permits the utilization of data communicated as characteristic language code, use the model straightforward for prediction (Vernieuwe, Georgieva, Baets, & Verhoest, 2005). In any case, the fundamental issue with fuzzy logic with no precise methodology to define the participation work values, which can be foreordained by master information about displayed framework. The development of the fluffy principle requires the connotation of premises and results as fuzzy systems. Simultaneously, ANN can gain from info and yield combines and adjust to it in an intelligent way. So as to beat the issues, the ANFIS coordinates ANN and Fuzzy Logic was used by Jang (1993). ANFIS can possibly catch the benefits the techniques in a solitary system. ANFIS wipes out the fundamental issue in fluffy framework structure by effectively utilizing the learning capacity of ANN for programmed fluffy on the off chance that standard age and parameter streamlining (Nayak, Sudheer, Rangan, & Ramasastri, 2004). Since the idea of ANFIS was first presented in 1993 (Yan, Zou, & wang, 2010), it has effectively been demonstrated in many designing applications like precipitation runoff and continuous repository operation (Firat & Gungor, 2007).

In this manner the present investigation plans to build up the ANFIS model dependent on two different grouping techniques and measurably distinguish the best among the two. Also, another objective is to evaluate the best model which helps to identify the most touchy water quality parameter that can responsible an adjustment in the anticipated water quality. Also, sensitivity analysis was conducted for each model to know the variation of water quality class from existing value of WQI.

2. METHODOLOGY

In this study, several types of working steps were taken for collecting data and analyse the ANFIS model through MATLAB. These steps are divided into following categories which are describe elaborately. Before analyse WQI of surface water with ANFIS modelling, surface water quality parameters were measured in the laboratory and hence discussed in the following articles.

2.1 Study Area

Khulna is situated in the south-western region of the Bangladesh. The city is situated along the streams the Rupsha and the Bhairab. City Solid Waste Management has turned into an intense issue for Khulna city. The large amount of wastes in Khulna city are generated from areas like Houses, Road clearing, Industry, Mechanical and different sources. A study was performed in Rajbandh Landfill situated in Botiaghata Thana in Khulna city. Solid wastes of Khulna city are generally dumped in this location. Surface water samples were taken from several ponds of different location. Total 70 observations were taken from 14 stations shown in Figure 1. Overall, 5 samples were collected from each station in monthly based data collection.

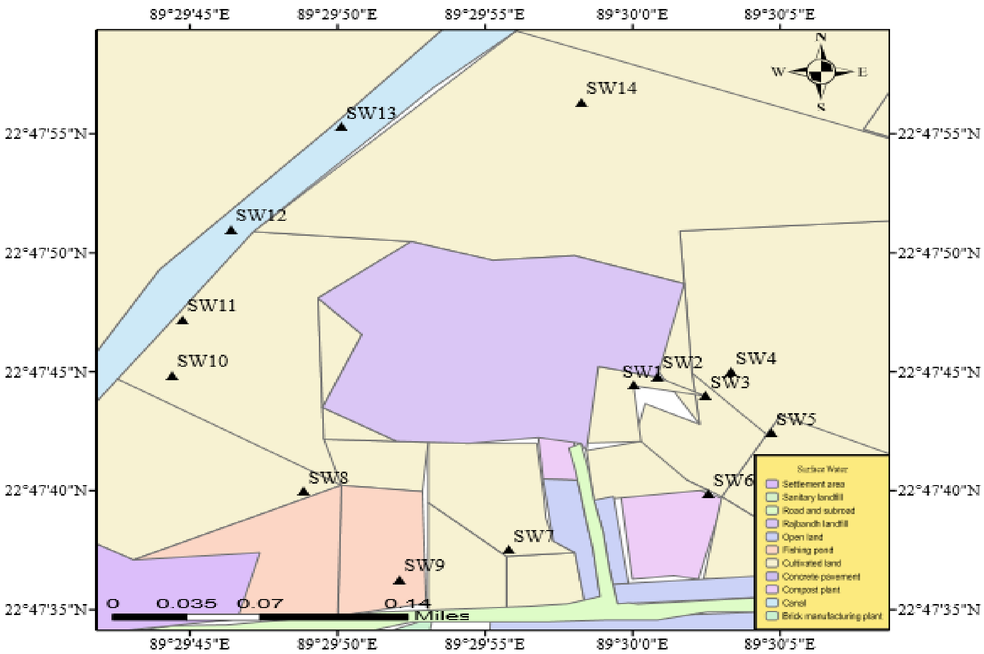

Figure-1: Location map showing surface water sampling from waste disposal site, Khulna

2.2 Water Quality Parameters

Several parameters can be used to determine the WQI for surface water. Some researchers (Puri, Meshram, Rana, & Yenkie, 2015) used the parameters of dissolved oxygen (DO) as well as biochemical oxygen demand (BOD) for calculating the surface WQI. But, these two parameters were not considered in the present study. Further research can be conducted with including these two parameters by using different fuzzy technique in future. In this research the parameters of pH, conductivity, chloride, sulphate, nitrate, phosphate and TDS were considered for determined the WQI. These 7 water quality parameters are generally identified for calculation of any surface water quality index. Following parameters are shown in Table 1, which shows the average value (among 5 Nos. sample) of each parameter of each station. Samples were taken monthly based at each station. After taken sample from study area, Parameters were determined from laboratory test through several tests according to each parameter. In case of conductivity and TDS parameters, the presented laboratory test value were largely deviated from realistic value of that study area. Due to the seasonal variation of sample collection, this may be happened.

Table-1: Mean concentration of parameters at each location around the selected disposal site

	Number of Stations													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
P^H	6.86	7	6.54	6.41	6.2	5.87	6.28	6.5	6.57	6.19	6.96	6.57	6.39	6.22
Conductivity	1413.2	1393.6	1762.6	1756.6	1621.93	1339.13	1295.73	1363.4	1092.2	1400.6	1707.18	1621.02	1299.11	1286.93
Chloride	61.99	71.14	65.05	74.99	67.6	79.85	69.09	83.91	70.74	86.73	73.19	88.49	76.37	89.53
Sulphate	108.91	98.08	107.6	92.53	11.67	91.07	90.2	54.2	57.93	65.2	108.77	100.32	103.56	90.38
Nitrate	0.46	0.08	0.28	0.1	0.19	0.11	0.14	0.11	0.12	0.11	0.11	0.11	0.11	0.10
Phosphate	0.43	0.38	2.5	1.40	2.01	1.23	1.71	1.13	1.49	1.08	1.32	1.05	1.21	1.03
TDS	2.1	1.84	1.91	1.97	1.82	2.11	1.79	2.24	1.77	2.38	1.75	2.53	1.74	2.66

2.3 Water Quality Index

Water quality represents physical, chemical and natural composition of water. WQI condenses various water quality information like Excellent, Good, Bad and so on, for answering to administrators as well as general population in reliable way. The WQI may be utilized like an apparatus in contrasting the water nature of various sources which give thought of the potential issues connected to water in a specific area. The records provide best approaches to convey the data on water quality patterns for the water quality administration (Boah , Twum , & Pelig-Ba , 2015). In this study, WQI was determined for surface water, where above parameters such as pH, conductivity, chloride, sulphate, nitrate, phosphate and TDS were used with their desirable limit of 8.5, 2000 µS/cm, 250 mg/L, 200 mg/L, 45 mg/L, 0.3 mg/L and 1000 mg/L respectively. The values of WQI were computed using weight factor (W_i) and quality rating (Q_i) of each parameter through the Equation 1 and Equation 2, respectively. The mathematical equation was used for determining the WQI, which is stated below with meaning. This equation consists of several steps which required for determining WQI in surface water.

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (1)$$

In above equation-1, W_i represents the relative weight and w_i denotes each parameter weight, also the number of parameters are indicated by n.

$$Qi = \frac{C_i}{S_i}\ x100 \qquad (2)$$

In above rquation-2, Q_i denotes rating of the quality, C_i denotes the individual chemical parameter concentration present in the water sample (mg/L) and S_i represents the desirable limit (mg/L) of each parameter according to BIS 1998, except the limit unit in case of conductivity (µS/cm) and the unit less pH. In this study, finally the values of WQI were computed using the following Equation 3.

Water Quality Index (WQI) = $\sum_{i=1}^{n} WiQi$ (3)

2.4 Adaptive Neuro-Fuzzy Inference System

ANFIS consists of multilayer feed-forward system which utilizations learning calculations based on neural system as well as fuzzy rationale to outline information space (Sun & Jang, 1995). Jang proposed adaptive neuro-fuzzy inference system (ANFIS) to develop an information yield mapping dependent on the underlying given fuzzy framework and accessible info yield information combines by utilizing learning methods. This framework can accomplish an exceptionally non straight mapping and is better than normal direct strategies in creating nonlinear time arrangement. During the time spent mapping information space to a yield space, two ordinarily FIS are utilized in different applications. Two different frameworks are included in this like Mamdani framework as well as Sugeno derivation framework. The outcomes of the fuzzy principles for these two deduction models are different, and hence their conglomeration methodology additionally differ likewise. The Sugeno framework is, be that as it may, thought about more conservative than Mamdani's framework. Sugeno FIS provides outcome parameters in two different FIS system (Jang, Sun, & Mizutani, 1997).

2.4.1 Framework of ANFIS

Seven different layers are utilized to build this deduction system where individual layer contains a few hubs portrayed by the hub work. Versatile hubs, indicated by squares, parameter sets are customizable in these nodes which indicated by circles shown in Figure 2. The yield information taken from hubs in the past layers has a contribution to the existing current layer. Sugeno FIS is evaluated in the current examination.

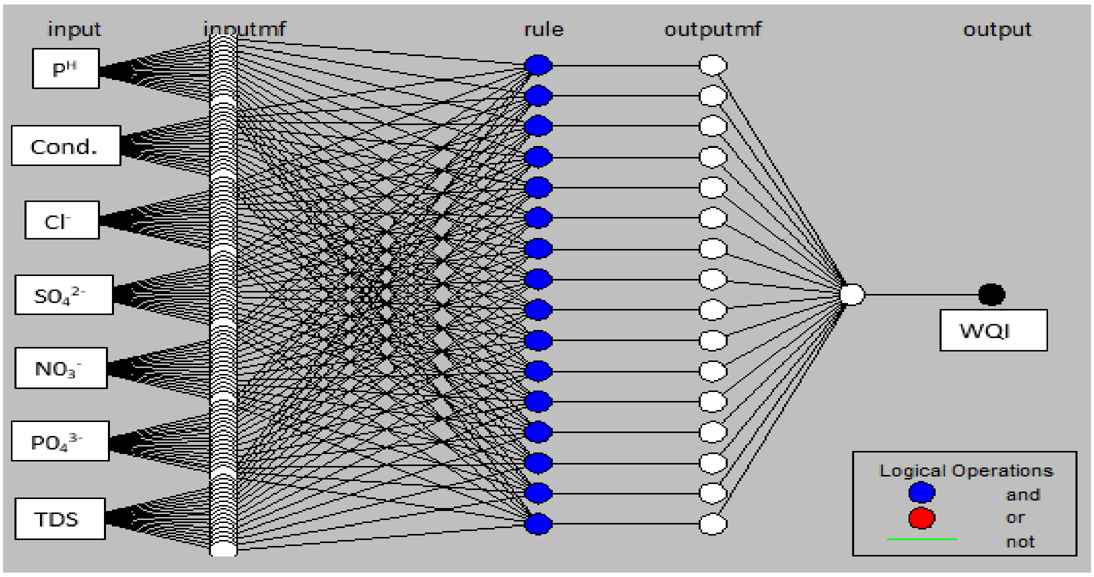

Figure-2: Framework of ANFIS utilised in this study

3. RESULTS AND DISCUSSION

In current study, for the determination of WQI with selected best technique of ANFIS, the following steps were taken which hence illustrated in the separate articles.

3.1 Model Development

For ANFIS modelling total 70 samples were taken from 14 stations. Two different fuzzy inference system was performed in this research for modelling shown in Figure 3. Subtractive-Clustering (SC) FIS was generated as well as Grid-Partition (GP) was performed. In case of SC ANFIS model, Gaussian membership function and In case of GP ANFIS model, several 8 membership functions were performed. GP mf's are triangular, trapezoidal, generalized bell, gaussian, two gaussian, pi, dsig and psig. In both ANFIS model, optimum method was taken backpropagation with epoch 10. Following parameters were developed during SC-ANFIS algorithm: Gaussian membership function, influence range (0.5), factor of squash (1.25), accepted ratio was 0.5 and rejected ratio was 0.15. Figure-3 reveals the output of each model and comparison between them with observed value. ANFIS-SC model was closely related with observed WQI and these two graphs were merged very closely. ANFIS-GP models consisted with eight different membership functions were deviated from observed value except dsigmoid membership

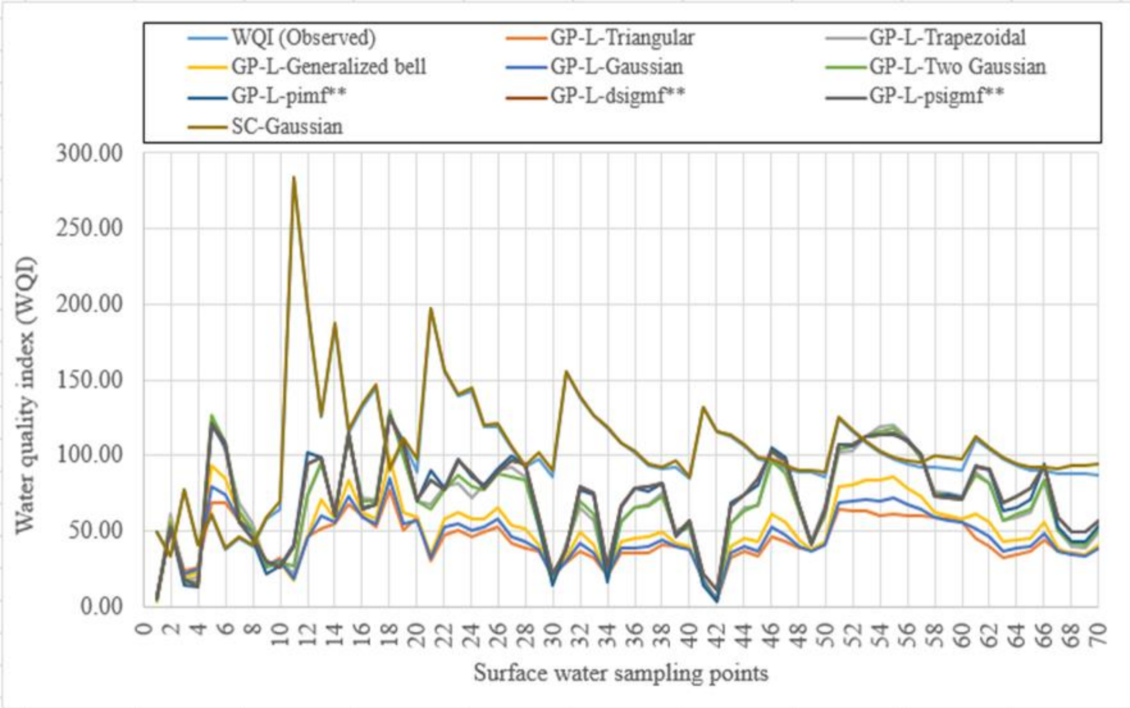

Figure 3: Comparison between Observed WQI and Predicted WQI by ANFIS-SC & ANFIS-GP (mf**= membership function)

3.2 Surface and Rule Viewer of ANFIS

Figure-4 represents the rule view of ANFIS-SC model by which predicted value was found. Each column from top left to right bottom shows the input value and last column in right side shows the output value of fuzzy inference system.

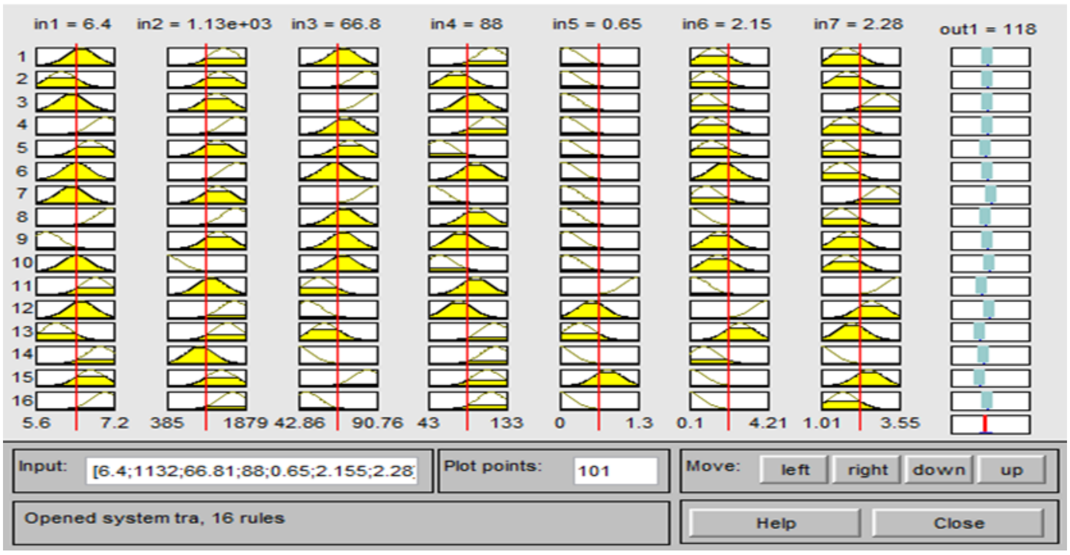

Figure-4: Rules view in ANFIS-SC model

Figure-5 shows the fit curve of ANFIS-SC algorithm. Among two different ANFIS modelling, ANFIS-SC showed best fit where correlation value (R=0.99866) was highest and RMSE (1.6807) was lowest. In terms of ANFIS-GP, value of 'R' was lower and RMSE value was higher than ANFIS-SC.

Figure-6 illustrates the surface viewers in ANFIS-SC model which represents the predicted value of WQI of surface water. For predicted value, input value was pH, conductivity, chloride, sulphate, nitrate, phosphates and TDS.

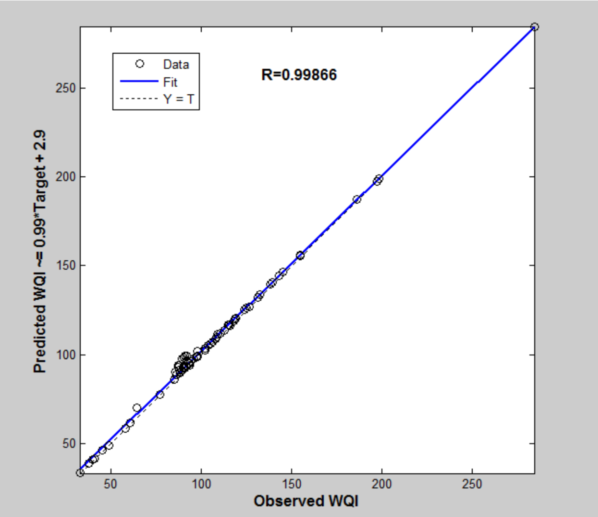

Figure-5: Best fit curve in ANFIS-SC model

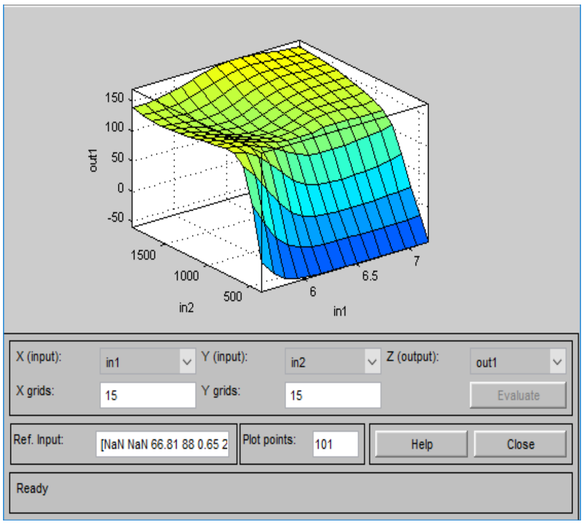

Figure-6: Surface view of ANFIS-SC

3.3 Sensitivity Analysis

Figure-7 represents the variation of water quality condition according to observed data and obtained data from ANFIS-SC and ANFIS-GP. Sensitivity analysis means the deviation of water quality index from existing water quality class. This analysis helps to know the variation of water quality in two different types of ANFIS modelling and observed value at the same station. According to Chatterji, Raziuddin (2002) and Brown (1972), water was classified into five (05) different classes with respect to water quality index. ANFIS-GP dsigmoid membership function largely deviated from other membership function and observed value. In case of Station 03 to 11, it indicated the sample water is not suitable for using in different purposes. Other analysis show the variation of water quality index which lies between excellent and very poor. Excellent water quality was found in station 01, 07, 08 and 09. Without station no 04 and 11, all analysis show the good water quality.

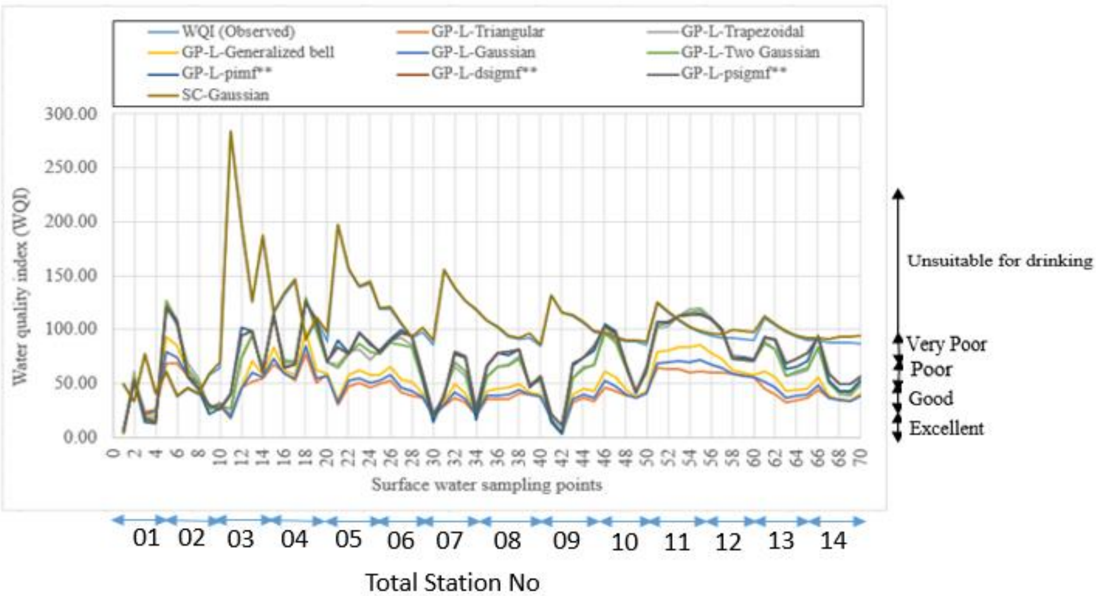

Figure-7: Sensitivity analysis of individual station with respect to Water Quality Index.

3.4 Model Verification

ANFIS models were verified with compare to the Pearson Product moment correlation coefficient value. From both ANFIS models, RMSE, MSE and R^2 were found. Table 2 shows the variation of RMSE, MSE and R^2 of different membership functions of two ANFIS modelling. This helps to compare the best fit according to Correlation value and RMSE. According to value of R^2, correlation is classified in Pearson's method (Table 3). From this classification, types of correlation can be identified which helped in validation of ANFIS-SC and ANFIS-GP modelling. Different types of correlation like very highly, highly, moderately, low and little was stated according to the magnitude of R^2 (Table 3).

Table-2: Water quality performance according to ANFIS-SC and ANFIS-GP

	SC-Gaussian	**GP-Triangular**	**GP-Trapezoidal**	**GP-Generalized Bell**	**GP-Gaussian**	**GP-Two Gaussian**	**GP-pi**	**GP-dsig**	**GP-psig**
RMSE	1.6807	8.8396	8.0131	8.5753	8.7420	8.0109	7.783	7.743	7.743
MSE	2.8249	78.1387	64.21	73.5365	76.4227	64.1755	60.57	59.95	59.95
R^2	0.9973	0.0107	0.0000156	0.0059	0.0074	0.00057	0.0179	0.0122	0.0122

Table-3: Pearson Product Moment Correlation Coefficient

Classification	**Magnitude of Correlation Coefficient (R^2)**
Very Highly Correlated	Between 0.82 and 0.99
Highly Correlated	Between 0.49 and 0.81
Moderately Correlated	Between 0.25 and 0.48
Low Correlation	Between 0.09 and 0.24
Little Correlation	Between 0.00 and 0.08

4. CONCLUSIONS

The validation of ANFIS model with eight membership functions for GP and SC algorithm was performed. Comparison of models gave the clear view that, ANFIS-SC models of Gaussian membership function was performed better and showed best fitting of regression model than that of ANFIS-GP. In case of ANFIS with SC and Gaussian membership function showed the highest R^2 value (0.9973) and lowest RMSE (1.6807) indicating very highly correlated according to Pearson correlation. This study express that fuzzy inference system (FIS) modelling with SC-ANFIS may be an effective way to deal with portrayal of water quality in terms of WQI. From sensitivity analysis of each model, ANFIS-GP dsigmoid membership function was deviated largely from existing water quality class which indicated the water quality is not suitable for different purposes. The other membership function of two different models were indicated the variation of water quality within the existing limit.

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