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MODELLING BOD CONCENTRATION BY USING ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM

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Abstract—**BOD is a parameter frequently used to evaluate the water quality on different rivers. The aim of the present study is to investigate applicability of artificial intelligence techniques such as ANFIS (Adaptive Neuro-Fuzzy Inference System) in water quality BOD prediction for the case study, Mahi river at Khanpur in Thasara Taluka of Kheda District in Gujarat State, India. The proposed technique combines the learning ability of neural network with the transparent linguistic representation of fuzzy system. ANFIS models with various input structures and membership functions are constructed, trained and tested to evaluate efficiency of the models. Statistical indices such as Root Mean Square Error (RMSE), Correlation Coefficient (R), Coefficient of Determination (R^2) and Discrepancy Ratio (D) are used to evaluate performance of the ANFIS models in forecasting BOD. ANFIS model is used for the estimation of BOD concentration.**

Keywords— Adaptive Neuro-Fuzzy Inference System, Bio-Chemical Oxygen Demand(BOD).

I. INTRODUCTION

Using the surface waters for the purpose of suitable and safely requires the determination of the water quality. To determine water quality is very important issue for drinking and irrigation water, and many other purposes. A mathematical model is a set of mathematical expressions, relationships and logic rules that mimic the behavior of a physical process. Modern artificial intelligence methods such as neuro-fuzzy systems can be used for forecasting. These methods provide fast, reliable and low-cost solutions. Another advantage of these methods is that they can handle dynamic, non-linear and noisy data, especially when the underlying physical relations are very complex and not fully understood. The purposes of this study are to investigate the applicability of ANFIS in predicting Water Quality parameter like BOD in the Mahi River.

BOD is a parameter frequently used to evaluate the water quality on different rivers. To estimate BOD accurately, inclusion of all past data is essential in this ANFIS model. In the present study to develop ANFIS model, past discharge, pH, temperature, EC, suspended solids, BOD of study area ANFIS models with various input structures and membership functions are constructed, trained and tested to evaluate efficiency of the models. Statistical indices such as Root Mean Square Error (RMSE), Correlation Coefficient (R), Coefficient of Determination (R^2) and Discrepancy Ratio (D) are used to evaluate performance of the ANFIS models in estimation of BOD concentration.

II. STUDY AREA

The study area of Mahi river basin is located near village Khanpur in Thasara taluka of district Kheda in Gujarat State, India. The latitude and longitude of the study area are 22^o 53' N and 73^o 13'E, respectively. The type of bed of river is rocky covered with sand.

The basin is comprised of two sub-basins: Mahi upper sub basin (65.11% of total basin area) consisting of 41 watersheds and Mahi lower sub basin (34.89% of total basin area) consisting of 22 watersheds. The Mahi river and its tributaries constitute an inter-state river system flowing through the states of Madhya Pradesh, Rajasthan and Gujarat. Mahi river is comprised of several tributaries on both the banks, viz. Som, Anas, Panam and others.

For this study, monthly discharge, pH, temperature, EC, suspended solids, DO & COD and data are collected for estimation of BOD of Mahi River.

III. METHODOLOGY

Adaptive Network-Based-Fuzzy Inferences System (ANFIS) approach was employed in this study.

The ANFIS architecture consists of 5 layers such as input layer, fuzzification layer, inferences process, defuzzification layer, and summation as final output layer. Typical architecture of ANFIS is shown by Figure 1.

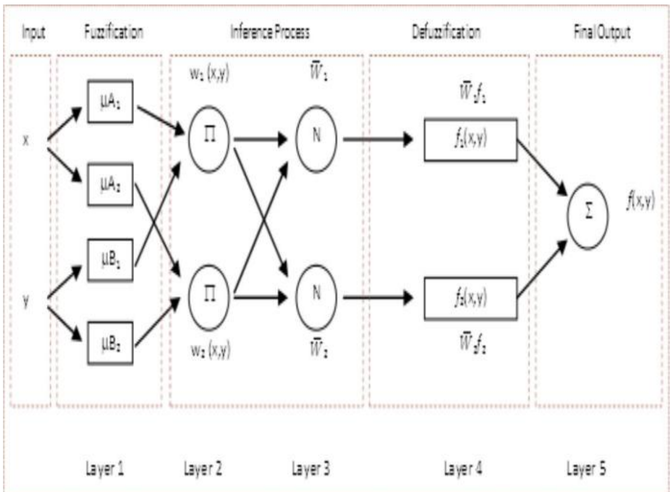

Figure 1: Typical Architecture of ANFIS

In above architecture the process flows from layer 1 to layer 5. It is started by giving a number of sets of crisp values as input to be *fuzzyfied* in layer 1, passing through inference process in layer 2 and 3 where rules applied, calculating output for each corresponding rules in layer 4 and then in layer 5 all outputs from layer 4 are summed up to get one final output.

The main objective of the ANFIS is to determine the optimum values of the equivalent fuzzy inference system parameters by applying a learning algorithm using input-output data sets. The parameter optimization is done in such a way during training session that the error between the target and the actual output is minimized. Parameters are optimized by hybrid algorithm which combination of least square estimate and gradient descent method. The parameters to be optimized in ANFIS are the premise parameters which describe the shape of the membership functions, and the consequent parameters which describe the overall output of the system. The optimum parameters obtained are then used in testing session to calculate the prediction.

The objectives for the study are,

1. Development of river stage-BOD concentration ANFIS model.
2. Validation of the formulated model.
3. Performance evaluation of the formulated model for the Mahi river system.

In this study, basic model is constructed by 4 inputs and 1 output. The inputs for BOD are discharge, pH, EC, temperature and BOD while for the output is predicted BOD. In this ANFIS model 70% data is used for Training and 30% data is used for Validation. After load the data in ANFIS Editor the Fuzzy Inference System (FIS) is generated with taking 5 number of linear triangular membership function.

The model is validated on the remaining 30% of the data by evaluating the following statistic performance indicators: Root Mean Square Error (RMSE), Correlation Coefficient (R), Coefficient of determination (R^2) and Discrepancy Ratio (D) which is given below:

Root mean square error (RMSE):

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X(i) - \hat{X}(i))^2}{n}}$$

Correlation coefficient:

$$R = \frac{\sum_{i=1}^{n}(X(i) - \bar{X})(\hat{X}(i) - \tilde{X})}{\sqrt{\sum_{i=1}^{n}(X(i) - \bar{X})^2 \sum_{i=1}^{n}(\hat{X}(i) - \tilde{X})^2}}$$

Coefficient of determination:

$$R^2 = \frac{\left(\sum_{i=1}^{n}(X(i) - \bar{X})(\hat{X}(i) - \tilde{X})\right)^2}{\sum_{i=1}^{n}(X(i) - \bar{X})^2 \sum_{i=1}^{n}(\hat{X}(i) - \tilde{X})^2}$$

Discrepancy Ratio (D):

$$D = \frac{\sum_{i=1}^{n} X(i)}{\sum_{i=1}^{n} \hat{X}(i)}$$

Where $\hat{X}$(i) is the n estimated value, X(i) is the n observed value, $\bar{X}$ is the mean of the observed values, and $\tilde{X}$ is the mean of the estimated values.

Results and Discussions

70% data is used for Training and 30% data is used for Validation. The results obtained from ANFIS are shown below:

ANFIS (BOD)

The Training data results for BOD for ANFIS is shown below in fig.2 and fig.3.

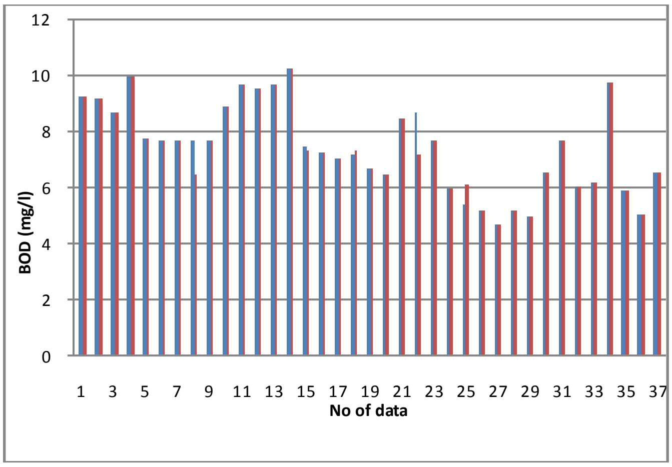

Fig.2 Comparison of observed & predicted BOD for Training using ANFIS

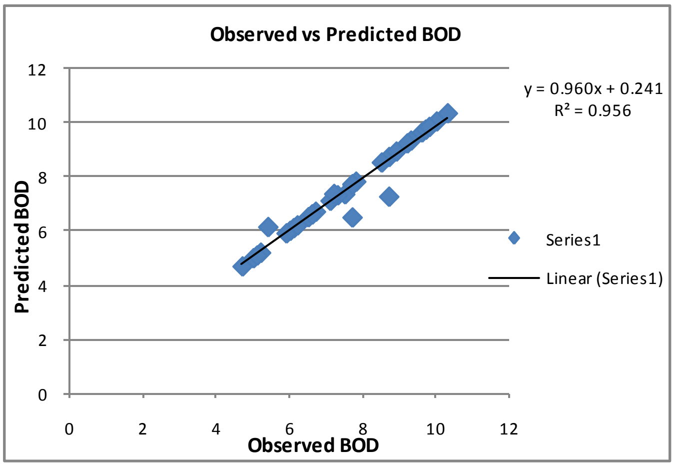

Fig.3 Scatter plot for Observed vs Predicted BOD for Training using ANFIS

The Validation data results for BOD for ANFIS is shown below in fig.4 and fig.5.

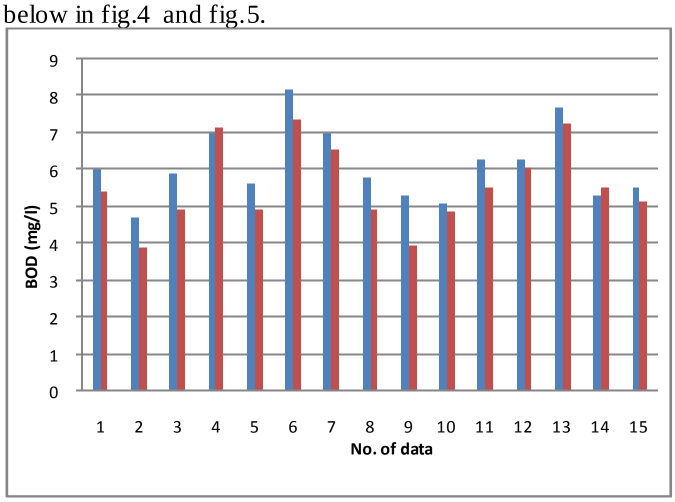

Fig.4 Comparison of observed & predicted BOD for Validation using ANFIS

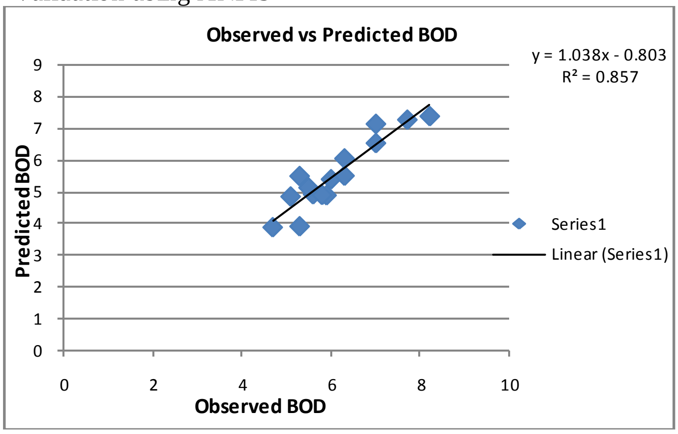

Fig.5 Scatter plot for Observed vs Predicted BOD for Validation using ANFIS

The forecast accuracy of model using ANFIS Tool was evaluated by calculating the following statistic performance indicators: Root Mean Square Error (RMSE), Correlation Coefficient (R), Coefficient of determination (R^2) and Discrepancy Ratio (D) described in Table I.

TABLE I

PERFORMANCE EVOLUTION OF MODEL ON TRAINING AND VALIDATION PERIOD FOR ANFIS MODEL (BOD)

		RATIO 70-30 %			
STATION	**PHASE**	**RMSE**	**CORRELATION (R)**	**R^2**	**DECRIPENCY RATIO**
KHANPUR	Training	0.335406	0.977829	0.956149	1.006987
	Validatio	0.698622	0.925935	0.857355	1.102561

Conclusion

In this study, an Adaptive Neuro-Fuzzy Inference System (ANFIS) model has been developed to concentrate BOD of Mahi river near khanpur.

BOD concentration has traditionally been used as a variable of water quality and for water systems. Therefore, modeling of water quality parameters is a very important aspect. The chemical, physical, and biological components of aquatic ecosystems are very complex and nonlinear. In recent years, computational-intelligence techniques such as neural networks, fuzzy logic, genetic algorithm, and combined neuro-fuzzy systems have become very effective tools to identification and modeling nonlinear systems.

The ability of ANFIS model in estimation of BOD water quality parameter has been investigated in this study. Results of simulation presented in this research showed that the values of RMSE, R^2, CORRELATION, DECRIPENCY RATIO. ANFIS (4, trapmf, constant) is best suited among other trials

The results showed that the temperature (T) is the most effective parameter to estimate BOD concentration in this stream-gauging station. ANFIS model can be successfully used in estimation of BOD when only temperature data are available.

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