Application of Artificial Neural Network to Predict TDS Concentrations of the River Thamirabarani, India

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ABSTRACT

River water quality modeling is of prime importance in predicting the health of the rivers and in turn warns the human society about the future possibility of water problem in that area. Total dissolved solids is a prominent parameter used to access the quality of the river water. In our current study, artificial neural networking models have been developed to predict the concentrations of total dissolved solids of the river Thamirabarani in India. Neural Network toolbox of the MATLAB 2017 application was used to create and train the models. Monthly data from year 2016 to 2019 at four different sites near Thamirabarani river were procured from Tamilnadu pollution control board. Many artificial neural network architectures were built and the best performing architecture was selected for this study. With several parameters such as pH, chloride, turbidity, hardness, dissolved oxygen as input and the total dissolved solids as output parameter, the model was trained for many iterations and a final architecture was arrived which predicts the futuristic TDS concentrations of Thamirabarani in a more accurate manner. The predicted and the expected values were very close to each other. The root mean square error (RMSE) values for the selected stations such as Papanasam, Cheranmahadevi, Tirunelveli and Punnaikayal were 0.565, 0.591, 0.648 and 0.67 respectively.

Keywords: Artificial Neural Network, Thamirabarani, TDS prediction

1 Introduction

Water is an essential commodity for the survival of every living thing from amoeba to human kind. Rivers play a vital role in meeting the water demands of the human society. One of the most prominent rivers in the region of south Tamilnadu is Thamirabarani river. This river water source is mainly used in agriculture and also in many industrial sectors. So maintaining the water quality of the river is of prime importance. There are many water quality parameters used to determine the water quality of the river. They are pH, chloride, temperature, total dissolved solids(TDS), turbidity, hardness, dissolved oxygen etc. TDS is one of the most important measures which is used for finding out the water quality of the river. TDS is defined as the total amount of dissolved particles present in the solution[3]. TDS is one of the important parameters which is used to assess the water suitability criteria. Depending on the TDS content of water, the water can be determined whether it is potable or not. Also the water quality for irrigation and industrial purposes can also be determined by the content of TDS. *Total* dissolved solids may consist of the salts such as potassium, magnesium, phosphates, calcium, bicarbonates, nitrates and few amounts of organic particle. Various factors affect the amount of total dissolved solids. Some of the factor are human activities on the water bodies, water movement in the stream, the salt and carbonate deposits, etc [2].

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1.1 Related Works

In the recent period the usage of artificial neural networks (ANN) have attracted many researchers for the early prediction activities [7]. ANN is widely used for the prediction of futuristic values in the areas of research such as ground water modeling, rainfall forecasting, water quality predictions, sediment yield modeling, etc. ANNs offer a very reliable, fast paced and flexible way of stimulating models in the area of water quality modeling[3].

Gholamreza A et al., 2017, used multilayer perceptron (MLP) and radial basis function (RBF) neural network to predict total dissolved solids of Karaj dam in Iran. The authors mentioned that they have taken datasets from two water quality monitoring stations to do this exercise. They also confirmed that the observed and predicted TDS were very close to each other. YifanZhang, 2019, stated that they successfully employed the multilayer artificial neural network (MANN) and mutual information (MI) to predict dissolved oxygen levels in baffle creek estuary system. They also concluded that the results of this prediction were very accurate and this can be used for water quality management systems effectively. Khadijah Sulaiman, 2019, mentioned that they have successfully investigated using a technique based on ANN that can classify water quality automatically. According to their study, different environmental data were utilized to train and test the artificial neural network system and the results showed good accuracy in water quality classification. In this study, artificial neural network technique was used for creating a model which can predict the levels of TDS of the water source.

1.2 Study Area

India is a country which is flourished by several rivers passing through. These rivers play a vital role in ensuring a livelihood of Indian people. There are many major rivers and number of tributaries flowing throughout the nation. Majority of the rivers merges with Bay Of Bengal Ocean. One such perennial river which flows in the Southern state of Tamilnadu is Thamirabarani. Thamirabarani river flows for about 60kmsthrough many villages, cities and suburbs and finally arrives the Bay of Bengal. For the present study, water samples taken from four important stations near Thamirabarani river were considered. The sites selected are 1)Papanasam, 2)Cheranmahadevi, 3)Tirunelveli, 4)Punnaikayal was selected.

Among these stations, Papanasam is the spot where Thamirabarani river originates from Agasthiar hills. Papanasam is a town which has many tourist attractions such as Papanasam dam and Agasthiar falls. Tirunelveli is a major town through which the river passes; Punnaikayal is the place where the river Thamirabarani finally meets the ocean Bay of Bengal. Physico chemical parameters data such as ph, calcium, dissolved oxygen, conductivity; total alkalinity, TDS, and chloride were obtained from Tamilnadu Pollution Control Board for these sites.

2 Methodology

Neural networking toolbox (nntool) of MATLAB 2017 software was used. The monthly data from the year 2016 to 2019 were used. So for each station, the number of datasets would be 5 x 12 =60. With different water quality parameters as inputs and Total dissolved solids as outputs, the various artificial neural network models were designed. The data were procured from Tamilnadu Pollution control board and the optimum one among those networks was chosen. For the chosen ANN architecture, the input data was simulated to yield the required output data(TDS).With this architecture the various performance evaluations were done. The LavenbergMarq Algorithm is utilized in this study. The training was done using the feed forward back propagation training algorithm.

The following steps were followed in creating a TDS prediction model for the sites discussed above.

Step:1 Selection of various input output parameters

Correlation analysis test was conducted to determine the relationship between various water quality parameters. This test is also used to decide the input fields for the training. The below formula was used to determine the input parameters.

Pearson Correlation Coefficient formula is given below

Équation 1

$$\rho(x,y) = \Sigma[(xi - \bar{x}) * (yi - \bar{y})] / (\sigma x * \sigma y)$$

where xi and yi are the two variables $\bar{x}$ and $\bar{y}$ are mean of x and y respectively

It is inferred that if the correlation coefficient value is negative, then the relationship between the variables is very weak. If the correlation coefficient value is equal to 1, then the relationship is very strong and if the correlation coefficient value is zero then there is no relationship between the variables. Table 1 shows the correlation co-efficient for the input and output variables used.

Table:1 Correlation Coefficient Matrix

	Dissolved Oxygen	pH	Turbidity	Chloride	Hardness	TDS
Dissolved Oxygen	1					
pH	0.729	1				
Turbidity	-0.128	0.023	1			
Chloride	0.034	-0.005	0.786	1		
Hardness	0.045	0.345	0.399	0.023	1	
TDS	0.641	0.342	0.034	0.859	0.651	1

Step 2 Neural Network Training

With the given input and output parameters the neural network model was designed and the model was trained for a number of iterations until the error value became minimum.

Step: 3 performance evaluation of the model

The next step is to evaluate the performance of the trained model using different statistical measures. Below measures were calculated for the models.

1) Mean square error: Mean square error is given by the below formula

Équation 2

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2$$

Where Xobs,i is the observed value and Xmodel, I is the predicted value and n is the number of elements. 2) Root mean square: Root mean square is the square root value of the mean square error. 3)Regression co-efficient(R): Regression co-efficient is calculated and plotted in the output of regression values in MATLAB r 2017. 4)Co-efficient of determination(R2): This is the square value of the Regression co-efficient(R)

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3 Results

Four different models for the site such as Papanasam, Cheranmahadevi, Tirunelveli and Punnaikayal were created and the models were trained for the optimum performance. Figure 1 shows the regression values of the model developed for the site Papanasam. Similarly, Figure 2 shows the regression values of the model developed for the site Cheranmahadevi. Figure 3 shows the regression values of the model developed for the site Tirunelveli. Figure 4 shows the regression values of the model developed for the site Punnaikayal.

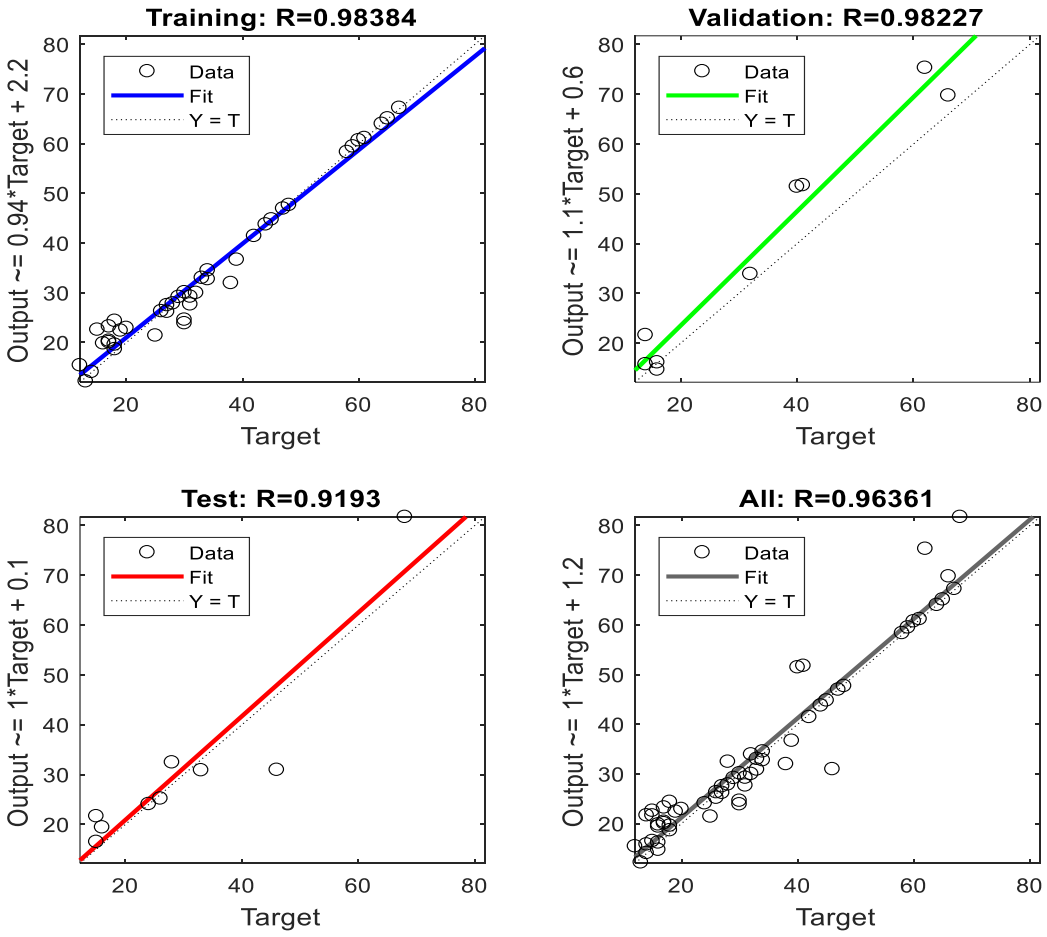

Figure:1 Regression Values For The Model Papanasam

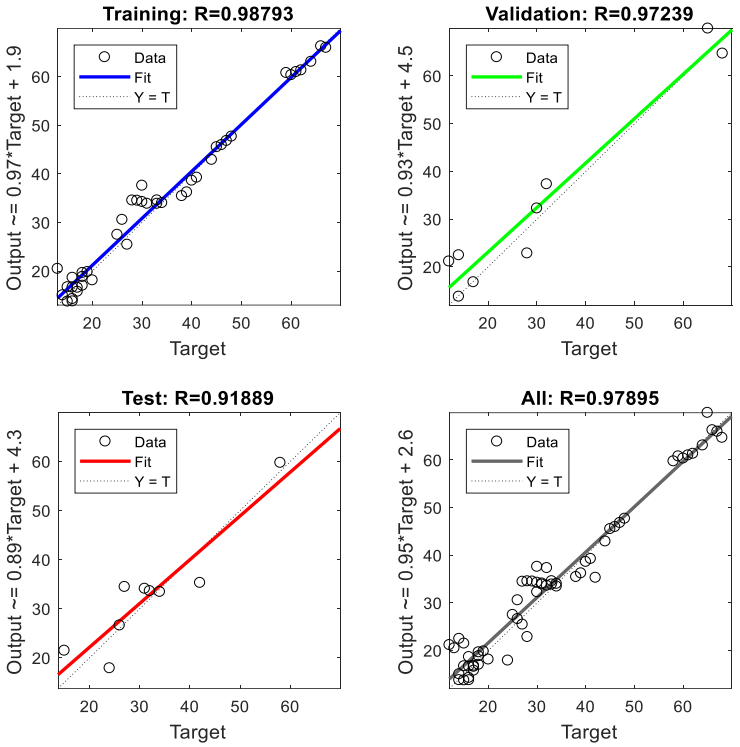

Figure:2 Regression Values For The Model Cheranmahadevi

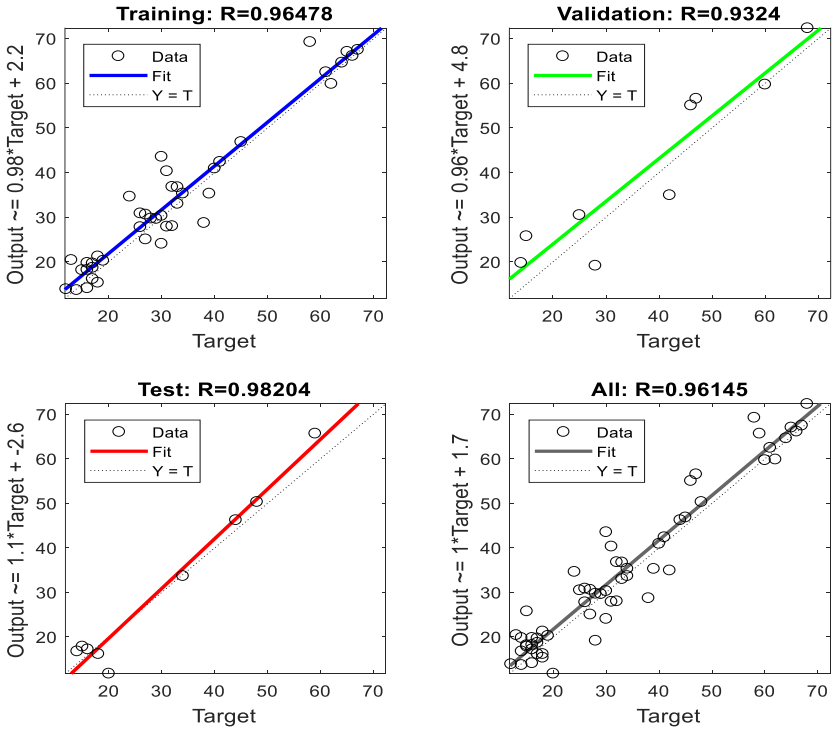

Figure:3 Regression Values For The Model Tirunelveli

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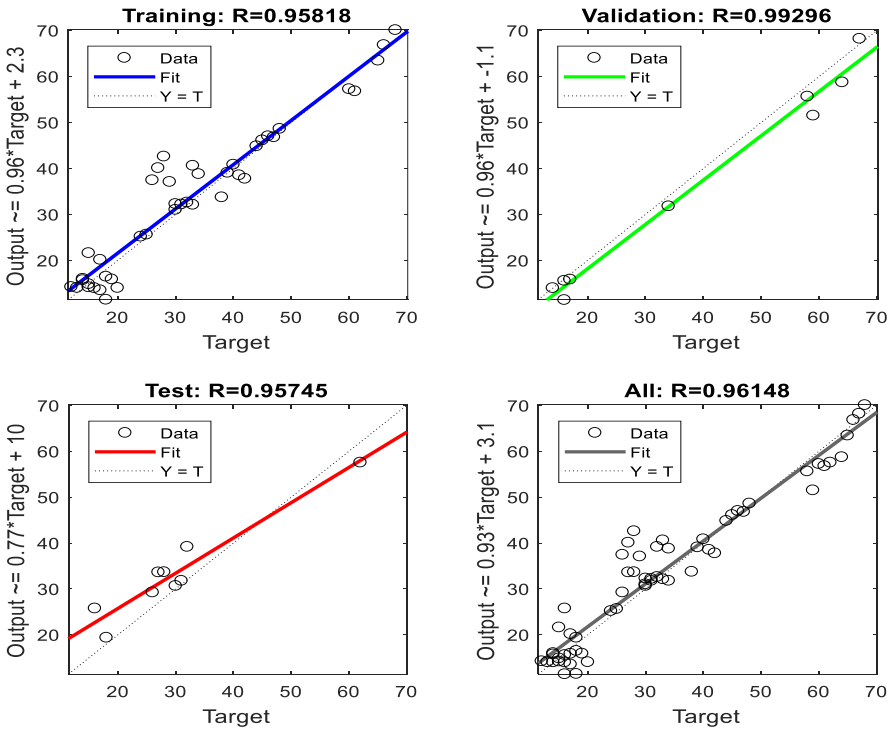

Figure:4 Regression Values for The Model Punnaikayal

Figure 5 shows the expected versus predicted values of TDS concentrations of the site Papanasam from the year 2016 to 2019. Similarly Figure 6 shows the expected versus predicted values of TDS concentrations of the site Cheranmahadevi from the year 2016 to 2019. Figure 7 shows the expected versus predicted values of TDS concentrations of the site Tirunelveli from the year 2016 to 2019. Figure 8 shows the expected versus predicted values of TDS concentrations of the site Punnaikayal from the year 2016 to 2019.

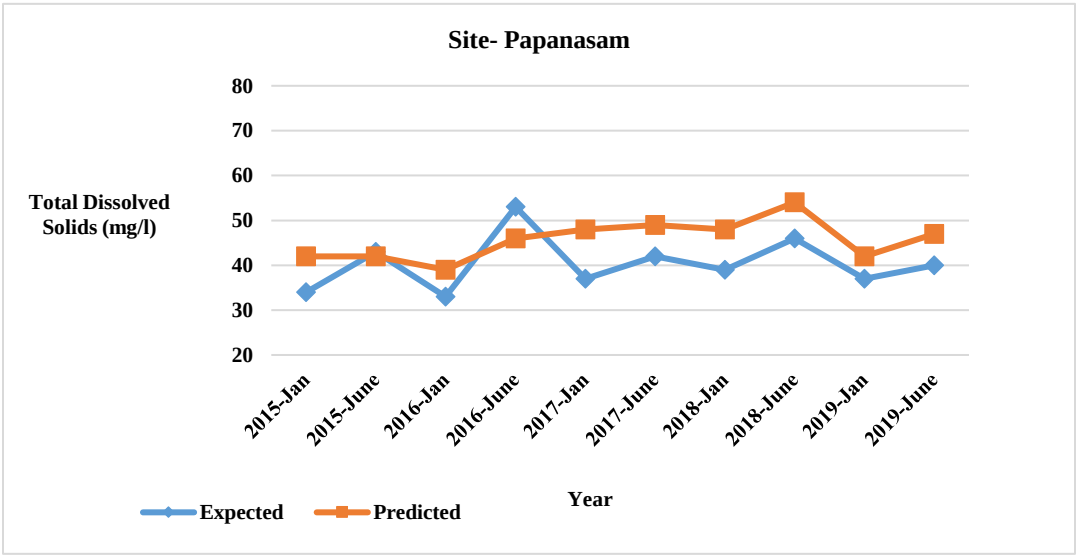

Figure:5 Expected Versus Predicted TDS Concentration at Papanasam Site

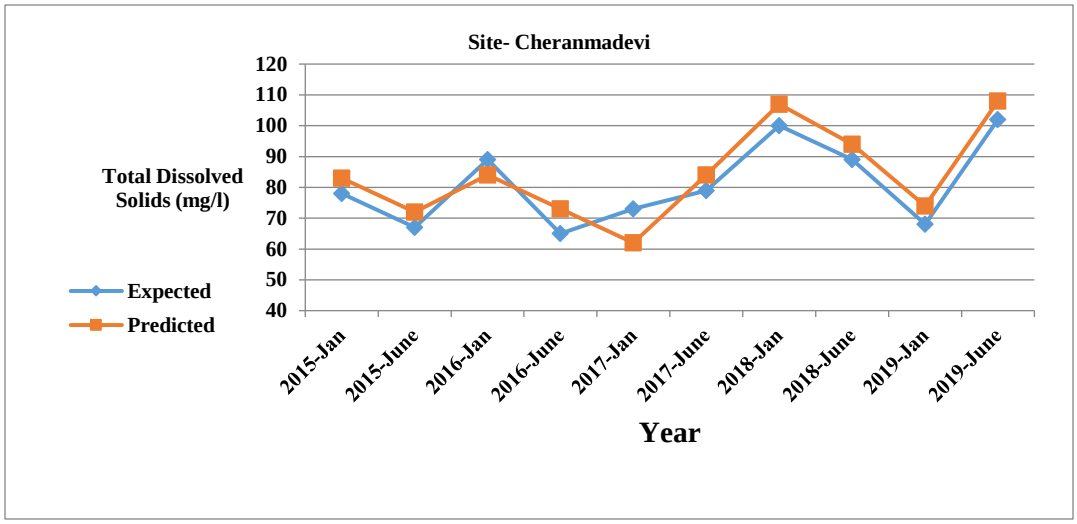

Figure:6 Expected Versus Predicted TDS Concentration At Cheranmahadevi Site

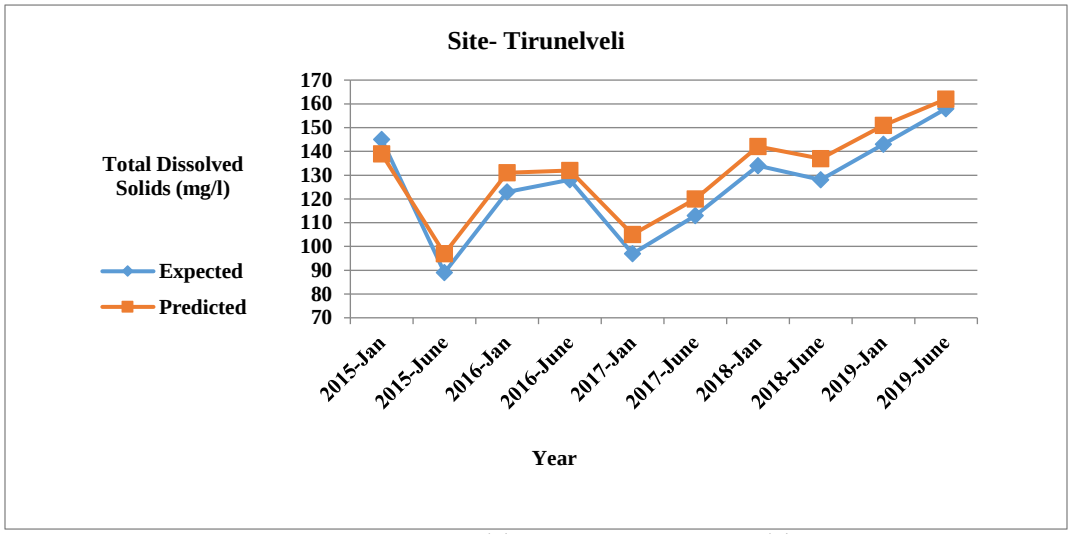

Figure:7 Expected Versus Predicted TDS Concentration at Tirunelveli Site

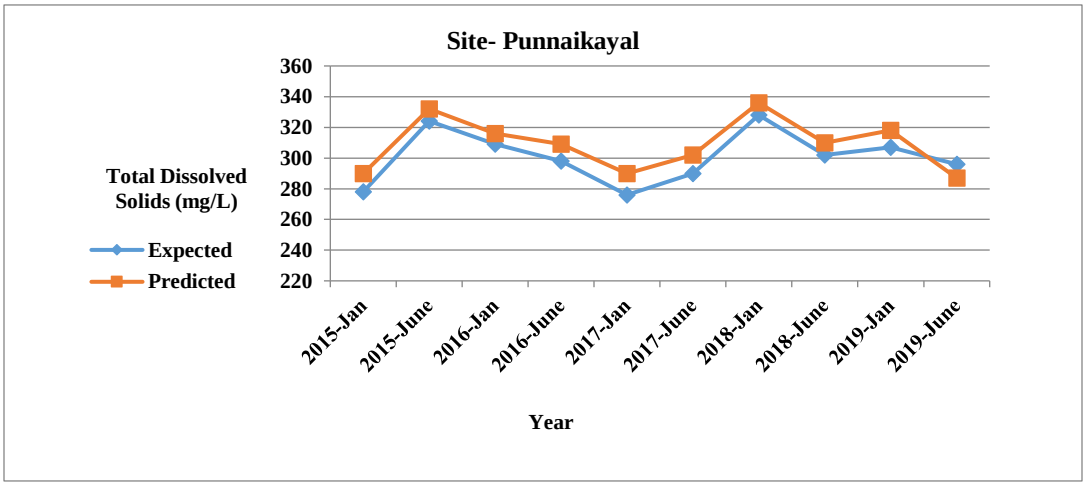

Figure:8 Expected Versus Predicted TDS Concentration ast Punnaikayal Site

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The table 2 shows the statistical performance measures of the models for the selected sites.

Table: 2 Statistical Performance Measures of the Models

Model	MSE	RMSE	R	R^2
Papanasam	0.32	0.565	0.96361	0.9285
Cheranmahadevi	0.35	0.591	0.97895	0.9583
Tirunelveli	0.42	0.648	0.96145	0.9243
Punnaikayal	0.45	0.670	0.96148	0.9244

4 Conclusion

Even though the TDS concentration modeling studies in the river Thamirabarani are very rare, there are many such studies conducted in other rivers in India. Anil Kumar Bisht et al., (2019) stated that they conducted a water quality modeling study for the river Ganges. They stated that the study was carried from the station Devprayag to Roorkee and the model trained was an effective one in the water quality predictions.Prajot D. Tarke1 et al., (2016), mentioned that they conducted a TDS concentration study for the station Pategaon in the river Godavari. The authors confirmed that they used artificial neural network technique and the result of prediction was good. They have stated the co-efficient of correlation was found to be equal to 0.98293.

In our study the model was trained tested and validated for the given input water quality parameters such as pH, chloride, TDS, turbidity, hardness, dissolved oxygen of the sites near Thamirabarani river. The data collected were from year 2016 to 2019 on a monthly basis. The best performing ANN architecture model was employed to interpret the prediction of TDS values for the sites Papanasam, Cheranmahadevi, Tirunelveli, Punnaikayal. It was observed that the predicted values were more or less nearer to the values of the observation. The Root mean Square error values calculated for the stations such as Papanasam, Cheranmahadevi, Tirunelveli, Punnaikayal were 0.565, 0.591, 0.648 and 0.670 respectively and the R value were 0.9636, 0.97895, 0.96145 and 0.96148 respectively. This indicates the models trained were efficient ones and these can be used to forecast the futuristic TDS values.

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