FORECAST OF RESERVOIR SEDIMENT TRAP EFFICIENCY USING ARTIFICIAL NEURAL NETWORKS

Qamar Sultana[1], M. Gopal Naik[2]

[1]*Assistant Professor, Muffakham Jah College of Engineering and Technology and Research Scholar, UCE, OU*
[2]*Professor of Civil Engineering, University College of Engineering (UCE) OU, Hyderabad,*
Corresponding Emails: [1]qamarsultana4@gmail.com, [2]mgnaikc@gmail.com***

Abstract

The reservoirs all over the world experience the sedimentation problem. There are a number of models available for the estimation of reservoir sedimentation and the simple way to estimate it is through the knowledge of the trap efficiency of the reservoir. In this study an artificial neural network (ANN) model developed using Matlab software is used to estimate the trap efficiency of the reservoir. One of the large reservoir in Telangana State , Sriramsagar reservoir located at Pochampadu village in Nizamabad district is taken as a case study. The input parameters used are annual inflow, annual rainfall and age of the reservoir and the output parameter considered is the trap efficiency(T_e) of the reservoir for twenty six years i.e. from 1987 to 2012. A conventional regression analysis is conducted, relating the output parameter (T_e) to the input parameters. From the values of the performance statistical indicators, it is found that the ANN model predicted the trap efficiency of the reservoir with better accuracy and less effort than that of the conventional method. Further since the forecast of the hydrologic data is very important for the engineers for the management of the available water resources, the time series forecasting of annual reservoir inflows and annual rainfall has been done and subsequently trap efficiency is predicted for the same series data for the next 26 years i.e. from 2013 to 2038 using ANN technique.

Keywords: *Forecast, Sedimentation of reservoir, Trap Efficiency method, Artificial Neural Network technique , Conventional Method.*

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1. INTRODUCTION

For the non-monsoon period, it has been an old practise to manage with the available water, by building dams and creating reservoirs. A major portion of the silt that is carried along with the river water settles down in the reservoir, which causes the reduction in its storage capacity and has become a great problem all over the world. Therefore the knowledge of the quantity of the sediments accumulating in a reservoir with time and the knowledge of the various methods available for the estimation of the sediments has become a necessity.

In this study, an ANN model has been developed using Matlab tool and the available input parameters for the estimation of the trap efficiency(T_e) in a large reservoir, Sriramsagar reservoir in India. The input parameters such as annual inflow(I_a) , annual rainfall(R_a) and the age of the reservoir (A_g) were considered and the trap efficiency (T_e) was considered as an output parameter.

3. STUDY AREA DESCRIPTION AND DATA ANALYSIS

The Sriramsagar Project (SRSP), formerly known as the Pochampadu irrigation project has been built on Godavari river which is one of the major peninsular rivers in southern India. This project is located at Pochampadu village (18°-58' N latitude and 78°- 20' E longitudes) in Nizamabad district of Telangana State (TS) of southern India at a distance of about 200Km from Hyderabad city which is shown in the Figure . The SRSP project has been built to utilize Godavari river water for irrigation and drinking purposes in Telangana state. The regions such as Nizamabad, Adilabad, Karimnagar, and Warangal districts of Telangana State are covered under this project.

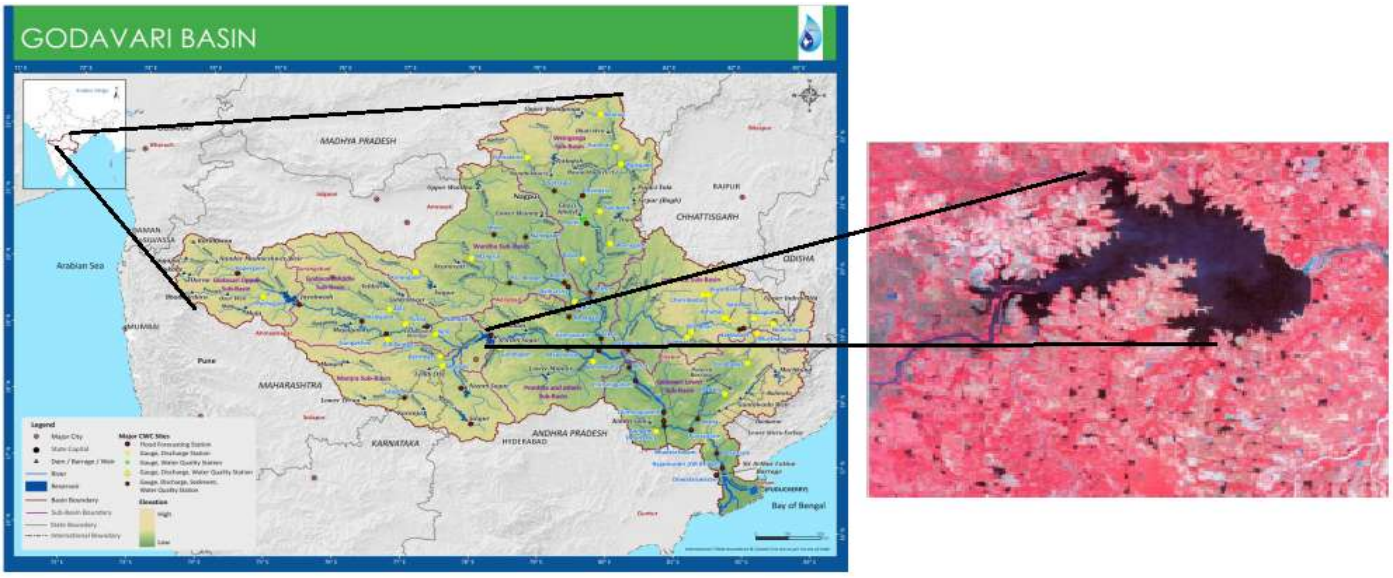

Figure 1. Location and Water spread area of Sriramsagar Reservoir.

4. METHODOLOGY AND MODEL DEVELOPMENT

4.1 Artificial Neural Network(ANN)

A neural network has an input layer, a hidden layer and an output layer. Each layer consists of several neurons and the layers are interconnected by sets of correlated weights. The neurons receive inputs from the initial inputs or the interconnections and produce outputs by the transformation, using an adequate nonlinear transfer function.

4.1.1 Developing ANN Model:

Designing of ANN model consists of five steps. They are (1) Data collection, (2) Pre-
processing of the data, (3) building of the network, (4) training the network and (5) test performance of model.

4.2 Conventional Regression Method.

A conventional regression analysis is conducted, between the output parameter (T_e) and the input parameters (I_a ,R_a, and A_g), using RegressIt an Excel add-in that performs multiple linear regression analysis.

5. RESULTS AND DISCUSSIONS

A conventional regression analysis is done relating the output parameter (Trap Efficiency(T_e)) with the input parameters (Annual Rainfall (R_a), Annual Inflows (I_a), Age of the reservoir (A_g)). The regression equation of the three variables with the output parameter which gave the best result is shown in the equation 2.

Estimated Trap Efficiency from regression method =

$$80.342 + (0.034*A_g) - (0.0000004857*I_a) + (0.004882*R_a) \quad (2)$$

The value of R for three input variables from the Table 4. is 0.207 , which is not satisfactory, and hence an attempt is made by using Artificial Neural Network (ANN) technique for the better results.

A Multilayer Perceptron (MLP) ANN architecture consisting of three layers with 10 neurons in the hidden layer is developed using the MATLAB tool. Since there is a large variation in the data, the data is normalised between 0 and 1 using the equation 1. Twenty six years data is used, out of which 70% is used for testing and the rest 30% is used for training and validation. Based on the values of R generated (0.9216), it is seen that a Feed Forward, Back Propagation (BP ANN) model shown in the Figure 4. with the structure 3-10-1 generated the trend of the trap efficiency values well with TRAINLM - training function, TRAINGDM - learning function and TANSIG - transfer function.

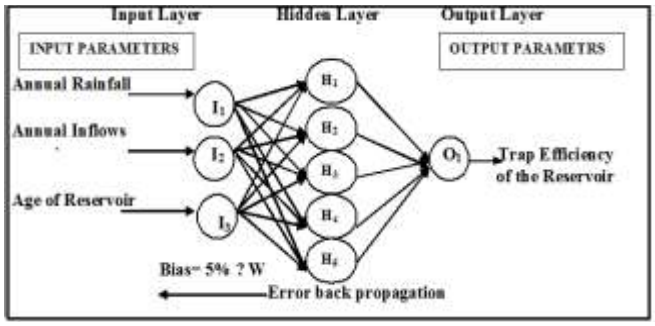

Figure 2. Neural network architecture used for prediction of trap efficiency of the reservoir.

Forecast of Reservoir Annual Inflows, Annual Rainfall and the Trap Efficiency.

The ANN model is used to predict the annual inflows , annual rainfall and the trap efficiency for a further period of 26 years i.e. from 2013- 2038

Forecast of the Reservoir Annual Inflows

Based on the values of minimum MSE value of 0.0052 and the optimum value of R generated (0.666), it is seen that a Feed Forward, Back Propagation (BP ANN) model shown in the Figure 4. with the structure 1-8-1 generated the trend of the trap efficiency values well with TRAINLM - training function, TRAINGDM - learning function and TANSIG - transfer function. The performance statistics of this model is shown in the Table 6.

Forecast of the Annual Rainfall

Based on the values of minimum MSE value of 0.0072 and the optimum value of R generated (0.7878), it is seen that a Feed Forward, Back Propagation (BP ANN) model shown in the Figure 4. with the structure 1-10-1 generated the trend of the trap efficiency values well with TRAINLM - training function, TRAINGDM - learning function and TANSIG - transfer function. The performance statistics of this model is shown in the Table 2.

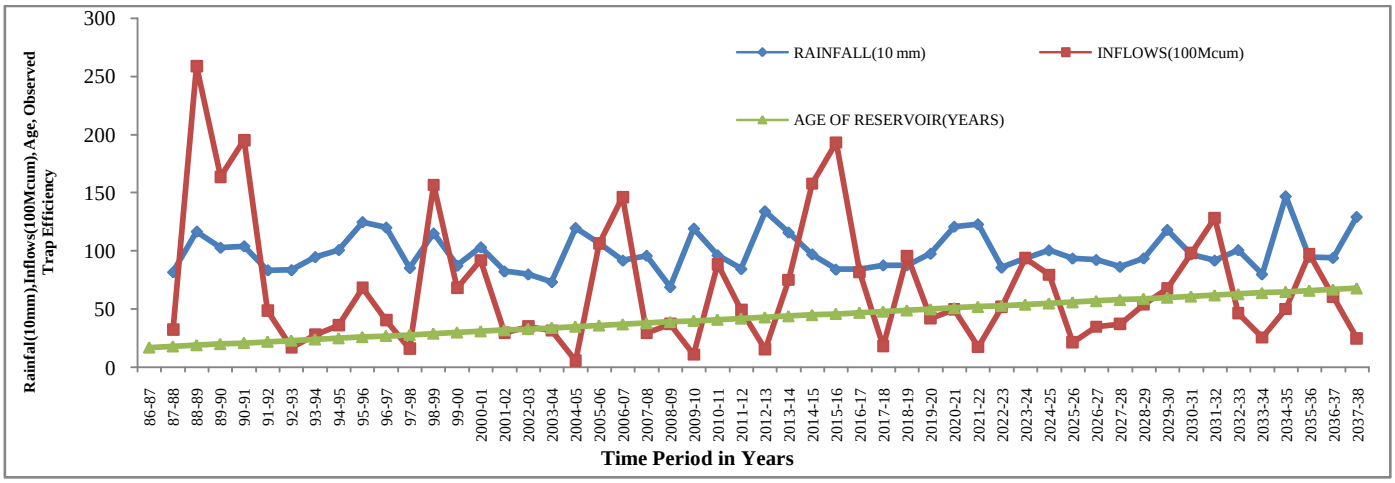

Figure 3. Time Series Plot of the Annual Inflows and Annual Rainfall for the observed data from (1987-2012) and Predicted data (2013-2038)

Forecast of the Reservoir Trap Efficiency

A Multilayer Perceptron (MLP) ANN architecture consisting of three layers with 12 neurons in the hidden layer is developed. The normalised data of the reservoir annual inflows for a period of 26 years i.e. from 1987-2012 is used, out of which 70% is used for testing and the rest 30% is used for training and validation and the annual inflows data is forecasted for the next 26 years i.e. from 2013-2038. Based on the values of minimum MSE value of 0.0152 and the optimum value of R generated (0.9276), it is seen that a Feed Forward, Back Propagation (BP ANN) model shown in the Figure 4. with the structure 3-12-1 generated the trend of the trap efficiency values well with TRAINLM - training function, TRAINGDM - learning function and TANSIG - transfer function. The performance statistics of this model is shown in the Table 2.

A conventional regression method is applied to forecast the trap efficiency values for the next 26 years. From the Table 1. it can be seen that both the ANN and the Conventional method produces the same average values but from the Fig. 4, it is seen that the trend of the observed values of the trap efficiency is well followed by the ANN model. Thus the ANN model generates better values when compared with the conventional regression method.

Table 1. Prediction of the Trap Efficiency of the Reservoir from 2013-2038.

Year	Age of reservoir (years)	Annual rainfall (mm)	Annual inflows ($10^6 m^3$)	Observed (Te%)	Predicted by ANN Model (Te%)	Estimated by Conventional Regression Method (Te%)
86-87	17	3828.96	43137.58	97.76	**89.75**	**99.32**
87-88	18	818.20	3215.82	82.74	**106.48**	**84.67**
88-89	19	1166.99	25900.39	99.99	**98.62**	**86.40**
89-90	20	1028.22	16351.96	60.19	**60.29**	**85.76**
90-91	21	1040.55	19509.94	75.24	**75.49**	**85.85**
91-92	22	833.75	4863.10	92.91	**90.43**	**84.89**
92-93	23	835.42	1666.60	90.86	**94.58**	**84.93**
93-94	24	947.89	2775.15	89.54	**89.63**	**85.51**

94-95	25	1008.65	3586.79	86.33	**87.00**	**85.84**
95-96	26	1248.73	6815.24	90.67	**92.97**	**87.05**
96-97	27	1201.49	4049.05	96.01	**94.38**	**86.85**
97-98	28	853.92	1583.05	93.11	**98.92**	**85.19**
98-99	29	1150.78	15672.72	89.47	**89.05**	**86.67**
99-00	30	872.89	6815.07	81.72	**87.02**	**85.35**
00-01	31	1031.16	9185.72	94.26	**92.86**	**86.15**
2001-02	32	823.50	2947.73	86.33	**83.67**	**85.18**
2002-03	33	798.66	3505.65	41.80	**41.80**	**85.09**
2003-04	34	733.10	3147.25	94.07	**93.00**	**84.80**
2004-05	35	1197.80	541.16	80.88	**77.52**	**87.11**
2005-06	36	1066.60	10622.35	91.25	**94.14**	**86.49**
2006-07	37	917.60	14625.44	98.91	**96.87**	**85.80**
2007-08	38	959.30	2920.04	92.84	**92.60**	**86.04**
2008-09	39	689.70	3707.05	97.99	**101.31**	**84.76**
2009-10	40	1192.70	1061.09	86.07	**85.47**	**87.25**
2010-11	41	962.90	8848.57	90.67	**91.81**	**86.16**
2011-12	42	845.40	4896.58	63.10	**59.45**	**85.62**
2012-13	43	**1538.82**	**1341.70**	-	**94.33**	**88.08**
2013-14	44	**7507.70**	**1158.88**	-	**99.99**	**87.22**
2014-15	45	**15778.67**	**970.68**	-	**50.53**	**86.33**
2015-16	46	**19324.39**	**839.78**	-	**53.83**	**85.72**
2016-17	47	**8147.53**	**842.17**	-	**51.69**	**85.77**
2017-18	48	**1798.91**	**876.31**	-	**92.59**	**85.98**
2018-19	49	**9558.85**	**876.77**	-	**51.40**	**86.01**
2019-20	50	**4206.63**	**976.29**	-	**95.96**	**86.53**
2020-21	51	**4960.76**	**1208.90**	-	**99.99**	**87.70**
2021-22	52	**1721.62**	**1229.61**	-	**99.99**	**87.84**
2022-23	53	**5185.17**	**857.09**	-	**76.32**	**86.05**
2023-24	54	**9375.44**	**935.79**	-	**61.86**	**86.47**
2024-25	55	**7933.48**	**1005.27**	-	**86.58**	**86.84**
2025-26	56	**2131.20**	**935.11**	-	**98.07**	**86.54**
2026-27	57	**3459.97**	**922.95**	-	**96.87**	**86.51**
2027-28	58	**3704.82**	**863.88**	-	**94.22**	**86.25**
2028-29	59	**5383.52**	**936.02**	-	**95.00**	**86.64**
2029-30	60	**6759.38**	**1181.24**	-	**99.53**	**87.87**
2030-31	61	**9813.33**	**970.41**	-	**79.49**	**86.87**
2031-32	62	**12830.21**	**917.52**	-	**57.33**	**86.65**
2032-33	63	**4648.42**	**1007.62**	-	**98.54**	**87.13**
2033-34	64	**2534.38**	**799.58**	-	**96.95**	**86.14**
2034-35	65	**5001.18**	**1469.94**	-	**99.99**	**89.45**
2035-36	66	**9725.84**	**948.22**	-	**85.66**	**86.93**
2036-37	67	**6049.20**	**940.54**	-	**97.39**	**86.93**
2037-38	68	**2474.56**	**1292.95**	-	**99.95**	**88.69**
Average				**86.34**	**86.14**	**86.61**

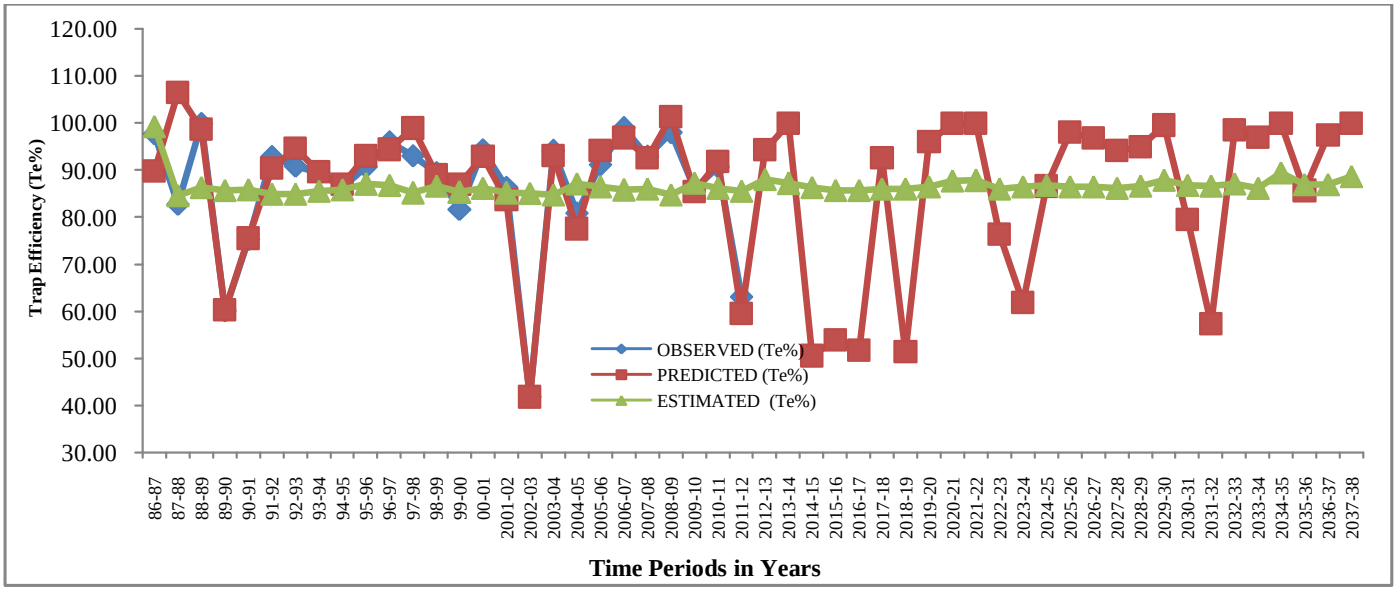

Figure 4. Plot of the Trap Efficiency for the Observed, Predicted (by ANN Model) and Estimated (by Conventional Regression Method) Data.

Table 2. Performance Statistics of the ANN Model for Prediction of Annual Inflows, Annual Rainfall and Trap Efficiency from 1987-2038

Statistical Parameter	Annual Inflows	Annual Rainfall	Trap Efficiency
R	0.6666	0.7878	0.9276
R^2	0.4443	0.6206	0.8604
MSE	0.0059	0.0072	0.0152
RMSE	0.0768	0.0849	0.1232

6. CONCLUSIONS

In this study, a conventional regression method and an ANN approach is used for the estimation of the trap efficiency in Sriramsagar reservoir on a yearly basis and their results are compared with the observed trap efficiency values for 26 years i.e. from 1987 to 2012 and the same technique is extended for forecasting the reservoir annual inflows, annual rainfall and trap efficiency from 2013 to 2038 . It is seen that the developed ANN model captured the trend of trap efficiency percentages well when compared to the traditional regression approach, which is seen from the trend of the curves in the figures 4. The evaluation criteria Correlation Coefficient (R) of 0.9276 , the Determination Coefficient (R^2) of 0.8604 as shown in the Table 2. confirms the accuracy of the ANN model when compared with the conventional method.

8. REFERENCES

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